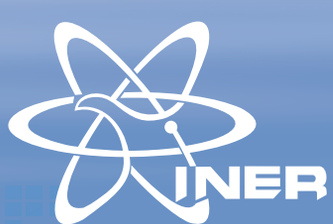

Institute of Nuclear Energy Research
Automic Energy Council, Executive Yuan

2014 Annual Report

Published in July 2015

Institute of Nuclear Energy Research

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2014 Annual Report

Contents

1 Preface

Carbon Reduction, Clean Energy, the Rising Green Energies - Beyond the Nuclear Energy in INER

The Institute of Nuclear Energy Research (INER), established in 1968, is a government agency with a history of credibly safeguarding dedicated to the research and development (R&D) on nuclear safety, nuclear facility decommissioning, radioactive waste treatment and disposal technologies. Moreover, INER also bears the mission of developing radiopharmaceuticals for the public well-being. For 46 years, results of INER's endeavors have received high recognition. Nowadays, Taiwan's energy policies are ensuring nuclear safety and waste reduction, building up green energy and a low carbon environment, and working eventually toward creating a nuclear-free homeland. In conformity with the national energy policy, INER has expanded its researches in recent years to including the development of green energies such as new and renewable energies, energy conservation and carbon emission reduction, in addition to participating in the energy-related economic policy research.

In compliance with the government's reorganization plan, INER will become an affiliate to the "Ministry of Economic and Energy Affairs" under the new name - the "Institute of Energy Research." We at INER will continue to abide by the government's directive in the implementation of our country's energy policies. Reorganization signifies a new starting point, a new assignment, and a new mission for us. To meet with our goal, INER has put together a vision to provide complete technological solutions for national energy security, environmental protection and national health. With creative thinking, pragmatic sprit and enthusiasm, we have set our goals to improve our professional knowledge, to put through innovation and to offer service so as to provide the best solutions to the energy-economics related issues of the country.

As the rewards to our technological researches on nuclear energy development and applications, with our joint efforts, we have gained remarkable accomplishments in the fields of new and renewable energies, and radiation application research and development. A number of the achievements of the year 2014 are provided below:

Years of hard work yielded fruitful achievements, INER has won a total of 13 awards in the 2014 Taipei International Invention and Technology Trade Show which include five gold medals, six silver medals, and two bronze medals. Meanwhile, we were accorded agreements on technology transfer, development cooperation, and joint research agreements with seven industrial corporations. Furthermore, we were awarded one gold medal award at the US Pittsburgh International Trade Show (INPEX), one silver medal award at the SWISS Genèva International Exhibition of Innovations, and one gold medal as well as one bronze medal awards at the Germany Nürnberg International Trade Fair (IENA).

To mention a few more feats, two nuclear medicine developments were honored for "National Innovation Awards" and "Distinguished Contribution Awards" respectively. The "development of the new therapeutic radiopharmaceutical, ^{188}Re-MN-

16ET/Lipiodol, for Hepatoma treatment" won the 11th National Innovation Awards from the Institute of Biotechnology and Medicine Industry. Another award is the "development of Nano diagnostic and therapeutic radiopharmaceutical technology and their applications" which won the Distinguished Contribution Awards at the 2014 Taiwan Nano Exhibition for its excellence.

On the aspect of nuclear safety technology R&D, several studies were completed including the combined nature hazards analysis, seismic and tsunami comprehensive risk analysis and quantitative seismic risk assessment for domestic nuclear power plants. Through these evaluations, safe and persistent operation of nuclear power plants can be reliably assured. Also worth mentioning is that a re-quantitation of seismic risk analysis and capacity upgrade model was also accomplished to provide the basis of decision making of the nuclear safety enhancement measures. All these efforts are to further ensure the safety of the public.

On environmental and green energy technology R&D, we have completed the system assembly, testing and initial start-up operation of the 2nd-generation 150kW wind turbine. The INER developed and manufactured wind turbine system is designed in compliance with the IEC 61400-1 Class-IA code. Its integrated power efficiency has been verified as up to 38% which is well credible as the international hundred-kilowatt grade wind turbines. Contracts of technology transfer to domestic industry are under negotiation. In this regard, INER has built up Taiwan's first outdoor microgrid demonstration site in Longtan District of Taoyuan City, the total installed capacity being 470 kW including the high concentration photovoltaic system, wind turbine system, energy storage and micro turbines. While being connected to TPC's (Taipower Company) high-voltage distribution feeder line, the microgrid is able to perform active and reactive power dispatching, power factor compensation or to operate in islanding operation mode solely. After all, green energy and high-tech material are two major aspects in the promotion of domestic green culture. We have successfully developed a variety of plasma-coated energy-saving thin-film devices for daily life applications. The films were verified to be capable of resisting solar heat and saving energy in air conditioning. Already, there are domestic companies participating in the early involvement of the high-end flexible energy-saving film projects. It is expected that the manufacturing industry would be transformed and upgraded as the result.

On radiation application technology R&D,the Radiopharmaceutical Manufacturing Center of INER was granted the certification of PIC/s-GMP which is the newest drug manufacturing standard from Taiwan Food and Drug Administration (TFDA). It is assured that INER will provide the highest-quality radiopharmaceuticals to meet the clinical need and make contribution to national healthcare program. We also developed the first image-reconstruction software which could significantly shorten the calculating time for evaluating 3D skull images data while still maintaining high image resolution. It is considered the foremost software program that meets the industrial standard of the commercial dentist CT. By using our software, domestic companies could be benefitted from not having to pay unreasonable amount of license fees to foreign vendors. Besides, it could also promote the quality of people's oral healthcare.

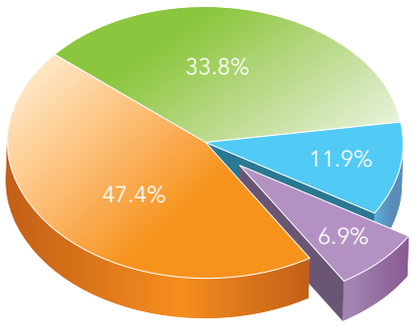
We at INER are engaging in comprehensive evaluation of the needs of the country and contributing for endeavors to advancing toward the objective set by the government policies. With substantial experiences in research of energy technology and strategy analysis that we have accumulated, we are committed persistently to our vision and strive to be the research institute which provides complete strategy and technological solutions to the nation's energy security, environmental protection and ultimately the well-being of its citizens.

Director-General

2. Human Resources and Budgets

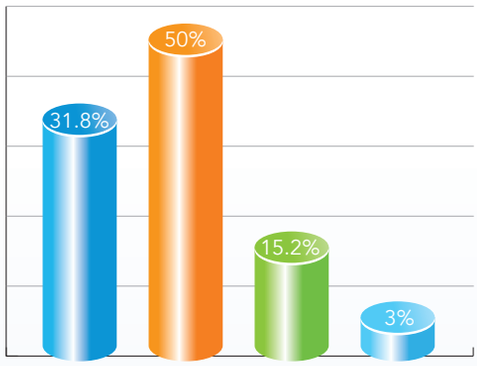
（Time of data: December, 2014）

Manpower Distribution of INER



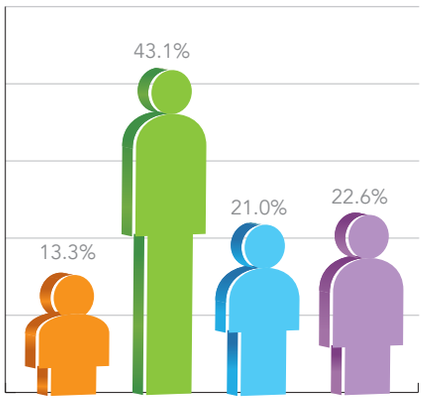
Research Staffs	362 persons	(47.4%)
Technicians	258 persons	(33.8%)
Administrative Staffs	91 persons	(11.9%)
Other Staffs	53 persons	(6.9%)
Official Staffs	764 persons	

Statistics of Educational Background for Research Staffs



Ph.D.	115 persons	(31.8%)
Master	181 persons	(50%)
Bachelor	55 persons	(15.2%)
Vocational School	11 persons	(3%)
Research Staffs	362 persons	

Statistics of Job Category for Organizational Research Staffs



Researcher	48 persons (13.3%)
Associate Researcher	156 persons (43.1%)
Assistant Researcher	76 persons (21.0%)
Research Assistant	82 persons (22.6%)
Research Staffs	362 persons

2014 Annual Budget

Unit: Thousand NTD

Line item	Number of accounts	Percentage
Administration and Safety	1,218,711	56.64%
Management, Operation and Maintenance	106,905	4.97%
R&D Projects	688,070	31.98%
Technology Promotion and Service	137,970	6.41%
Total	2,151,656	100.00%

3 Events of the Year

3-1 The Establishment of Energy Information Platform (EIP)

Fu-Kuang Ko

1. Introduction

According to the increasing of diversity on energy issue, and the rapidly development in new energy and carbon reduction technologies, Center of Energy Economics and Strategy Research, Institute of Nuclear Energy Research (INER), established a knowledge-sharing website named "Energy Information Platform (EIP)" in 2014, which provides multiple dimensions of energy information for the public. EIP integrates all energy-related research achievements of INER, which includes energy technology, energy economics and energy strategy. Thus, EIP is an important platform to share energy information and release research results of INER.

2. Achievements

EIP is different from other domestic energy-related websites; it provides multi-dimension, multi-technology and various forms of energy information. EIP collects important reports and data, which include energy economics, energy technology, environment and energy strategy issues from abroad and Taiwan. It is effective to reduce the information-gathering cost. EIP and National Energy Program-Phase II (NEP-II) will link to each other's website in 2015 and thus to share information and resources bilaterally.

Current contents of EIP are summarized as follows. (1) Energy Illustrations: It releases 18 indicators that are often used. Stiff statistics are replaced by simple chart and brief descriptions. (2) Energy Insights: it reveals short articles with comments on current domestic and international energy issues from interdisciplinary experts. Users can understand energy related issues quickly by it. There are 45 articles and we release at least one article per month. (3) Research Report: It archives technical, economic or strategy research in INER. There are 950 reports and we release at least 40 reports annually. (4) References Database: It collects domestic and abroad reports to provide reference for energy strategy decision. There are 1600 references currently and we are updating at least 120 references quarterly. (5) Useful Links: EIP archives database and important reports links, and illustrates briefly about the website, thus to enhance the convenience and efficiency.

3. Conclusions

EIP at INER was built and underwent trial operation in the end of 2014, to which the number of visitors continues to grow. The information from EIP has been actively shared by websites of some other domestic energy-related community. EIP is expected to be in operation formally in March, 2015. In order to strengthen links with the community and promote consensus of society, Center of Energy Economics and Strategy Research will continue to release research achievements and strategy suggestions, based on solid studies of INER. EIP has also received great feedback from general public, industry and NGO, during the communication with them. In the future, in order to make EIP more diversity, objectivity and neutrality, we will include more experts and scholars' insights on crucial and debatable topics. Furthermore, we will add links to energy-related news and share EIP information to social networking sites, which will make message transmission more rapidly and conveniently. EIP could be a valuable platform for energy information sharing and diffusion for domestic industry, government, academia, research institution and NGO. We believe that EIP can facilitate the information transmission and interdisciplinary interaction.

▲ Energy Information Platform (EIP)

Welcome to visit the EIP website: http://eip.iner.gov.tw/

3-2 Development of the solid oxide fuel cell technology and establishment of the industrialization platform

Ruey-Yi Lee

In the year of 2014, some major achievements for the SOFC project are highlighted as follows:

Technology transfer of SOFC cell fabrication technology: In January of 2014, an official contract was signed with the LEATEC Fine Ceramics Co., regarding the fabrication techniques for the SOFC membranes and cells. Through intensive technical discussions and elaborative demonstrations, the core technology to fabricate a full cell has been satisfactorily transferred to the local company, which is now able to produce SOFC cells with good performance.

Coating technology on Interconnect: A collaborative work with Han Tai Technology Co., was conducted to deposit the lanthanum-strontium- manganese (LSM) protective layer on SOFC interconnect via the atmospheric plasma spraying (APS) coating processes. Through the processes, protective layers with high quality and low electric resistivity can be obtained at a high yield.

Collaborative work on the SOFC system: The collaborative project between the INER and China Steel Cooperation (CSC) on the kilowatt-class SOFC power system has been completed. A thermally self-sustained power system was successfully assembled, installed, and tested at the CSC. Through the collaborative project, CSC intends to scale up the size of the SOFC power system for further applications. A newly cooperative work with the Green Technology Research Institute, China Petroleum Corporation, Taiwan, is undergoing for the SOFC power system as well. In addition, a contract of preliminary collaborative work has been signed with Edison International Energy Inc. in September, 2014; then, affairs of technology authorization on SOFC power system are expected in 2015.

Awards: In the 2014 Taipei International Invention Show & Technomart, some awards were granted: (1) "Process to produce fine ceramic powder through a chemical reactor with powder collection device"-- gold award; (2) "An anode on a pretreated substrate for improving redox-stability of solid oxide fuel cell and the fabrication method"-- silver award; (3) "A plate type fuel reformer of fuel cell" -- bronze award.

3-3 ^{188}Re-Liposome Approved by TFDA for Phase I Clinical Trial

Shu-Pei Chiu , Chih-Hsien Chang

The therapeutic radiopharmaceutical, ^{188}Re-Liposome, has been approved by TFDA and IRB at VGHTPE for Phase I clinical trial in treatment of metastatic stage patients. Aims of the trial are to evaluate safety, tolerance and preliminary efficacy of the therapeutic radiopharmaceutical. The carrier of the radiopharmaceutical is liposome. It can prolong the pharmacokinetics of encapsulated drugs or radionuclides due to the property of nanoparticles. Nutrients for growth of tumors are supported by new blood vessels, which cause leakages of vessels during formation. These reasons cause ^{188}Re-Liposome passed the leakages and specifically accumulated in tumor lesions. Rhenium-188 (^{188}Re) is a radionuclide used for imaging and therapeutic dual applications due to its short physical half-life gamma emissions for imaging, and its beta emission for tumor therapeutics.

The Phase I clinical trial of ^{188}Re-Liposome is ongoing. We expect the radiopharmaceutical to meet the requirements of cancer therapy, fulfill the applications of nuclear energy in human health care.

▲ Rhenium-188-Liposome injection

3-4 Persistence is the key to success: breakthrough of cellulosic ethanol technologies initiates the times of bioeconomy industry

Wen-Song Hwang

Bioeconomy is the commercial activities derived from the utilization of biotechnology and bio-resources. It is regarded as the most important trend in the development of economy and industry following the information and communication economy. Moreover, the white biotechnology, also known as the biotechnology used in industrial and energy field, attracts more attention in bioeconomy development in comparison with green biotechnology on agriculture and red biotechnology on medicine. At the present stage, biofuel development is the primary driving force for initiating bioeconomy industry, due to the needs in diversity of energy supply, energy security, greenhouse gas emission reduction, activation of rural economy and the increase of employment opportunities.

To date, at least 64 countries have announced the policy of biofuel for transportation, for which bioethanol is the most popular biofuel worldwide. Bioethanol from lignocellulosic feedstock, such as rice straw, bagasse, wood residue and napiergrass, also called as the second generation bioethanol, has demonstrated the practical potential because it does not compete with food resources and has shown lower carbon footprint, compared to that from corn and sugarcane. However, the development of key technologies employed in cellulosic ethanol production, such as fermenting strain with high performance, depolymerization and saccharification of lignocellulosic biomass, are challenging research works. The cost, including initial investment on equipment and the collection/transportation of lignocellulosic biomass, still needs to be reduced. Therefore, governments have devoted to developing cellulosic ethanol technologies over the past several years and expected to overcome the technological bottlenecks of cellulosic ethanol production to show the commercial benefits.

To comply with the national energy policy, the Institute of Nuclear Energy Research (INER) has been dedicated to developing cellulosic ethanol technology since 2005. During the period, a leading and unique pilot plant with a capacity of 1 ton biomass fed per day was completed in Taiwan to validate the applicability of cellulosic ethanol production at massive scale. INER also promoted the integration of research capacity in Taiwan and then made the key technologies for cellulosic ethanol production, which has been demonstrated to keep a pioneering position in Asia. Furthermore, a business model such as "co-located cellulosic ethanol plant" was also proposed by INER to promote the commercialization of cellulosic ethanol. The cellulosic ethanol plant was supposed to be built and co-located with an existing factory, which could produce large amounts of wastes with high contents of fiber. Both plants could use the utilities related to steam, water and power together and then it is thought as a useful way to reduce initial investment on the facilities. The cost for the collection/transportation of lignocellulosic biomass can also be decreased, because the location of feedstock source is very close to cellulosic ethanol plant under the co-located design. As a consequence, a Malaysia plywood company has shown much interest in INER's cellulosic ethanol technologies, which facilitated the signing of a technical authorization contract with INER in 2014 and the contract amounts is up to tens of million dollars. Construction of the first advanced biofuel plant in Asia will be completed for commercialization within the next three to five years under this contract. This achievement shows that cellulosic technologies through long-term development by INER exactly exhibits a level of commercial application and has prospect of increasing industrial output value by technological export. Moreover, INER's cellulosic technologies can further provide domestic capacities on independent production of alternative fuel and then economic and social benefits are acquired if commercialization is implemented in Taiwan in the future.

As mentioned above, the goal of commercialization is coming for INER's cellulosic ethanol technology, which also starts a new era of biotechnology in energy field. Nevertheless, the application scope of key technologies for cellulose-to-ethanol is not limited to biofuel production. Depolymerization of lignocellulosic biomass

produces sugars and it can also be biologically converted into building blocks of bioplastic and biochemical by another fermenting strains. For instance, lactic acid-produced bacteria can convert sugars to lactic acid, which is often polymerized to a kind of polyester, plastic-polylactic acid (PLA) for package materials production. Therefore, the application of core technologies derived from cellulosic ethanol is looking forward to expanding from energy to industrial field. Its potential is believed to be very promising in the future.

3-5 Plasma Coating Technology on Smart Energy-saving Application

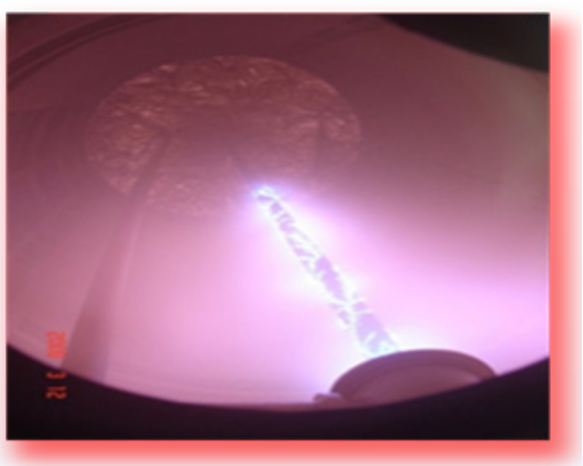
Der-Jun Jan

Institute of Nuclear Energy Research (INER) has a lot of experience in plasma technology research and applications over 20 years, thus accumulating profound industrially-relevant plasma-based technologies and abilities. It is a great asset and unique to Taiwan. At present, on the basis of the core plasma technology and market demand, INER has developed energy-saving and environmental products as well as relevant industrialized process systems, aiming to be a new model of self-supported and innovative development. The R&D achievements not only fulfill the national requirements in energy saving and carbon reduction, but also help the green industry to enter international market. The highlights of 2014 are as follows:

1. An innovative plasma arc technology on energy-saving film coating

INER adopts an innovative plasma arc technology (Fig. 1) to produce high-end energy-saving films. The films can reflect over 90% IR and heat of the sun, with visible light transmission over 70%. The color of the films is variable. This plasma arc technology is a unique technology in the world, which can reduce the production costs.

The total solution of plasma arc technology for high-end energy-saving films at INER is implemented in one go, from design and simulation of device mechanism, through mass-production processes and system equipment integrated development, to the output of roll products. It is completely indigenous and self-supported. INER now has contracted with Taiwan's largest company in color films for early involvement in high-end flexible energy-saving films. It marks a big step in spreading the high-threshold roll-to-roll plasma arc coatings to the high quality energy-saving industry.



▲ INER's innovative plasma arc technology.

2. A self-supported photovoltaic (PV) powered electrochromic (EC) device

INER used core plasma process technology to develop energy-saving electrochromic thin-film devices. The electrochromic (EC) devices control the amount of sun light and solar heat by dynamically switching across the whole spectrum between darkened and clear states. This is the best way to realize significant energy savings and reduce electrical demand in buildings. We have carried out the PV-powered EC device testing by using white light LED to illuminate the thin-film PV solar cells of 100 cm^2, for generating the low-power DC voltage required to power the flexible EC device of 25cm×25cm. The integrated device provides a way to show the integration of generating power, sensing and energy saving without external hard-wired connection, which was recommended by the e-newsletter at 2014 Taipei International Invention show and Technomart (INST 2014) (Fig.2). INER now has contracted with a technology company for the cooperative development of electrochromic modules and an optoelectronics company for the technology service of electrochromic modules.

▲ Fig.2 INER's PV-powered EC device was recommended by e-newsletter at INST 2014.

3. An all-solid-state thin-film lithium-ion battery

INER has developed a high-safety, thin and lightweight all-solid-state thin-film lithium-ion battery, manufactured by magnetron sputtering. The battery is composed of thin-film cathode, electrolyte and anode, deposited on a substrate in series with total thickness less than 10 μm. The capacity of the battery is 300 μAh and capacity retention is 85.7% after 120 charge-discharge cycles. We have developed successfully a multi-chamber vacuum system for the fabrication of thin-film batteries. Each chamber works independently without inter-contamination and exposing the films to atmosphere to reduce the oxidation and deterioration of the films. This system can increase the production yield and improve the electrochemical properties of the batteries to increase the capacity and cycle life. The thin-film batteries have high voltage to power LED lights, electronic watches and electronic armbands, exhibited at the INST 2014 (Fig. 3).

The preliminary effect of plasma coating on smart energy-saving applications has been noticed. In 2014, we integrated individual flexible devices into one system. For example, flexible thin-film solar cells and a flexible EC device are combined to form one energy-saving system with smart transmission tuning. The excellent function was exhibited in public to look for industrial partners to involve in and improve further development. In the future, we will continue to promote the integration development of energy-saving devices, make the integrated system have the multi-functions of energy generation, storage, tuning and sensing. This integration will provide next-generation applications of flexible 3C and IoT products. These planning will be the future development direction of new green energy-saving industry.

▲ INER's all-solid-state thin film battery powered a electronic watch.

4 Current Major R&D Activities

4-1 Preface and Perspectives on Nuclear Safety Technology Research

Tsu-Mu Kao

In response to reflect the impact of year 2011 Fukushima Daiichi nuclear power plants (NPPs) accident in Japan, Taiwan government declared the new energy policies that the nuclear safety of the 4th NPP must be ensured prior the commercial operation and no life extension will be granted to current 3 operating NPPs. Taiwan government decided the 4th NPP to be mothballed since 2014. The spent fuel dry storage of 1st NPP is still held up by local government and legal challenge.

Over 46 years of devotions, the INER has established its fame as the top research institution equipped with the most advanced nuclear technology in Taiwan. The major tasks include supporting governmental safety reviews and regulations in NPPs, as well as enhancing operational safety and efficiency for the plants. Currently as the energy prices and CO_2 emissions have become the main issues of the domestic energy supplies, the nuclear energy has proved itself as an one of the efficient alternatives and as an important "transition source of power" to the low carbon society. The INER will continue its efforts to the researches and development of nuclear safety, and the operational safety of NPPs. The INER sets goals at continuously supporting the safety for operating NPPs, and assisting the Taiwan Atomic Energy Council (AEC) in their regulatory requirements to review and audit the NPPs of Taipower.

Major achievements of the nuclear safety technology research during 2014 will be described in details project by project as follows: (1) Development of key technology for improving safety in NPP management and operation project including research in safety maintenance of NPP, severe accident and compound disaster prevention, and investigation for the radiation protection and the emergency response for the nuclear accident. (2) The development and application of radwaste management technologies for nuclear power system lifecycle project including the study of volume-reduction technologies for decommissioning radwaste, the study of treatment technologies for special liquid radwaste, and the development and application of radwaste final disposal technologies. Through the valuation and validation process, the developed technologies will ensure the safety and domestic possession while they are applied to the nuclear power plant decommissioning. (3) Implementation of clearing nuclear facilities by law project including cleanup and improvement of nuclear reactor and affiliated facilities, and the reduction treatment and safety storage of radwaste.

4-1-1 Development of Key Technology for Improving Safety in Nuclear Power Plant Management and Operation project

Lainsu Kao

1.Introduction

In the wake of Japan's 311 Fukushima nuclear disaster, countries around the world were proceeding in succession to conduct stress tests for their nuclear power plants and review their current nuclear energy policies. To put in practice the major assertion of the national energy policy and the outline of the national sustainable energy strategy which were committed by our government in 2011, the project "Development of Key Technology for Improving Safety in Nuclear Power Plant Management and Operation" is formulated to achieve the following goal : (1) maintaining the safety in management and operation of the existing nuclear power plants to assure the stability of the domestic self-produced nuclear energy supply system; (2) Enhancing the safety and self-defense capabilities of the existing nuclear power plant facilities to avoid the occurrence of the compound nuclear disasters; and (3) Preparing a solid core-meltdown prevention oriented Ultimate Response Guide (URG) to prevent a nuclear disaster and establishing an appropriate radiation protection and emergency response plan to minimize the environmental impact resulting from a nuclear disaster in case a disaster can not be prevented.

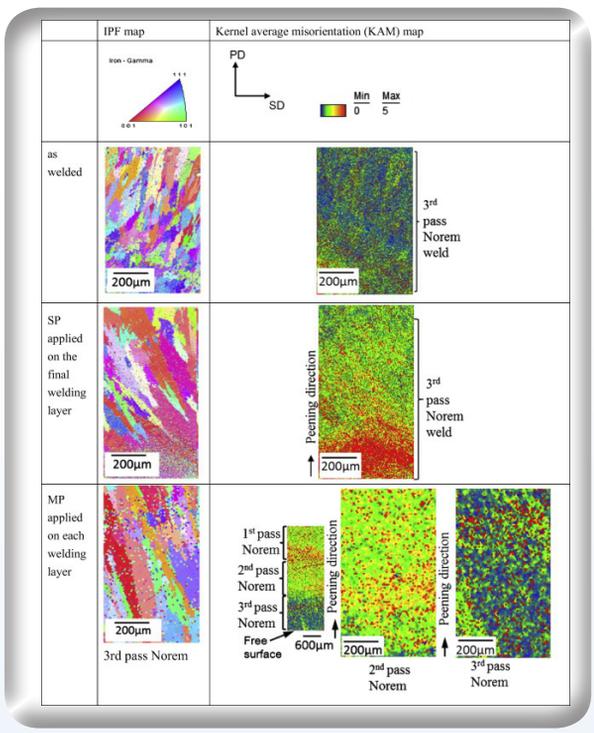
2. Major Research Results

2.1 Research in Safety Maintenance of Nuclear Power Plant

In order to ensure the nuclear power plant operation safety and the stability of power supply during the designed lifetime of Chinshan, Kuosheng, and Maanshan power plants, this sub-project is aimed at improving the plant's operating performance by using software analysis techniques, activating the components of plant facility and shortening the maintenance working period by using key hardware techniques. The important research results for this sub-project in the year of 2014 are as follows:

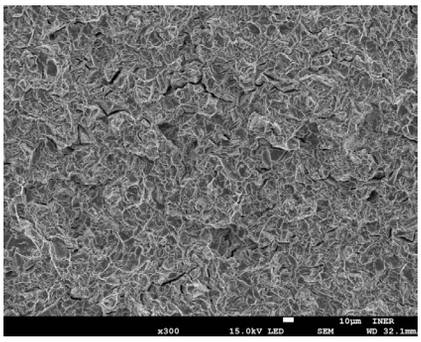
(1) An in-house neutronics and thermal-hydraulic safety analysis methodologies and licensing support technology for the nuclear power plants has been developed. Up to 2014, a cumulative total of thirty-nine (39) topic reports had been submitted to the Atomic Energy Council of the Republic of China (ROCAEC) for reviewing, and thirty-six (36) of which have been reviewed and accepted with respective SER issued by ROCAEC, and the other three (3) are still under review. The certified neutronics and thermal-hydraulic safety analysis methodologies will then be formally employed in the nuclear power plants for licensing support analyses. These certified technologies have been successfully applied in the safety analysis support for the power uprate program of the existing plants, including Chinshan, Kuosheng, and Maanshan plants. Currently, they are also used to perform the control room dose analysis in response to the GL 2003-01 Control Room Habitability issue. This achievement provides further assurance for the nuclear plant operation safety.

(2) During the development of components aging prevention and welding repair technologies applicable to prevention of deterioration of the welding, it is worthy to be noted that the hammer peening process could help prevent crack initiation and propagation in Norem welds by reducing the welding residual stress and inducing a great number of low angle grain boundaries. The results also show the technology of acoustic microscopy has the potential for detecting the degradation of centrifugal-cast stainless steel CF8A.



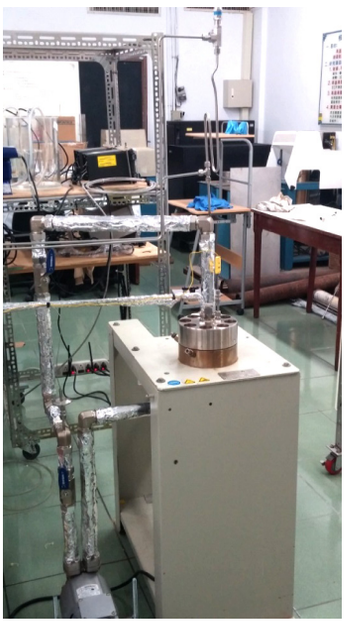
EBSD IPF and Kernel average misorientation (KAM) maps of Norem welds subjected to SP and MP processes

(3) Spent nuclear fuel dry storage technology has been developed,including using hydrogen charged zirconium alloyspecimens to simulate the high burn-up fuel cladding, and characterizing the material properties which are applicable to the integrity assessment of transportation after the long period of dry storage.



▶ Tomography of Zr specimen (750 ppm H2 content) ruptured under test temperature at 100°C

(4) A reactor anti-corrosion and water quality control technology has been developed. This includes using flow accelerated corrosion test to compare corrosion resistance quantitative data between carbon steel and low alloy steel, as well as using chemical simulation software to simulate the chemical environment of the fluid systems of Chinshan,Kuosheng and Maanshan plants. This also helps plant personnel to interpret or evaluate the chemical data.



2.2 Severe Accident and Compound Disaster

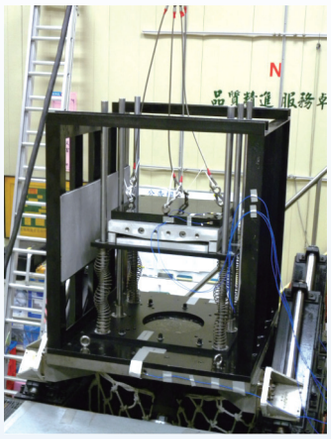
The fluid systems of chinshan, Kuosheng and Maanshan plants. This also help plant personnel to interpret traluate the chemical data.

▶ Experiment equipment of bypass loop and circulation pump

Prevention

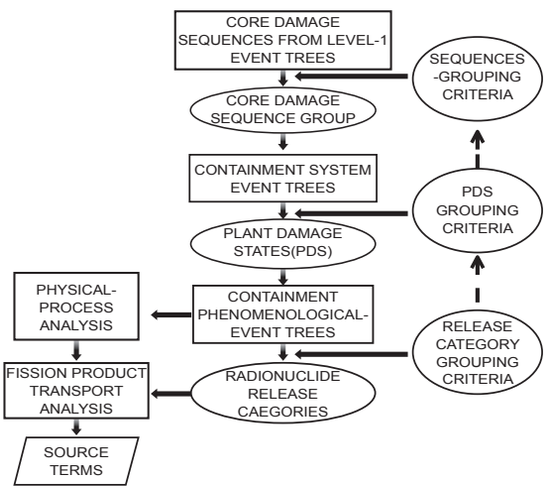
The purpose of this sub-project is to develop the Level-2 PRA and related analytical techniques with respect to the potential risk resulting from earthquake. Meanwhile, the work of reinforcing the plant's earthquake resistant features for the existing buildings, structures, facilities, and electrical distribution panels and enhancing plant's self-defense capability and disaster warning system are in progress in order to effectively reduce the probability of occurrence of the nuclear disaster. The important research results for this sub-project in the year of 2014 are as follows:

(1) In accordance with the requirement of the shock isolation for the nuclear-graded distribution panels, the isolator currently sold in markets are improved in order to comply with the specification requirements provided by the plant. Distribution panels isolators were actually tested in INER's seismic testing facility and the results show that the installed isolation platform performs very well for the shock isolation and can significantly reduce the horizontal acceleration g-force encountered by the distribution panel during the earthquake.



Test of multi-roller bearing isolator ▶

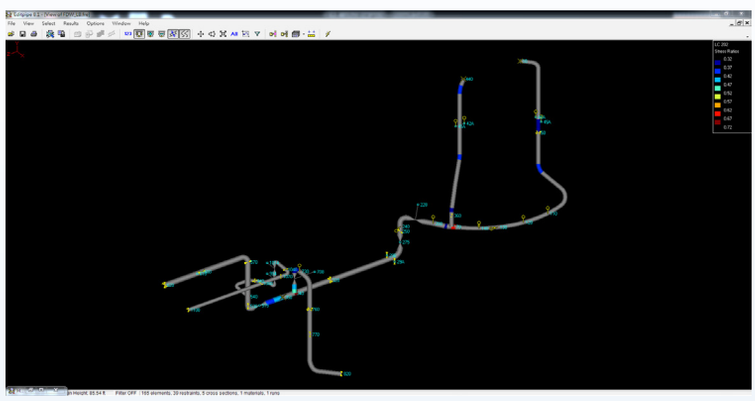
(2) Fukushima nuclear accident reveals the necessity of strengthening the probabilistic risk assessment of the external events. The PRA analysis is able to evaluate more realistically the potential threat of natural or man-made disasters that could affect plant's safety, since the geographical and environmental characteristics surrounding the site is appropriately included in the PRA model. The more sophisticated PRA Level-2 analysis method extends the scope of the Level-1 assessment to analyze the integrity of containment and perform the quantitative assessment of the offsite radiation released, allowing the plant's risk spectrum to be even more complete and thus further deepening the concept of defense in depth. The PRA Level-2 analysis also can provide information to help make more practical decisions and thoughts of the plant's safety under severe accident scenarios.



▲ The framework for Level-2 PRA

(3) To have the capability to establish the tsunami hazard probability formula, this project covers several studies, including the seismic source, tsunami simulation technology, the affected plant site, and the anti-tsunami facilities As for the research in the seismic source, we completed the study of Ryukyu trench earthquake frequency and established a tsunami record research in the historical data aggregated since the first tsunami caused. As for the outcome of the tsunami simulation technology, the research report of earthquake caused tsunami simulation and analysis of empirical data aggregated was issued. In addition, National Cheng Kung University was commissioned to complete the reports of the probability model of a tsunami wave height and wave propagation research (in year 2014) and the probability assessment of the influence of the tsunami waves built in the plant site (in year 2014). As for the anti-tsunami research project, a research report of case study for nuclear power plant anti-tsunami wall design was also issued.

(4) A verification and validation (V&V) test program for seismic analysis and reinforcement technology has been performed with respect to the safety-related plant structures, reactor internal components, and system piping of the nuclear power plant. The feedwater piping seismic assessment has been completed this year and the safe shutdown earthquake (SSE) value was analyzed to be increased from 0.3g to 0.4g. In addition, it was found that some tube supporting frames need reinforcement or design modification to meet the ASME design specifications and thus assure the plant can be operated safely.

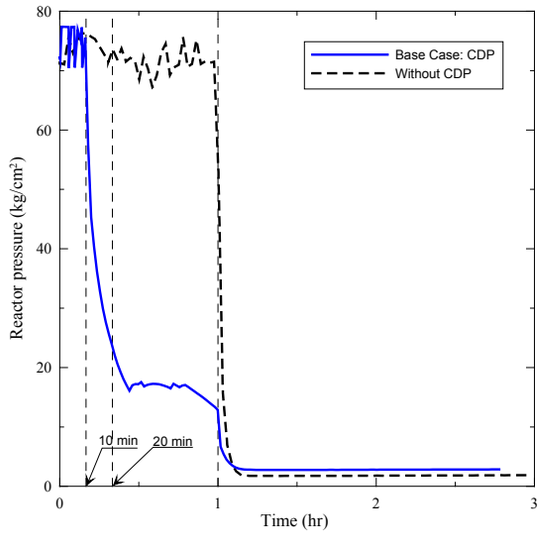


▶ Stress Analysis Result for Class 1 Feedwater Piping

2.3 Investigation for the radiation protection and the emergency response for the nuclear accident.

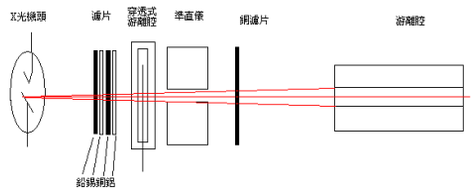
In order to strengthen the emergency response capability to the Fukushima-type accident, this sub-project is aimed at developing serval technologies, including severe accident analysis, more sophisticated instrumentation and calibration for the radiation detection and monitoring system, radiation prevention and protection measures, as well as contingency preparedness during the severe accident, and environmental restoration and repopulation. The technologies developing process are based on the comprehensive review report for the protection system of the existing domestic nuclear power plants, as well as the in-site and out-site needs for the contingency protection. The important research results for this sub-project in the year of 2014 are as follows:

(1) The URG has been integrated with the associated procedures (EOP, SAMG,and EDMG) for the Chinshan plant. MAAP5 model was established and used to perform the extended station blackout (SBO) cases for Chinshan plant in order to obtain the critical parameters for URG' usage. Key parameters from MAAP5 results are also compared with those calculated by the RELAP5 code. The calculations performed in this sub-project not only provides the current URG with the critical parameters as a reference basis for taking the key actions, but also increases the analysis capability for the severe accidents.

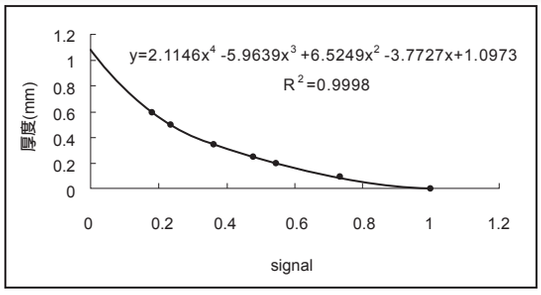


▲ RPV pressure-change chart during implementation of URG for Chinshan NPP

(2) In response to the nuclear accident, the medium-energy (320kV) X-ray dose irradiation system was built in accordance with the standard of the X- ray emission quality proposed by the International Standards Organization (ISO). The low-energy dose standard was established to provide the environmental radiation measurement at the accident location and the low-energy radiation dose calibration for the radiation dose detector. According to the resolution characteristics of the X- ray spectra, the X- ray emission quality standard is divided into four series: low air kerma rate (LK) series ray, narrow spectrum (NS) series ray, a wide spectrum (WS) series ray, and high air kerma rate ray (HK). The NS and WS standards established for the beam are in compliance with the requirements of ISO4037-1 and American ANSI N13.11.

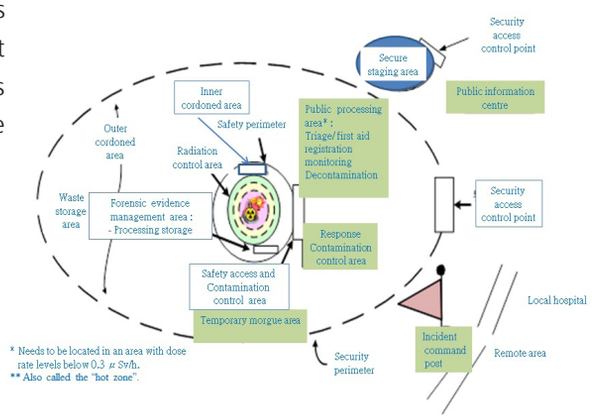


▲ The thickness of HVL measurement



▲ The thickness of HVL measurement result for INS 60

(3) By integrating, in the form of meteorological data bank, the three-dimensional wind field meteorological forecasting model of the higher-order turbulence model for atmospheric circulation (HOTMAC) and the cloud atmospheric dispersion analysis of a Monte Carlo dispersion and transport model (RAPTAD) as well as the environmental radiation dose assessment system, the real-time post-accident radiation dose rate and cumulative dose can be evaluated for the succeeding five days after the accident, with the results provided as an important information for the decision making by the emergency response organization. The emergency radiation response scenario, the action guidelines for the emergency response personnel, the radiation protection measures and the dose limits instructions are prepared and provided to the first line task force of the central and local governments as a guideline for the mission execution such that the safety of the radiation protection can be assured.



▲ Generic layout of the response facilities and locations within areas established for a radiological emergency

(4) To help people reduce their concerns for the radiation safety in the radiation incident, several works have been done, including learning the international experience in dealing with radiation accidents, study of good public communications skills, and providing the necessary information regarding the long-term recovery plan and protective actions. The report entitled, "Establishment of Experience and Technology for restoring and repopulating the Environment" has been completed through the efforts of gathering the restoration experience after the Fukushima nuclear accident. In addition, the food radioactive tolerance standard is highly concerned by people after the Fukushima nuclear accident. Hence, the report entitled, "Comparison of the Radioactivity Tolerance Standard in Food for Different Countries" was completed through analysis of the standards of radioactive contents in food for major international organizations or nations. This report serves as a reference for the relevant regulatory authorities in development or amendment of the future regulations.

(Unit:Bq/Kg)

Nuclide	Type of food	Taiwan	CODEX	Canada	EU	US		Japan		Singapore	HongKong
						Old	New	Old	New		
131I	Milk	55	100	100	500	55	170	300			
	Infant foods			1000	150					100	100
	Other foods	300	100		2000	300		2000		100	100
134+137Cs	Milk	370			370	370	1200	200	50		
	Infant foods								50	1000	1000
	Other foods	370			600	370		500	100	1000	1000
134Cs	Milk		1000	300							
	Infant foods			1000							
	Other foods		1000								
137Cs	Milk		1000	300							
	Infant foods			1000							
	Other foods		1000								
90Sr	Milk		100	30	125		160				
	Infant foods			100	75					100	100
	Other foods		100		750					100	100
89Sr	Milk		1000	300	125						
	Infant foods			1000	75					1000	1000
	Other foods		1000		750					1000	1000
106Ru	Milk		100	100	1000		450[c]				
	Infant foods			300	400					100	100
	Other foods		100		1250					100	100
103Ru	Milk		1000	1000	1000		6800[c]				
	Infant foods			1000	400					1000	1000
	Other foods		1000		1250					1000	1000
238Pu	Milk		1	1	20						
	Infant foods			10	1					1	1
	Other foods		10		80					10	10
239Pu	Milk		1	1	20						
	Infant foods			10	1					1	1
	Other foods		10		80					10	10
241Am	Milk		1	1	20						
	Infant foods			10	1					1	1
	Other foods		10		80					10	10
Pu+Am	All foods						2				

▶ A comparative study of national standards for allowable amount of radioactivity in foods

3.Perspective

Currently there are three operating nuclear power plants in Taiwan providing 18% of electricity demands 2014, which is in line with the sustainable energy policy incorporating with the characteristics of low-carbon emission and relying less on import energy. To maintain a reasonable electrical price without power shortage as well to meet the international carbon reduction commitments in principle, Taiwan's nuclear power is not to be lightly abolished. On the premise, how to ease off people's nuclear safety concerns is becoming a much-needed issue just in front of the nuclear energy sector. At the current stage, the measures taken to develop key technologies in order to maintain the safety of nuclear power plant operation are to prevent equipment aging and deterioration, to enhance plant seismic resistant capability, to prevent the occurrence of compound disasters, and to develop methodologies of dealing with nuclear accidents and analysis capabilities. All above mentioned measures are also viable objectives of this project for future implementation.

4-1-2 The development and application of radwaste management technologies for nuclear power system lifecycle

Tsong-Yang Wei

The nuclear energy user has the obligation to fulfill the commitment of stabilizing radioactive wastes economically in order to store them safely. A valid waste management can enhance operation safety of a nuclear facility and mitigate the public concerns regarding radioactive contamination to living environment.

This project is aimed to develop and verify novel radioactive waste management technologies for the necessity of nuclear power system lifecycle. The strategy is to achieve the waste treatment necessity form the operation and decommissioning for existed facilities in INER at first. Then the established technologies are supposed to support the radioactive waste management of domestic nuclear power plants for both operation and management associated with decommissioning activities in the future.

In 2014, three subprojects including, (1) The study of volume-reduction technologies for decommissioning radwaste, (2) The study of treatment technologies for special liquid radwaste, and (3) The development and application of radwaste final disposal technologies were conducted. To develop and apply the core technologies of radwaste treatment and disposal are the main value of this project. Some technologies have been used to stabilize the existed wastes practically. Further, through the valuation and validation process, the developed technologies definitely ensure the safety and domestic possession while they are applied to the nuclear power plant decommissioning.

4-1-2-1 The study of volume-reduction technologies for decommissioning radwaste

Ling-Huan Chiao

This project is aimed to develop cleaning and dismantling technology that could minimize radioactive wastes resulted from future site work. Applications are firstly focusing on clearing INER research facilities. In the future, the developed technologies will also serve the decommissioning of domestic nuclear power plants. For year 2014, the major accomplishments are as follows,

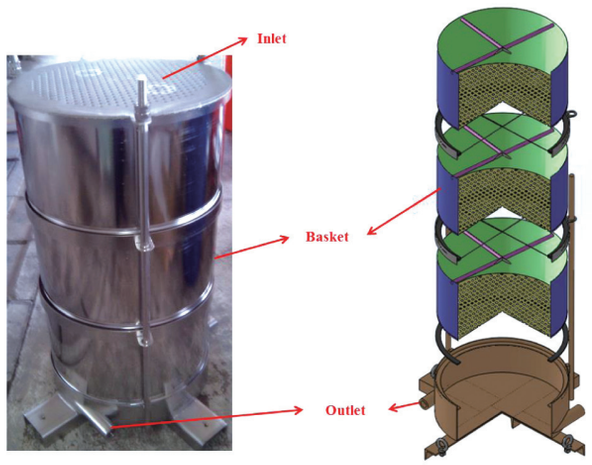
- Completion of a study on augmented reality application for SLAM-based nuclear facility decommissioning task,
- Establishment of spent fuel water Submersion Adsorption system,
- Granted a working permit for uranium sludge stabilization process,

- Establishment of QA system, in compliance with ISO criteria, for on-site measurement of building clearance,
- Completion of remote handling equipment testing and packaging of a total of nine 55-gallon drums of cut spent fuel pipes.

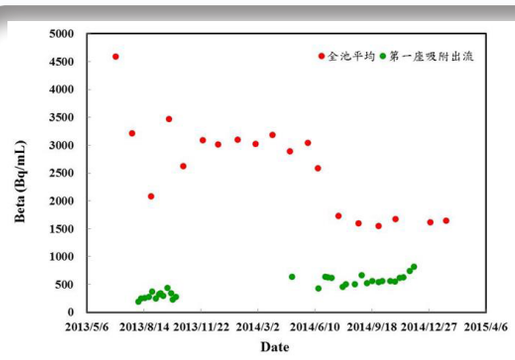
4-1-2-1-1 The Effectiveness of Removing Beta Emitters from TRR Spent Fuel Pool Water by Submersion Adsorption Unit

The decommissioning of spent fuel pool is the phase I task in the Taiwan Research Reactor (TRR) decommissioning project. The water purification units including adsorption, flocculation/precipitation and filtration had been gradually established from 2011 to 2014. Most of the radionuclides in water such as ^{137}Cs and ^{90}Sr could be efficiently removed by the adsorbent. However, the development of decommissioning techniques encounters several challenges including the very limited space of warehouse and further retrieving of the spent purification media with strong radiation. A special designed water submersion adsober is not only workable for the limited space but also efficient for the removal of radionuclides. The unit is able to be placed underwater without heavy shield jacket, and easy to be assembled and disassembled. After being disassembled, the piece of unit is fit with the standard container, the assembled adsorber is easy to be disassembled, retrieved, and packaged.

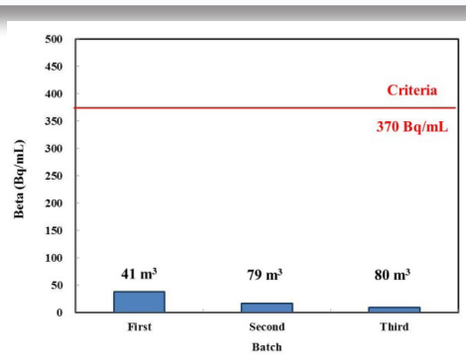
There were two adsorbers have been installed in the TRR spent fuel pool. The first one was demonstrated that it can efficiently remove over 90% of beta-emitters from water. The second adsorber has been treated three batches 41, 79 and 80 m^3 of pool water, so there are accumulative 200 m^3 of treated water which meets the acceptance criteria of Liquid Radioactive Treatment Plant at INER. As the water level lowers down, the adsorber will be disassembled piece by piece to accommodate to the water level. Hence, the adsorber is compact, readily assembled, simple structure, and flexibly disassembled. Also, the removal efficiencies of the adsorption process for the radionuclides including ^{137}Cs and ^{90}Sr are satisfactory.



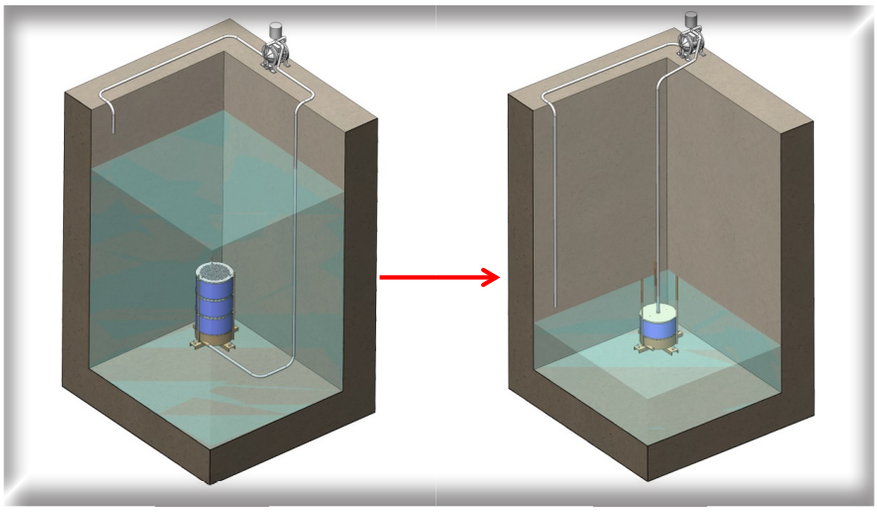
The structure of the adsorber ▶



▲ The gross beta activity of pool water and effluent from 1st adsorber



▲ The gross beta activity of purified batch pool water



▲ A schematic diagram of the modified adsorber

4-1-2-1-3 Hot test of the remote taking-out equipment for high-active wastes

The remote taking-out equipment developed in year 2013 for high-activity waste was successfully tested in 2014. It was consequently used to clear the cut spent fuel casing pipe which, with high dose rate, were dispersedly stored in one of underground vault of INER. A total of nine 55-gallon drums of cut spent fuel casing pipe cut had been taken out and repacked this year. Samples were also sent for nuclide and activity analyses. A better storage condition is achieved.

▲ Remote taking-out underground naked high-activity wastes

▲ Remote packing naked high-activity wastes

4-1-2-2 The study of treatment technologies for special liquid radwaste

Jen-Chren Chung

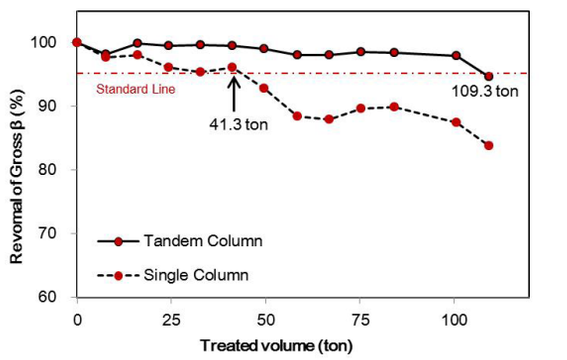
How to effectively treat radioactive wastewater generated from routine operation of nuclear facility and people's livelihood application of nuclear energy is a public concern and extremely important issue. To meet current stricter discharge requirement formulated by regulatory authority, we continuously devoted to develope various technologies in this project. Currently, some of them have been practically used in liquid waste treatment plant in INER and show a very good performance. Furthermore, these developed technologies also will be able to be promoted to domestic and foreign markets to solve related radioactive wastewater problems in the future.

4-1-2-2-1 The development of inorganic selective adsorbent for INER's wastewater treatment plant

This study established the design of inorganic adsorbent (AC-Sr) for the removal of gross β, Sr-90 and Cs-137 from radioactive wastewater. Some tests were conducted by using a pilot scale continuous column system in INER's wastewater treatment plant, in which raw radioactivity of each aimed species was 0.613, 0.279, and 0.178 Bq/mL, respectively, and the loading AC-Sr of each column was 45 kg.

Effluents sampled from tandem column (column 1 and column 2) represented different hydraulic retention time which were 12 and 24 min, respectively. To meet the discharge requirement of gross β by regulation, the capability of single column (column 1) can bear approximately 41.3 ton wastewater treatment; and those of series column (tandem column 2 with column 1) can bear approximately 109.3 ton wastewater treatment. The results indicated that extending hydraulic retention time and increasing the amount of tandem columns obviously enhanced the adsorption effectiveness of the column system for the removal of radionuclides.

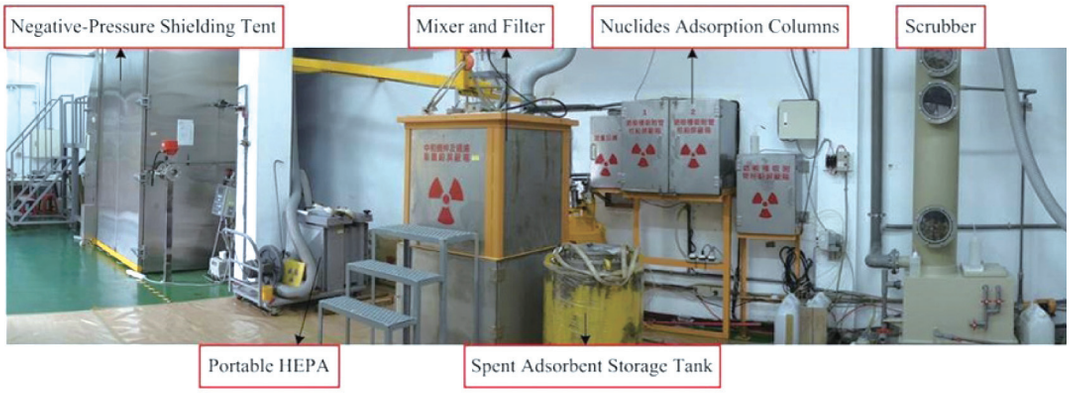
▲ Pilot-scale adsorption system in INER's wastewater plant



▲ Variation of gross β removal efficiency against accumulating treated volume

4-1-2-2-2 Development of treatment process for radioactive wastewater generated from Molybdenum-99 study

A practicable process has been developed for treating radioactive waste generated from molybdenum-99 (Mo-99) study, it can effectively remove radionuclides from a nitric acid solution. At first, after the waste was sucked from the bucket, the PH value was adjusted to about 10.0 through acid-alkali neutralization. Then, an adsorbent of natural zeolite powder was added to adsorb nuclides, and two adsorption columns filled with Cs-treat and Sr-treat adsorbents were used for removing nuclear species of Cs-137 and Sr-90. In this step, the nuclear species of Cs-137 and Sr-90 contained in the liquid waste are significantly reduced to a degree for manual operation allowable. Then, nitrate ion and mercury ion were removed through another procedure. As a result, the operations were safer and more efficient than other conventional methods. Additionally, the hazard of accidental leakage caused by corrosion of the bucket after long period of storage can be effectively prevented and potential pollution threats are also eliminated.

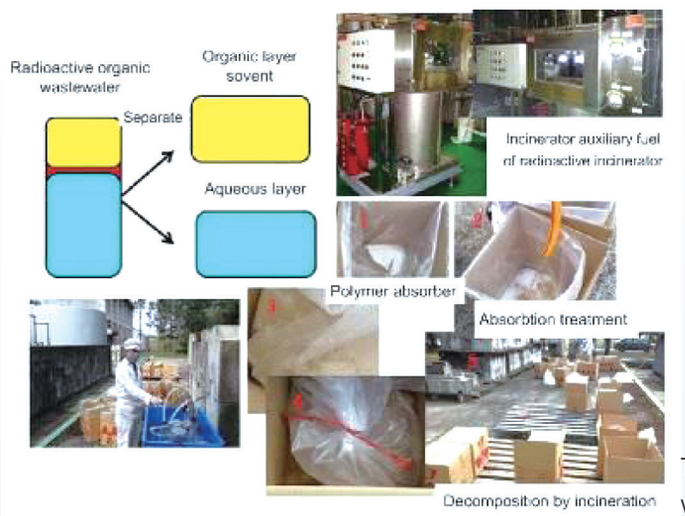


▲ Treatment facilities for Mo-99 liquid waste at INER

4-1-2-2-3 The study of radioactive organic wastewater treatment of INER

INER has been collecting low-level radioactive liquid waste generated from domestic hospitals and research institutions. Over time, this kind of liquid waste has separated into three layers including the top organic layer, the middle aqueous layer and the bottom gel layer. Estimating the composition, the organic layer occupied about 23% of the total volume (no chlorine), the intermediate aqueous layer accounted for 75% (containing 0.7% sodium chloride), and the bottom mastic was about 2% (containing 0.9% chlorine ion). Due to containing 20,000 ppm of total carbon content in the aqueous layer, a special polymer material was adopted to absorb it in which each kilogram of polymer absorber can absorb 45 kg aqueous solution to form a solid combustible material. According to combustion test, it shows good treatment performance and all samples can be decomposed completely by incineration. Currently, the experiment of incineration has conducted the test of more than 150 batches and treated 2100 kg low-level radioactive organic aqueous solution.

Organic waste solvent was diesel miscible with similar calorific value and low viscosity. Therefore, it can be used as an incinerator auxiliary fuel. The treatment process has successfully carried out 1000 Kg treatment test. In addition to effectively solving this kind of liquid waste, it is also expected to save fuel diesel consumption of incineration.



◀ The treatment of radioactive organic wastewater

4-1-2-3 The development and application of radwaste final disposal technologies

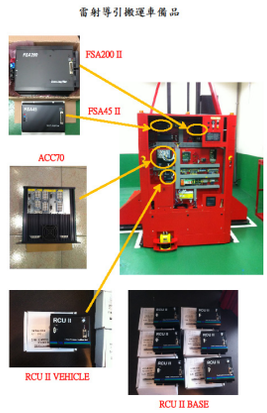
Fu-Lin Chang

This study established an operation platform for waste drum inspection to meet the ongoing accept standard for disposal, the outlook inspection, ventilation and image taking and recording to perform the inspection. And also builds the certificating technology for waste characteristics was built, and to modify present analysis technology for nuclides was modified. The project was also focused on developing nuclides releasing prevention technology to block pollutants distribution for maintaining environmental radiation safety. The goals of safe management of radioactive waste, such as maintaining an excellent ecological quality, ensuring public health, and enhancing public trust were achieved.

4-1-2-3-1 Inspection and repairing study for radwaste final disposal

For repairing the small users radioactive waste final disposal, this study improved the refurbishment of radioactive waste operating platform to inspect the waste drum, and set up the waste delivery database system planning in 2014. This study also completed "Public Attitudes toward Low-Level Nuclear Waste Siting Issues in the Surrounding Areas of Potential Sites" Research Report and invited experts to participate discussions,and to provide future policy reference.

▲ A symposium on Radioactive waste disposal site final acceptance



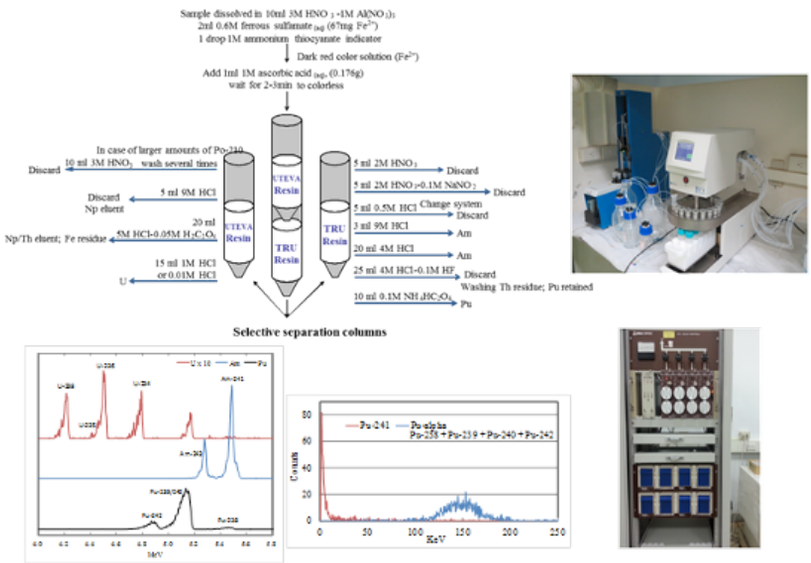
▲ Improve the refurbishment of radioactive waste operating platform

4-1-2-3-2 Technical research on radwaste characterization and nuclide activity analysis

With respect to radwaste characterization, sample pretreatment using the air compressor and reduced pressure concentrator, and improvement on separation and detection using the automatic SPE (solid phase extraction system) and alpha spectrometer, respectively were developed. Analysis of U isotopes and TRU (Pu, Am, Np included) elements in the TRR spent fuel pool water and discharge water from the waste water treatment plant met the reqairments of the regulatory body.

As to receiving the radiation anomalies for radionuclides detection, the media reported an unoccupied radiation source that was picked up by the Hualien town citizen in the ditch nearby his home was sent to INER for characterization and analysis by Radiation Protection Division of AEC. A total of 67 batches of radiation anomalies were detected this year.

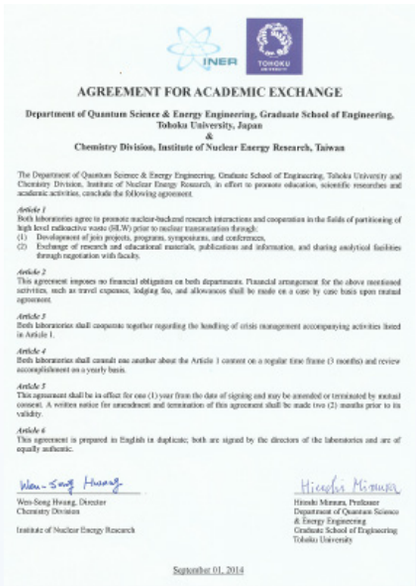
In addition, INER and Prof. Hitoshi Mimura's laboratory of department of quantum science and energy engineering, graduate school of engineering, Tohoku University, Japan have signed the cooperation agreement of technology development on radionuclides partitioning from high level radioactive waste (HLW) prior to nuclear transmutation. The Memorandum of Understanding (MOU) became effective on September 01, 2014.



▲ The flow chart of U/TRU separation and determination using automatic SPE and alpha spectrometer

◀ Unoccupied Co-60 radiation source

▶ On site detection of receiving the radiation anomalies



AGREEMENT FOR ACADEMIC EXCHANGE

Department of Quantum Science & Energy Engineering, Graduate School of Engineering, Tohoku University, Japan
&
Chemistry Division, Institute of Nuclear Energy Research, Taiwan

The Department of Quantum Science & Energy Engineering, Graduate School of Engineering, Tohoku University and Chemistry Division, Institute of Nuclear Energy Research, in effort to promote education, scientific researches and academic activities, conclude the following agreement.

Article 1
Both laboratories agree to promote nuclear-backend research interactions and cooperation in the fields of partitioning of high level radioactive waste (HLW) prior to nuclear transmutation through:
(1) Development of join projects, programs, symposiums, and conferences.
(2) Exchange of research and educational materials, publications and information, and sharing analytical facilities through negotiation with faculty.

Article 2
This agreement imposes no financial obligation on both departments. Financial arrangement for the above mentioned activities, such as travel expenses, lodging fee, and allowances shall be made on a case by case basis upon mutual agreement.

Article 3
Both laboratories shall cooperate together regarding the handling of crisis management accompanying activities listed in Article 1.

Article 4
Both laboratories shall consult one another about the Article 1 content on a regular time frame (3 months) and review accomplishment on a yearly basis.

Article 5
This agreement shall be in effect for one (1) year from the date of signing and may be amended or terminated by mutual consent. A written notice for amendment and termination of this agreement shall be made two (2) months prior to its validity.

Article 6
This agreement is prepared in English in duplicate; both are signed by the directors of the laboratories and are of equally authentic.

Wen-Song Huang
Wen-Song Huang, Director
Chemistry Division
Institute of Nuclear Energy Research

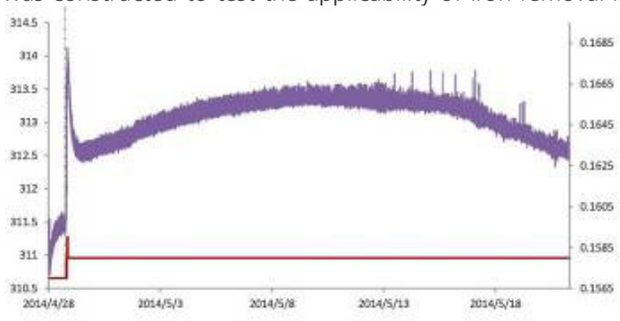
Hitoshi Mimura
Hitoshi Mimura, Professor
Department of Quantum Science & Energy Engineering
Graduate School of Engineering
Tohoku University

September 01, 2014

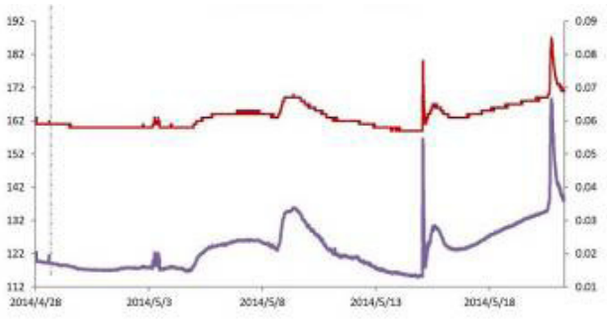
▲ MOU between INER and Tohoku University, Japan

4-1-2-3-3 Study on the monitoring and assessment technology of hydrogeological test site

The monitoring and assessment technology of hydrogeological test site were developed in this study. First, a saline water tracer test was performed. The saline water with 200,000 μS was injected into the injective well continuously in 17 days. The electric conductivity was detected in observed well located at 20 m, 180 m and 250 m downstream. The results showed (1) at 20 m: when test stared, the electric conductivity increased immediately, but the value compared to the source is very low only 314 μS. (2) At 180 m: few peaks occurred after testing. This phenomenon shows the peaks were affected by the rainfall. (3) At 250 m: there was not any significant change of the observed data. The reason is this observation well is far away of the injective well. In addition, pump/treat/inject pilot equipment was constructed to test the applicability of iron removal in the environment. The design maximum treating capacity is 50 L/min. The effectiveness and applicability were still under evaluation.



▲ The electric conductivity distribution at 20 m downstream



▲ The electric conductivity distribution at 180 m downstream

▲ The pump/treat/inject pilot equipment

4-1-2-4 Prospect

The established technologies have been implemented in the practical waste treatment operation in this fiscal year. The contaminated fuel pool water of TRR, about 200 cubic meters, was treated in situ and then transferred to the liquid waste treatment plant for further polishing. The stored organic liquid waste, about 7 cubic meters, was treated with the aid of incineration. The novel inorganic ion-exchanger pellets were installed at the waste water treatment plant site for field application. Furthermore, the equipment installation and software establishment for the waste drum disposal preparation facility, were completed, the existed waste drums waiting for disposal will be through the inspection and documentation with it. The Geohydrology investigation results of ground water and its remediation method for radiological contamination was improved and verified, the relative technologies will be applied to the practical work if the nuclear facility site needs to monitor and clean the contamination.

4-1-3 Implementation of Clearing Nuclear Facilities by Law

Ling-Huan Chiao

INER has contributed in nuclear technology development for more than 40 years. Most of the facilities built to meet R&D requirement 40 years ago are shut-down. To comply with regulator's nuclear safety policy, INER sets up a project to proceed with nuclear facilities clearing step by step. The work scope of this project for year 2014 includes "cleanup and improvement of nuclear reactor and affiliated facilities" and "minimization and safe storage of radioactive waste". The former aims to release the public from concern in uncertainty to the radiation contamination while the latter focuses on decreasing the amount of radioactive waste and consequential decrease of radioactive waste treatment and disposal costs. The achievements made in this year are good for the subsequent tasks.

4-1-3-1 Cleanup and Improvement of Nuclear Reactor and Affiliated Facilities

Chih -Chun Chu Ko

The 4th revision Decommissioning project of Taiwan Research Reactor (TRR) has been permitted by Atomic Energy Council in 2014. To accord with the current cleanup schedule, the spent ion exchange resins were successfully removed from the spent fuel pool on 2014 and temporarily stored on site pending for the stabilization process established. Therefore, the treatment and discharge of the pool water could be further performed. The shipping and storage technology of stabilized spent fuel products were successfully applied to the first storage cask in TRR. INER has sealed the cask after helium filling and leakage test. The International Atomic Energy Aqency(IAEA) was invited to verify the quantity and sealing procedure. And then it was transported to the warehouse for safe storage. The hot tests of scrap metal melting and casting facility in the building 17 were accomplished. Sufficient culmulative operation skills and nice experiences feedback of melting and casting practices lead to the risk reduction of dangerous accidents. Effective management should be necessary to ensure operation safty, good facility maintenance and sufficient experience inheritance.

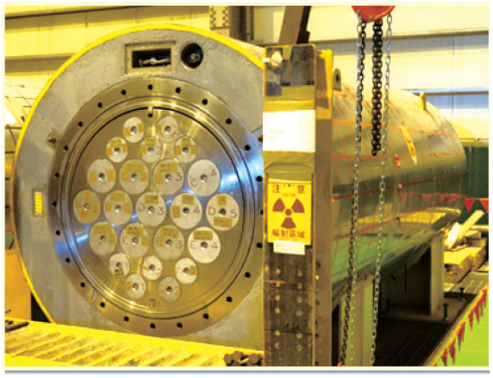
4-1-3-1-1 The Shipping and Storage Technology of Spent Fuel stabilized product

Kuo-Yuan Chang

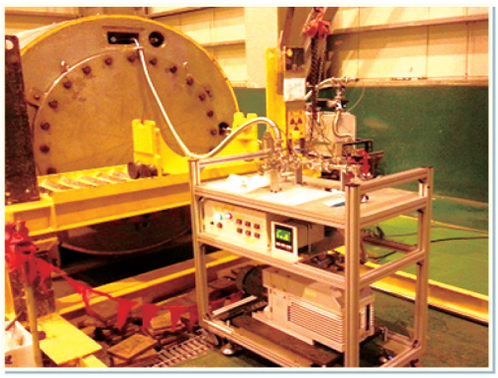
The 4th revision Decommissioning project of Taiwan Research Reactor (TRR) has been permitted by Atomic Energy Council in 2014, and the decommissioning activities are ongoing performed. The cleanup of TRR spent fuel pool is the first phase of the decommissioning project, and the radioactive wastes have been removed step by step. The spent fuels stored in the spent fuel pool are required to be stabilized and stored in the cask for interim storage, which is one of the important missions of TRR decommissioning project.

The cleanup processes of the spent fuel rods includes removing from the spent fuel pool, transferring to the hot cell, stabilization , loading the stabilized products into the cask one by one, sealing and then transporting the fully occupied storage cask to interim storage warehouse. The interim storage of the first fully occupied storage cask with 23 sets stabilized products had been completed on schedule. To comply with transportation criteria and radiation work safety at INER, all the processes have been well designed, optimized and verified. .

All the processes include the equipment installation, sealing valid, leakage testing and transportation were established based on the ALARA principle. The technology has successfully applied to the interim storage of the first storage cask in TRR. INER has sealed the cask after helium filling and leakage test. The International Atomic Energy Aqency(IAEA) was invited to verify the quantity and sealing procedure.



▲ Storage cask



▲ Helium leaking test

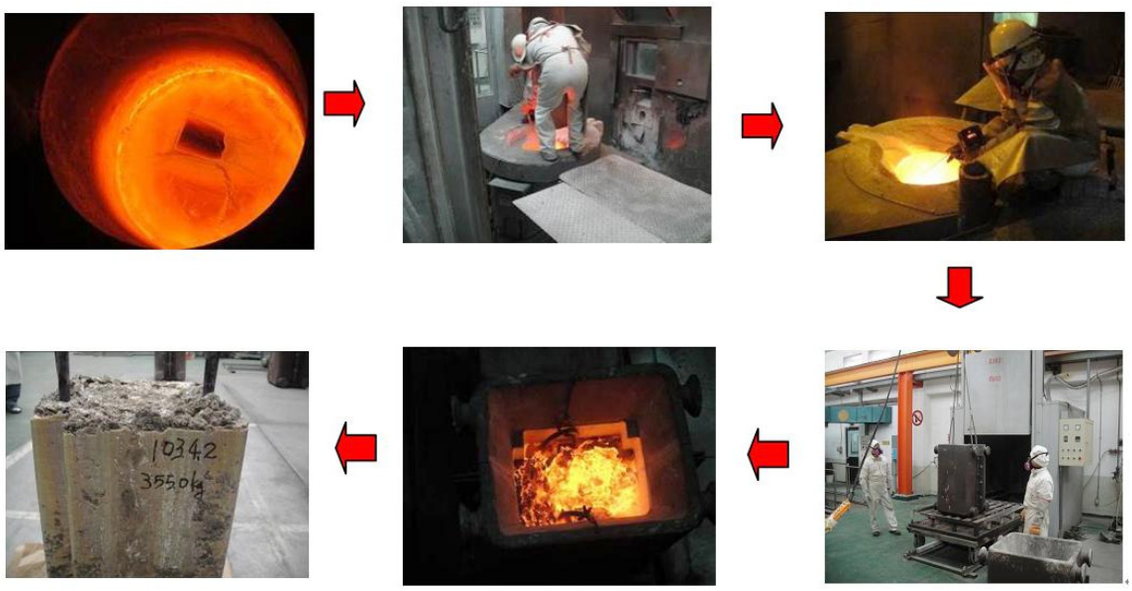
▲ verified and sealed by the IAEA

▲ Warehouse for safe storage

4-1-3-1-2 The technique of Melting and Casting Radioactive Contaminated Scrap Metal

Yaw-Hwa Shiu

To reduce the volume of radioactive waste for saving storage space and expenses, melting and casting radioactive contaminated scrap metals is a promising technique. The scrap metal melting and casting facility in the building 17 is one of important radioactive waste treatment facilities in INER (Institute of Nuclear Energy Research). The facilities started to operate since 1996 and associated operation experiences had been accmulated. Exact evaluation of processing cost can show an important index of competitiveness of the technique and use as a guidance to improve its performance. Good maintenance of refractory lining of melting furnace can prevents from penetration by moten metal and extended furnace life to reduce the amount of secondary contaminated radioactive wastes. Stric control of airborne radiation and pollution by tight ventilation filter system and measures during operation process should prevent the release of radioactive nuclides and pollutant into the environment. Sufficient Culmulative operation skills and good experiences feedback of melting and casting practices can assure to reduce the risk of dangerous accidents.Effective management should be necessary to assure safe operation, good facility maintenance and sufficient experience inheritance.



▲ The technique of Melting and Casting Radioactive Contaminated Scrap Metal

4-1-3-2 The reduction treatment and safety storage of radwaste

Feng-Jung Chang

In 2014, the project has completed about 24 metric tons of combustible radwaste volume reduction of incineration to effectively support the planned clearing work of INER's nuclear legacy facilities. Besides this, it also adopts the developed remote taking-out equipments to clear underground-stored high-active wastes, setting up one alpha-tight PC tent for TRU wastes' repacking next year, and goes on to decontaminate produced metal wastes and execute their clearance measurement, to raise the safety of waste storage and reduce produced wastes' quantities.

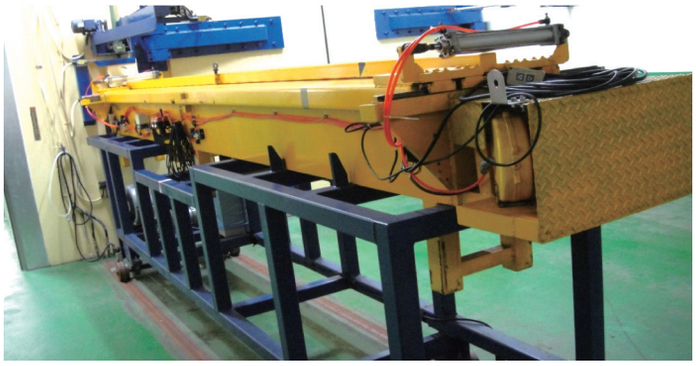
4-1-3-2-1 The clearing of the underground-stored high-activity spent fuel casing pipes

Tzu-Hsin Chou

In order to conduct the high-activity's spent fuel casing pipes stored in underground vaults of INER, one remote gripping and one cutting device had been developed. This gripping device is mainly used five retractable sleeve clamps to grip a spent fuel casing pipe one time, and put it into a shielding body. This shielding body is designed to transport the pipe to the 067 building for cutting processing jobs. We adopted these devices to finish gripping and cutting a total of 44 high-activity spent fuel casing pipes in2014. In the future we will continue to clear these underground-stored high-activity spent fuel casing pipes to ensure their storage safety.

▲ spent fuel casing pipe gripping

▲ Cutting status of spent fuel casing pipe



▲ Deliver spent fuel casing pipe by a combination of transmitting device and lead room

4-1-3-3 Outlook

Ling-Huan Chiao

Safety is the most important thing in clearing nuclear facilities since the core tasks deal with radiation. INER maintains upgraded radiation protection measures in accordance with the principle of ALARA to effectively safeguard personnel and environmental radiation safety. With the work moving forward, INER will uphold the principle of safety first. One major policy goal of Atomic Energy Council is "upgrading the management and processing techniques of radioactive waste to enhance the quality of environment". To meet the policy goal, INER keeps devoting in clearing its legacy nuclear facilities and properly manage the radioactive wastes. Once the nuclear facilities are cleared and recovered, the plant buildings and land can be reused. The potential impacts against the environment can be totally eliminated.

4-2 Research on Environmental and Energy Technologies

Yau-Pin Chyou

The Intergovernmental Panel on Climate Change (IPCC) of United Nations has issued the Fifth Assessment Reports (AR5) since late 2013, which persistently warns the related impacts of climate change. Climate projections based on the current understanding for Earth Energy Model have been formulated via Representative Concentration Pathways (RCPs). A projection referred as RCP2.6 envisages the scenario of controlling the global average temperature rise within 2°C, similar to the so-called 2DS scenario, for which the prediction indicates that the CO_2 concentration in the atmosphere must be kept below 421 ppm at the end of this century. Since the CO_2 concentration in the atmosphere has already surpassed the threshold of 400 ppm, the challenge to accomplish the 2DS scenario turns out to be an ordeal for the years to come. Furthermore, the recent report on Energy Technology Perspectives (ETP 2014) published by International Energy Agency (IEA) illustrates the technology portfolio for contributing to the accomplishment of 2DS scenario, including End-use fuel and electricity efficiency (33%), End-use fuel switching (10%), Power generaon efficiency and fuel switching (2%), CCS (14%), Renewables (34%), and Nuclear (7%). In view of the macro-scale impacts, the countermeasures to mitigate climate change should also be executed in the global arena; hence, development of clean energy technologies has been prevailing worldwide recently.

The "Sustainable Energy Policy Guideline" has been inaugurated in Taiwan since 2008, which led to the announcement of national planning for energy saving and carbon abatement in 2010, and set the corresponding targets for 2025. National Energy Program-phase II (NEP-II), launched since 2014, has been aiming at energy safety, energy efficiency and clean energy. The action represents one of the options to implement the guidelines for industry development and to fulfill the requirements for economic development, environmental protection and social justice. To comply with national policy, Institute of Nuclear Energy Research (INER) has been devoted to R&D on Environmental and Energy Technologies, for which the major achievements in 2014 will be summarized in the following sections.

1. Energy-saving Environment: Accomplish plasma coating for high-performance energy-saving films, and flexible self-supported electrochromic device; Develop all-solid-state thin-film lithium batteries and reverse thermosyphon loop (RTL); Improve the discharge uniformity of large-area VHF plasmas; Implement plasma coating on smart energy-saving applications, and provide the future development direction of new green energy saving industry.

2. Alternative Energies:

   (1) Photovoltaic: Successfully develop techniques for gallium arsenide (GaAs) epilayer thin film and large-area mass-production of polymer solar cell (PSC), which have been internationally recognized; Improve co-evaporation process for CZTS solar cell and accomplish a entrustment project of CPC; Enhance the power conversion efficiency of concentration PV micro-module to 35.15%, reduce the cost and carbon footprint of CPV module; Execute a cooperative development project for solar application system with a domestic company.

   (2) Fuel cell: Develop solid oxide fuel cell (SOFC) power generating system, execute tests for stacks composed of commercial cells with kWe output and degradation rate of 0.64%/kh; Fabricate YSZ-ceramic and metal-supported cells to improve performance with degradation rate <1%/kh and power density >1100 mW/cm^2; Synthesize fuel reforming nano-catalyst with good methane conversion rate and reactivity of catalyzation; Establish industrialization platform, satisfactorily transfer core fabrication technology to a local company, and collaborate with industry for coating processes and system development.

   (3) Bio-energy: Establish steady operations of the whole cellulosic ethanol plant, design a 100 tons/day conceptual process; Improve co-fermentation and mass-production processes that one ton dry rice straw

and cellulosic feedstock can produce max. 200 L ethanol and 220 ~ 250 kg lactic acid; Improve the ethanol co-fermentation yeasts and lactic acid strains, set up a bench-scale separation and purification system for cellulosic lactic acid; Realize technology commercialization, sign a technical authorization contract with a Malaysia plywood company for commissioning an advanced biofuel plant, acquire economic and social benefits by technological export in the future.

(4) Wind energy: Accomplish system assembly, dynamic testing, installation, control tuning of the 2nd generation 150 kW wind turbine, hold inauguration and technical conference, conduct preliminary power performance test; Comply with the international offshore guideline IEC 61400-3 to define the design load cases, analyze the extreme as well as fatigue loads, and establish the design evaluation technique of offshore wind turbine in the near future.

3. Carbon Reduction and Clean Coal: Perform gasification system experiments and process design related to SNG, cooperate with industry to evaluate multiple applications of gasification that could be viable domestic options; Accomplish MGBF system tests with filtration efficiency higher than 90% at 500°C, build a production platform for desulfurization sorbent with capacity of 0.5 kg/day; Modify the sorbents to mimic natural limestone and establish the operation parameters of 10 kW fixed-bed reactor, demonstrate robust resistance against sintering, and gradually establish key technologies of CO_2 capture.
4. Smart Grid: Build the first active-power dispatched microgrid for TPC to develop a virtual power plant, information databank, EV charging schedule design and platform; Conduct the circuit simulation of static switch system by PSIM, integration of converter and battery system, and 3-D thermal simulation of power converter; Design the distributed energy source power communication and information structure by IEEE 2030 standard, with multi-agent system structure and performs, to realize the autonomous electricity marketing of the microgrid.
5. Policy Assessment: Inaugurate the Center of Energy Economics and Strategy Research, for conducting research and providing strategy recommendations; Perform analysis about achieving CO_2 emission reduction targets of industry, summarize the results of energy intensity (EI) analysis, inquire focus groups about consumer willingness-to-pay for electricity price; Establish a knowledge-sharing website named "Energy Information Platform (EIP)," provide multi-dimensional energy information and research achievements of INER, serve as an important platform to share energy information and release research results.

Looking ahead, as the concluding remarks of the National Energy Meeting held in 2015 stated: "#4.8. To establish, as soon as possible, national program and schedule for renewable energy, energy efficiency improvement, carbon capture, storage and utilization; simultaneously, to promote scientific education and information spread of related contents." In summary, the crucial measures for the current development of domestic energy technology should be focused on commanding key technologies, which are expected to achieve the policy goal of clean carbon abatement, spread commercial applications, and promote indigenous industry.

4-2-1 Development and Applications of Plasma Technologies on Green Energy-saving Environment

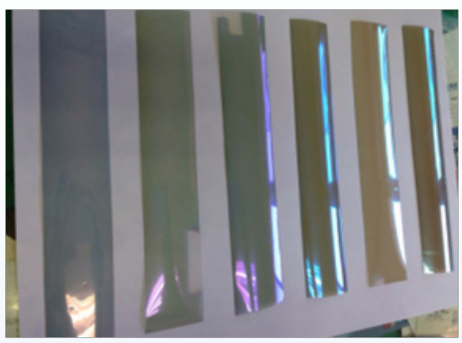
Der-Jun Jan

Taking advantages of core plasma technology and plasma clean process, INER has developed green energy-saving devices to be used in an environmentally-friendly, energy-efficient building or community. These key devices and technologies are innovative plasma arc coating technology, self-supported electrochromic devices, thin-film lithium ion batteries, an innovative VHF plasma source and novel heat pipes. Our aim is to make the energy-saving products more popular to meet the national requirements of carbon reduction. Several feature achievements are as follows:

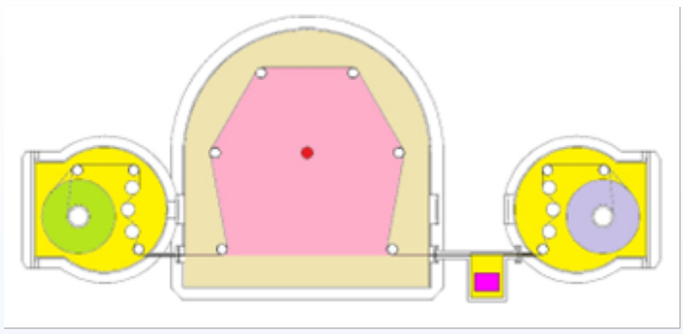
1. Innovative plasma coating technology for high-performance energy-saving films

The demand for energy saving and carbon reduction is steadily increasing. In consideration of economic aspects, it is inevitable to develop low-cost coating technology and provide a variety of functions for energy-saving applications to promote the popularity of solar control films effectively. In this program, we proposed a novel coating method which put together a unique plasma source with a roll-to-roll plasma coating equipment. The deposited films include metal, dielectric and multilayer optical films. The solar control optical properties of the films are verified by numerical simulation and spectrum measurement. The various colors of the energy-saving films are shown in Figure 1. The energy-saving films come in many colors, such as blue, purple, yellow, green, silver, brown and so on, because of thin-film interference effects. With optimum thin-film composition and visible light transmission of 70%., the energy-saving film can reflect over 90% IR and heat of the sun These products are good for applications of green building materials, because of their energy efficiency and colorful appearances.

In addition, we are planning an innovative plasma coating equipment for mass production of the energy-saving films and its patent deployment. Comparing with other sputtering technology, the production cost can be reduced significantly according to our evaluation. We expect that this complete self-supported technology can help local industries to upgrade their competitiveness in energy-saving films in the future.



▲ Fig. 1. Various colorful energy-saving films

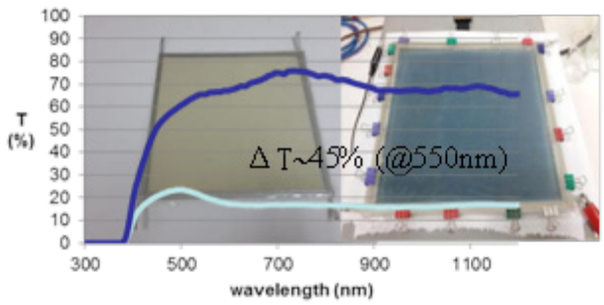


▲ Fig.2. Configuration of an innovative plasma coating equipment

2. A self-supported electrochromic device

Green energy and materials have been the two main schemes of green-living. The materials for smart, environmentally-friendly, and energy-saving buildings have been the future trend of zero-carbon buildings. A lightweight, flexible, electrochromic (EC) device with energy-saving function has been developed by a roll-to-roll plasma coating technology at INER. The EC device with visible light transmission varied up to 45% and IR cutting-off more than 90% within solar illuminations has been manufactured by plasma coating process. The thin-film device with high added value can let the energy-saving technology infuse into home life. At the same time, INER is further developing flexible photovoltaic (PV) devices using stainless steel as substrates. Our aim is to develop flexible thin-film solar cells with a concept of energy recycling, which can generate power with weak indoor light illuminations. This device is less dependent on the angle of incident lights as well as thin, lightweight, and unbreakable, providing the possibility of integrated application.

According to the concept of integrated application, we have combined a flexible PV cell as a photo sensor with an EC device to be a smart energy-saving device. This smart device has three functions of energy saving, power generation and sensing together. A flexible solar cell provides sufficient electricity to power the EC device throughout the day. No external power is needed. Thus, the PV-powered EC devices provide architects and building owners more space for design and applications, because that this integrated device possesses beauty and practicality simultaneously.



▲ Optical variation of a 25cm×25cm flexible electrochromic device

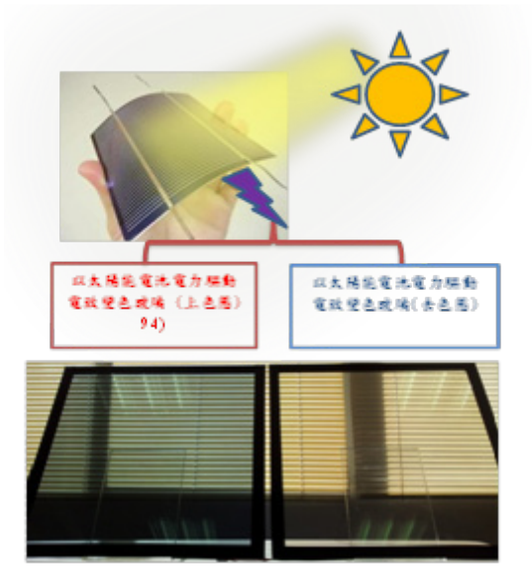


Fig.4. Illustration of a PV-powered EC glass ▶

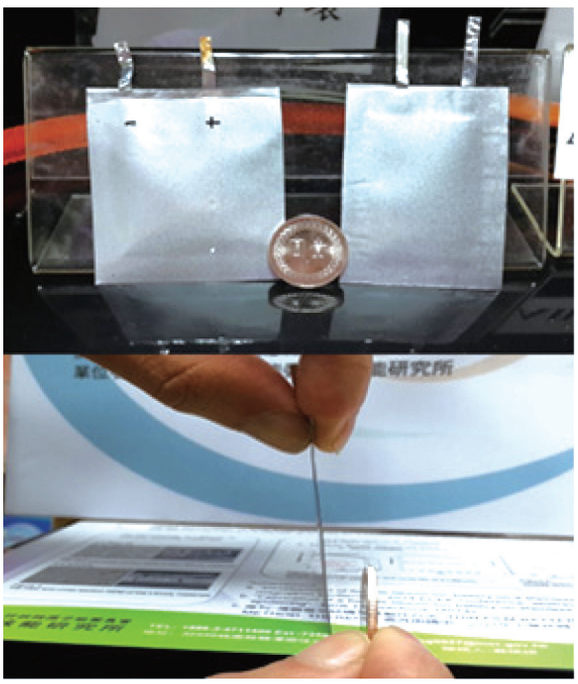
3. A flexible thin-film lithium-ion battery

Wearable electronics, such as smart watch, electronic tags, smart cards, fitness bands and patient vital sign monitors, with huge market potential of $16.04 billion in 2013 and expected to grow to over $80 billion by 2024, have received much attention in the research communities. The growth of wearable electronics is towards the development of lightweight, slightness and being close to people life. Batteries used in wearable electronics require not only high performance but also other characteristics such as shape, size, safety, thickness and flexibility. However, conventional Li-battery technology employs liquid electrolyte which is lithium salts in an organic solvent. Conventional Li batteries need expensive membranes to separate the cathode and anode, as well as an impermeable casing to avoid leakage. Therefore, the size and design of the batteries are limited. In addition, liquid electrolyte has safety and health issues, as it uses flammable and corrosive liquids.

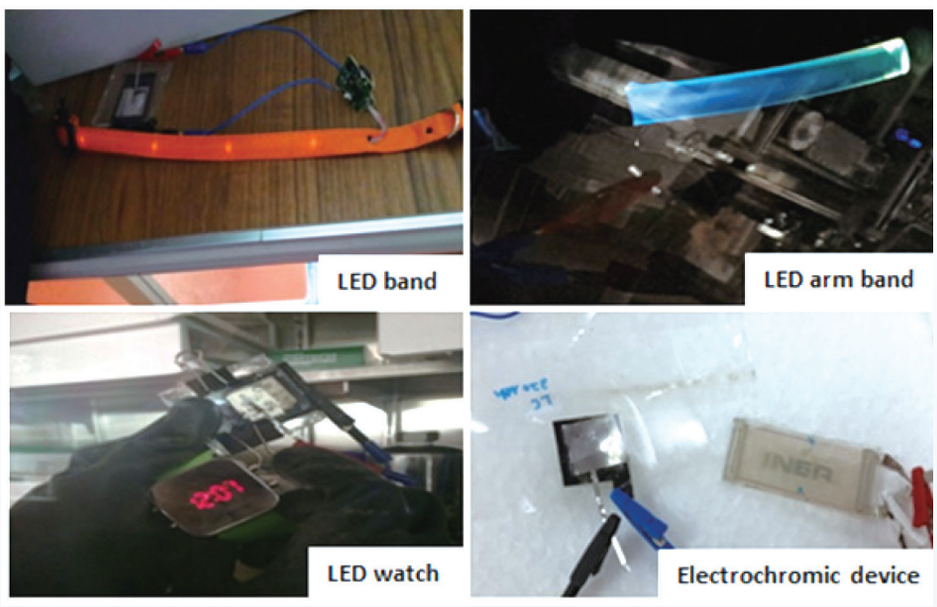
All-solid-state thin-film lithium batteries are composed of solid materials and assembled layer by layer. It is easy to make them thin instead of thick. Solid-state electrolytes allow scaling down due to the elimination of certain components (e.g. separator and casing). Therefore, solid-state electrolytes have high energy density and

power density. Furthermore, they are very stable during temperature variation and cause no physical damages after usage . Thus, all-solid-state thin film lithium batteries have potential to be micro-power supplies for a variety of micro-electronic systems.

INER has been applying the radio-frequency magnetron sputtering technology to develop flexible all-solid-state thin-film lithium batteries. They were successfully fabricated on 70 μm thick, flexible stainless steel (SS304) substrates. Electrochemical characterization of this flexible battery revealed a discharge capacity of 700 μAh (or 48 uAh um^{-1} cm^{-2}) between 4.3V and 3V. Maximum capacity retention in excess of 94 % was also achieved after 50 charge-discharge cycles between 4.2V and 3V. They have been used successfully for some wearable electronics, such as LED lights, LED bracelet, LED watches and voice-activated LED luminous clothes which were exhibited at 2014 Taipei International Invention show and Technomart.



▲ Fig.5. flexible all-solid-state thin film lithium batteries



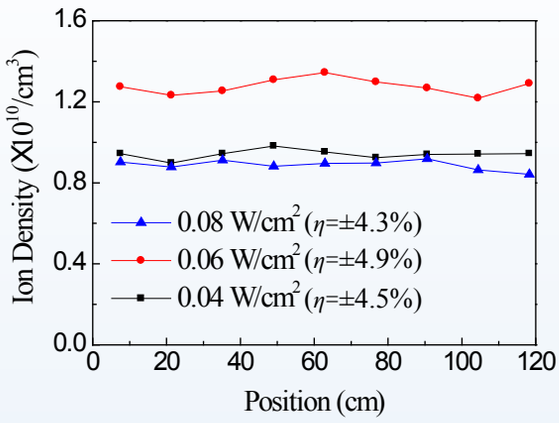
▲ Fig.6. flexible all-solid-state lithium batteries powered some wearable electronics

4. Development of an innovative industrial-scale large-area VHF plasma source

Because of being able to effectively increase the thin-film deposition rate without deteriorating (or even improve) the film quality, VHF (very high frequency) plasmas have become an essential technique for the manufacturing of high-efficiency HIT (heterojunction with intrinsic thin layer) and silicon thin-film solar cells. On the other hand, scaling-up the electrode size to reduce the production costs by increasing the production throughputs is essential as well. Unfortunately, the combination of higher frequency and large electrode would result in a more substantial standing-wave effect, which would result in limitation on deposition uniformity.

To resolve the issue, we have proposed an innovative technique, in which two specific waves are applied at the same time to launch a traveling wave, to improve the discharge uniformity of large-area VHF plasmas. The feasibility of such an innovative technique has been successfully demonstrated, using an industrial-scale linear plasma reactor (120 cm 10 cm). The input electromagnetic waves are introduced into the reactor from different sides of the powered electrode. Two independent power supplies are adopted to separately control two specific standing waves. The spatial pattern of each standing wave depends on the phase difference between the electromagnetic waves introduced from opposite sides (denoted as $\Delta\theta$). Figures 7(a) and 7(b) display the discharge patterns when only one standing wave is applied. Apparently, the discharge pattern is highly non-uniform with a single standing wave. However, as shown in Figure 7(c), the discharge uniformity can be improved effectively by superposing the standing waves given in Figures 7(a) and 7(b). Figure 8 shows the ion density distribution as a function of power density with the superposition of two standing waves. Clearly, the proposed technique can generate VHF plasma discharge with non-uniformity <±5%, which can meet the requirement for HIT and thin-film silicon solar cell industries. Moreover, one of the advantages of the innovative technique for the linear large-area VHF plasma source is that the power feeding design mentioned above can be applied to different frequencies.

▲ Fig. 7: (a) and (b) both show the discharge pattern when only one standing wave is applied. Δ θ is 0o and 180o for (a) and (b), respectively. (c) shows the discharge pattern as both standing waves are launched simultaneously. The frequency is 80 MHz.



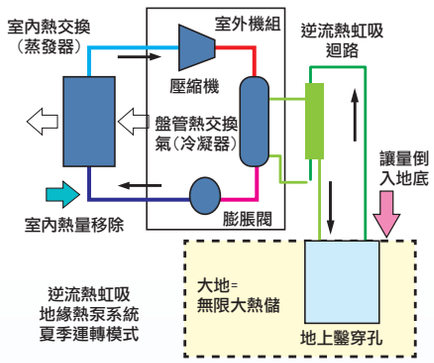
◀ Fig.8. Ion density distributions by superposing two standing waves with various power densities. η stands for the non-uniformity of plasma discharge. The frequency is 80 MHz.

5. Novel heat-pipe technology on energy-saving application

A two-phase closed thermosyphon is a gravity-assisted wickless heat pipe, of which the work principle depends on the natural upward movement of hot liquids and the downward movement of cold liquids. The thermosyphon has been widely applied in many industrial fields, where it is necessary to transport heat from lower to higher positions, because of its high efficiency, reliability, simplicity and cost effectiveness. There are many fields, such as solar energy, waste thermal recovery, boiler performance improving, and industrial heating process, need spontaneous downward heat transfer technology. The ways to solving this problem are usually to change to a complex design or to use the pumps.

To solve the above problems, INER has designed a two-phase reverse thermosyphon loop (RTL) to effectively move the thermal energy downward to a heat remove apparatus or thermal storage tank. The two-phase RLT is a passive device, much like a non-wick heat pipe, driven by thermal energy and having extremely high thermal conductivity. The experimental prototype of two-phase RLT consists of a working liquid circulation loop with heat transfer in the downward direction, opposite from the direction of natural convection. The process transfers huge thermal energy by saturated vapor pressure and gravity, which then transfer the heated liquid or vapor downwards. The two-phase RTL can transfer heat over a long distance under small temperature-difference and at high speed without any capillary structure, additional driving power, and any valves.

A ground source heat pump (GSHP) with a novel reverse thermosyphon loop has been developed. The heat pump system with RLT ground heat exchanger has the lowest condense temperature than an air-cooled and water-cooled heat pump, which was calculated to have a high COP and save electric consumption of 51 %. This system can be utilized to heat a room in the winter or cool a room in the summer by transferring the heat from or to the ground. In summer, the novel heat pump operates in cooling mode and removes the heat from the building to the ground with RTL as shown in Fig. 9. The RTL GSHP testing platform set-up at INER is shown in Fig. 10.



▲ Fig.9. A GSHP transfers heat to the ground with a RTL in summer.

▲ Fig.10. A testing platform of a GSHP with a RTL.

On the basis of green energy-saving environmental concept, this program has successfully developed energy-saving devices and technologies. The devices were exhibited in public in an application reality of household life. We are looking for the industry to involve in and improve the development. Then, the practical energy-saving products could be further developed. In the future, we will continue to upgrade the plasma clean coating technology to the development and integration of lightweight, thin and flexible energy-saving devices. Our aim is to create a total green reality of energy saving from plasma green clean processes, through green energy-saving devices, to green environment with applications of energy-saving devices to community buildings.

4-2-2 Development and Application of Solar Photovoltaic Technology

Cherng-Tsong Kuo

1. Introduction

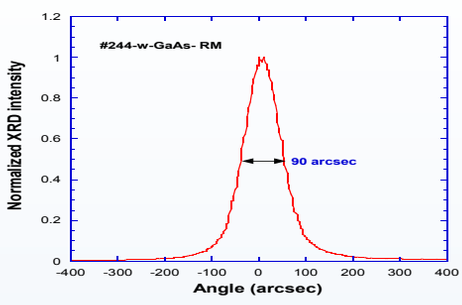
"Development and Application of Solar Photovoltaic Technology" project is devoted to the R&D of solar photovoltaic technologies, for which the goal is to develop advanced solar cells, explore the application on solar energy, and further assist the establishment of local PV-related industries with international competiveness. This project includes: (1) development of advanced solar cell technology, (2) development of low-carbon footprint module technology, and (3) development of solar application system technology.

2. Main Achievements

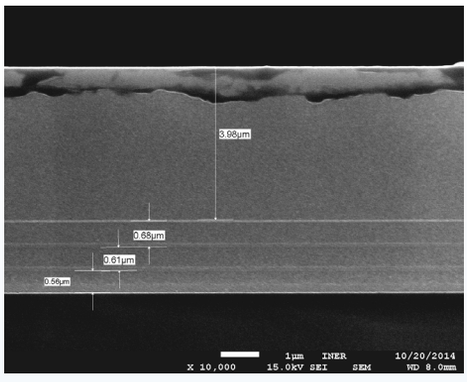
2-1 R&D achievement of advanced solar cell technology

(1) Technological development of III-V multi-junction solar cell

For the III-V multi-junction solar cell project conducted in 2014, we have successfully achieved the important goal of completing the epitaxial growth technique of gallium arsenide (GaAs) thin film on the silicon (Si) substrate via the integration of MOCVD epitaxial growth technique with the application of strain-controllable buffer layer method. The best FWHM (full width half maximum) result of the DXRD (double crystal X-ray diffraction) measurements conducted on the completed GaAs epilayer could be as low as 90 arc-second, which is superior to those (~100 arc-second) published in the conventional reports, and indicates the excellent thin-film quality of GaAs epilayer grown on the Si substrate. Based on the research results accomplished in this year, the high quality epi-layer can be provided for using as the important template of fabricating III-V solar cells on Si substrate. In addition, the associated epitaxial growth techniques of III-V semiconductor can be further adopted to explore the application fields of other optoelectronic devices, such as high-speed transistors, laser diodes, light-emitting diodes, and so on, so as to strengthen and enhance the value of the completed technique, and become helpful for the increase of job opportunity.



▲ The XRD measurement result of the completed GaAs epitaxial layer grown on the Si substrate



▲ The SEM picture measured from the cross section of the completed GaAs epitaxial layer grown on the Si substrate

(2) Technological development of CZTS solar cell

The CZTS solar cell project in 2014 focused on co-evaporation process and entrustment of Green Technology Research Institute of CPC Corporation. The achievements are listed as follows:

- After finishing the "Thin-film solar cells with the concept of environmental protection" entrustment in June 2013, the Green Technology Research Institute of CPC Corporation entrusted INER a new project "Thin film solar cell with new concept" in September 2013 for reference to renewable energy development of CPC Corporation. This entrustment was finished in September 2014 and the total amount was 2.7 million NT dollars.
- In device fabrication development, CdS buffer layers of high coverage with thinner than 100nm, and ZnO:Al transparent conductive layers with resistivity less than $1\times10^{-3}\Omega$-cm were successfully made, which can be used in other optoelectronics development.

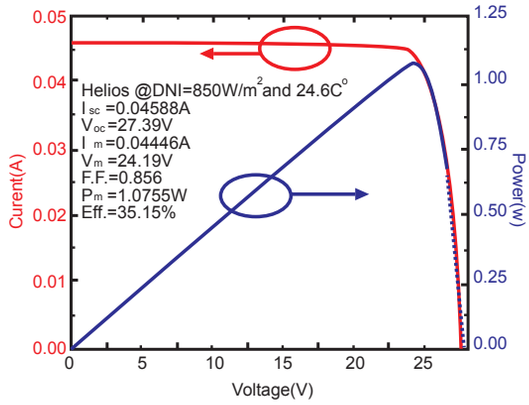
2-2 R&D achievement of low-carbon footprint module technology

(1) Technological enhancement of concentration PV module

In 2014, we achieved the goals to raise the power conversion efficiency of micro-module to 35.15% and to reduce the cost of CPV module below 1 USD per watt by adopting LED auto-encapsulated technique to decrease both material usage and cost of the secondary optical element. Also, by shrinking the hotspot of CPV module and via optimizing module design, carbon footprint of CPV module designed by INER was cut down 7%, which met the project expectations of 2014

	傳統模組	微型化模組
厚度	~24公分	~8公分
瓦數/重量比	~6.25瓦/公斤	~7.9瓦/公斤
轉換效率	~31%	~35%
自動化程度	低	高
可靠度	中	高

▲ Characteristic comparison of traditional and micro CPV module



▲ I-V curve of 1100X micro CPV module measured by solar simulator

(2) Technological development of polymer solar cell module

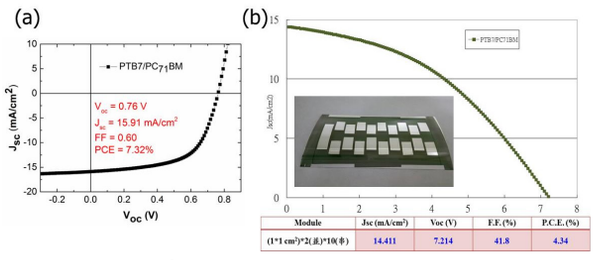
Polymer solar cell (PSC) is the third generation solar cell with the advantages of easy fabrication, solution-processing and roll-to-roll (R2R) large-area printing. PSC has the unique superiority due to the characteristics of transparence, thin, light , flexibility, low-energy, low-carbon and low cost compared to the inorganic solar cells. The scope of its applications includes portable, wearable and flexible 3C consumer electronics. Moreover, the PSC products can be integrated with building, vehicle and human body. We have established the critical technologies of PSC to date. The main research results are as follows:

- We developed the large-area mass-production technology of PSC. The PTB7/PC_{71}BM PSC was fabricated in air by R2R slot die coating process on flexible ITO/PET substrate. The power conversion efficiency (PCE) of 7.32% with the cell device area of 0.3cm^2 was achieved. The PCE of our large-area PSC module with the size of up to 100 cm^2 was 4.34%. Using this technology to fabricate the flexible solar bluetooth keyboard which combines the PSC with flexible keyboard in a flexible thin film. The solar keyboard could be used in both

outdoors and indoors, and it can be stored as a compact and portable roller. The solar bluetooth keyboard prototype has won silver and gold metal awards in 2014 Geneva and Pittsburg International Exhibition of Inventions, respectively.

- We developed the PSC micro-module technology to supply electricity for portable smart electronics. We designed a novel stack structure to enhance the power conversion efficiency under a limited space of module. We can effectively minimize PSC module area to obtain a sufficient output power for portable and wearable electronics via our innovative stack structure. The PSC micro-module can be integrated with smart card. The PSC module can replace the commonly used Li-battery in the smart card, and the PSC micro-module would provide an independent power source with increasing the lifetime of electronics and reducing the environmental pollution. The smart card integrated with PSC prototype has won a bronze medal award in 2014 Taipei International Invention Show & Technomart Invention Contest.
- The equivalent carbon dioxide emission of the PSC module was calculated to be 132Kg in our project. The emission contribution of the process of nitrogen glove box (~ 39% of total emission) during the fabrication of PSC module is the hot spot. The second largest emission contribution is thermal deposition process fabricating top electrode. The third largest emission contribution is the using of ITO transparent electrode. How to develop the ITO-free and solution-processing (in air) PSC would effectively reduce carbon emission in our design.

Our current PSC technology has achieved the level of international standard in both high-efficiency devices manufacture and commercial mass production. We would further develop the PSC module technology, and integrate the PSCs with various advanced products. Furthermore, we will reinforce the interaction with domestic industries, and promote the emerging PSC industry.

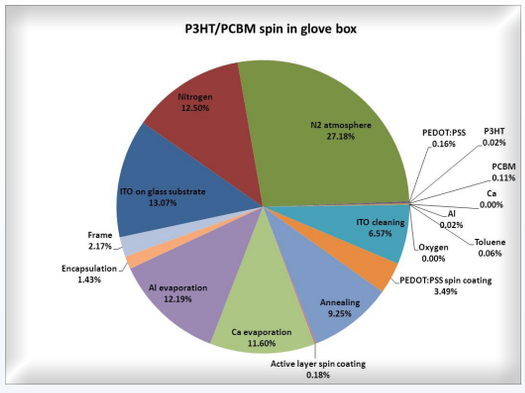


Module	Jsc (mA/cm²)	Voc (V)	F.F.(%)	P.C.E. (%)
(1*1 cm²)*2(並)*10(串)	14.411	7.214	41.8	4.34

▲ J-V curve of PTB7/$PC_{71}BM$ polymer solar cell. (a) polymer solar cell (cell area: 0.3cm^2), (b)polymer solar cells module(module area larger than 100cm^2)

▲ The solar bluetooth keyboard prototype has won silver and gold medal awards in 2014 Geneva and Pittsburg International Exhibition of Inventions, respectively.

▲ The smart card integrated with PSC prototype has won bronze medal award in 2014 Taipei International Invention Show & Technomart Invention Contest



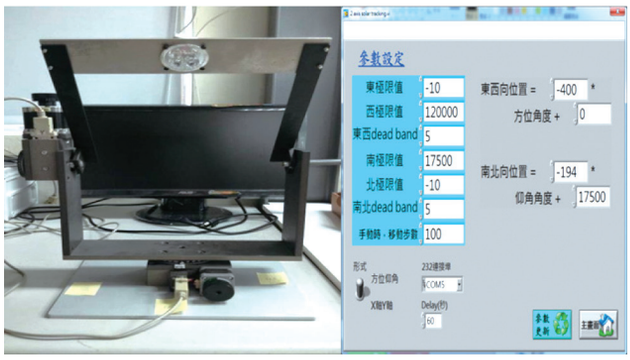
▲ carbon emission of polymer solar cell modules

2-3 R&D achievement of solar application system technology

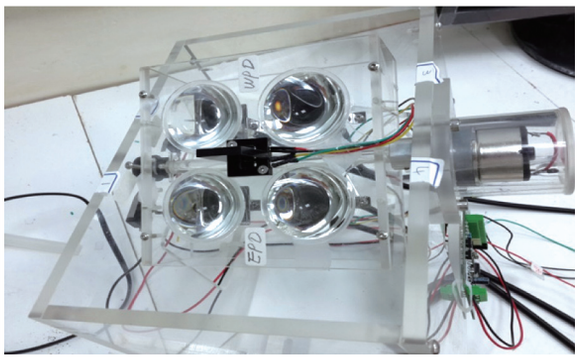
(1) Technological development of solar lighting system

The achievements are listed as follows:

- Established light-guiding and spectrum-division platform, and completed an INER report entitled "Design of a Sunlight Simulation Platform" (INER-11158R).
- Developed a sunlight collector prototype, and completed an INER report entitled "Design of a Wall-Mounted Tracker" (INER-11156).
- Has executed the cooperative development project for applying the sun light to the plant growth box with Ying Tang Sustainable Services Company, Ltd.
- Showcased "A Passive Sunlight Collection for Solar Lighting" in 2014 Taipei International Invention Show & Technology Trade Show, and was awarded a gold medal.



▲ A light guiding and spectrum division platform

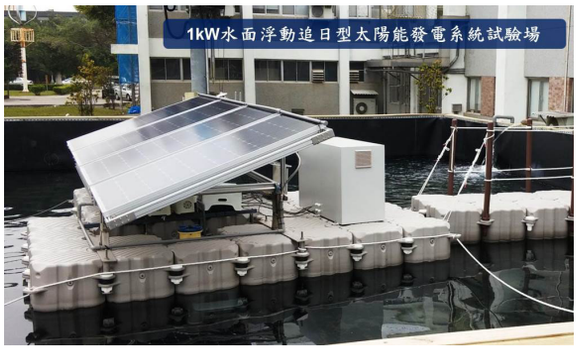


▲ A sunlight collector prototype

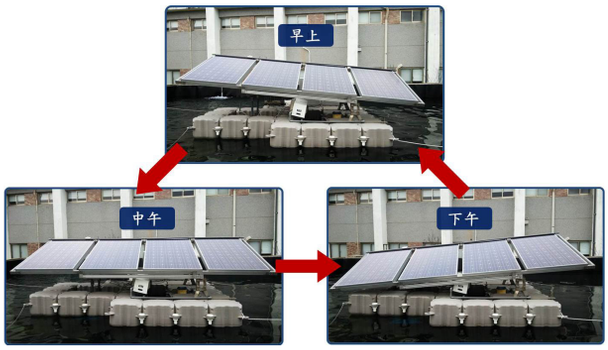
(2) Technological development of floating PV system

The main R&D objectives in 2014 include design of floating platform, manufacture of solar tracking equipment for floating PV power system, and integration of floating solar panels and surrounding systems. The achievements are listed as follows:

- We replaced the high-cost steel or aluminum alloy frames with high-density polyethylene (HDPE) pontoons to sustain the whole system including solar power apparatus and surrounding installation by buoyancy mechanism.
- In contrast to foreign designs that use complicated electronic facilities and huge mechanical structures, we designed low-cost and simple machines to achieve the solar tracking function. In addition, solar tracking equipment also provides cleaning and cooling capabilities, which can further improve the efficiency of solar panels.
- We have built a 1kW floating PV experimental station with solar tracking mechanism in INER for environmental qualification and data monitoring, which can promote the development of domestic floating solar energy industry.
- By the design of platform shape and the integration of mooring system, the platform can survive in the following wind conditions: 3.3 m/s, 7.9 m/s and 13.8 m/s and in wave height: 0.2 m, 1 m, and 3 m under the dynamic environments in our simulation.



▲ Floating PV experimental station can provide research people to carry out environmental qualification and data monitoring



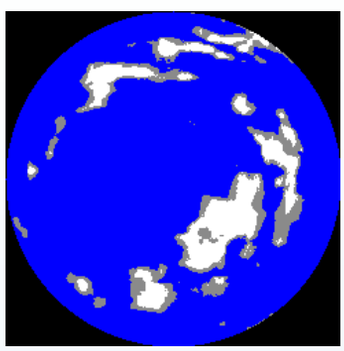
▲ Solar tracking system is equipped with timer, which can proceed with tracing of three periods (morning, noon, and afternoon). In addition, it also provides cleaning and cooling capabilities by using water pipelines and drain holes which are set up on the upper side of solar panel

(3) Technological development of solar energy prediction

"Big data and artificial intelligence are producing ultra-accurate forecasts that will make it feasible to integrate much more renewable energy into the grid", as pointed out by American MIT Technology Review magazine in its report of "10 New Breakthrough Technologies 2014", reveals how important the solar energy prediction is. Given the only existence of weather forecasting and broadcasting in Taiwan, while lacking solar energy forecasting research, INER has taken the plunge into the related technologies and work achieved in 2014 are: A. the short-term prediction (30 min or less), using the image processing techniques to reconstruct and restore the raw image of Sky Imager (TSI-880), i.e., taking away the images of support arm and sun-blocking band and rebuild the image; B. mid-term (30min ~ 6hr), by programming to acquire MTSAT satellite images over Taiwan; and C. for the long-term (6 ~ 48hr), establishing the platform for installing the numerical weather prediction model WRF. In addition, using logistics regression on historical GHI data to build up the probability classification prediction model showcases the data mining technology. All the technologies mentioned above are to build up the ability of solar energy prediction, to assist location selection for the solar power plant, to sustain a stable supply of electricity and to maintain the power quality normal as well.

▲ Original sky image

▲ Images of support arm and sun-blocking band removed



▲ Cloud decision (opaque, white 9%; thin, grey 10%; clear sky, blue 81%)

3. Future Prospect

Subsequently, the established epitaxial growth technique of GaAs on Si substrate will be used to build GaAs template, and hence develop the manufacturing techniques of III-V single- and multi-junction solar cell. In addition, INER will work with domestic industry to assess the epitaxial growth technique of GaAs thin film on the silicon (Si) substrate; also, will estimate the feasibility of utilizing the above-mentioned technique to the red-light LED and high-speed transistor. As to the concentration module, micro-module techniques will be continuously adopted to reduce the size of module and amount of materials, and carry on to develop low-carbon footprint material and process as well to reach the goal of accumulative reduction to 15%. In the aspect of polymer solar cell, after pioneering mass production of one-meter long module has achieved, which is under the generic air condition and in the all-solution large-area roll-to-roll module manufacturing process, the pilot mass-production line will be planned and completed to be the pioneer of Taiwan's organic solar cell industry. Furthermore, the solar lighting system technology will focus on developing the technologies of sunlight collection, spectrum division and light mixture; other than the wall-mounted type of solar lighting merchandize, INER will enhance the production's popularization by applying the sun light to the plant growth box, and the healthy lighting for the people in ecological society and sustainable city. The developing key of floating solar power system is to continually research and develop low-cost product, modularity mechanism, promote and prevail its application. Lastly, flood-fill method will be adopted to compare the cloud groups at different time, incorporate with prompt satellite data and match the weather initial conditioning data of NCEP-FNL, in order to estimate GHI for the solar energy prediction. With all the successful completion of conducting this project, it helps meet the expectations of National Energy Project (NEP), save energy and reduce carbon emission, and promote industrialization of the developed technologies as well.

4-2-3 Development of the solid oxide fuel cell technology and establishment of the industrialization platform

Ruey-Yi Lee

1. Foreword

Solid oxide fuel cell (SOFC) technology possesses the characteristics of being environmentally friendly, high power efficiency and helping emission cut. In compliance with the nation's policy on energy saving and carbon reduction, this project is devoted to developing critical SOFC technologies. The overall objective is to construct a high-efficiency, reliable, and low-cost SOFC power generating system. The objectives of the project are: (1) setup of a 3-5 kW SOFC power system with combined heat and power efficiency over 85%; (2) performance improvement of the ceramic and metallic SOFC cells with maximum power 600 mW/cm^2; (3) manufacture of fuel reforming catalysts with a conversion rate over 98%.

2. Accomplishments

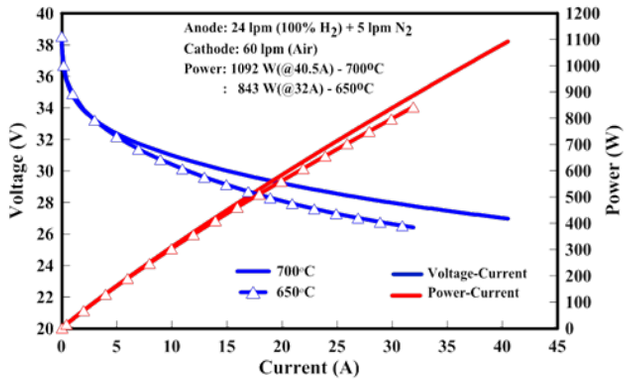
(1) Development of the solid oxide fuel cell power generating system and establishment of the industrialization platform (by Yung-Neng Cheng)

(i) A 30-cell stack composed of commercial anode-supported cells and other components was assembled and tested. The result showed that the electrical output of the stack was 1,092 W (449 mW/cm^2) at 27V (0.9 V/cell) and 843 W (347 mW/cm^2) at 26.3V (0.88 V/cell), at the operating temperatures of 700 and 650°C, respectively (Fig. 1). A durability test with a 3-cell stack illustrated a low degradation rate of 0.64%/kh at 650 °C for 6700 hours, as shown in Fig. 2.

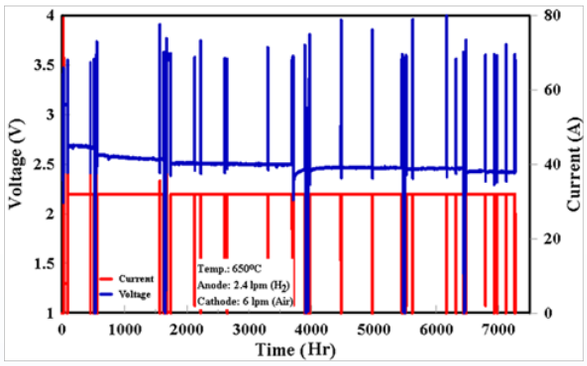
(ii) Taguchi method was employed to systematically optimize the operating parameters of an anode-supported SOFC cell. The L27 orthogonal arrays of Taguchi experiments were designed and carried out. The analysis of variance (ANOVA) reveals that, under the operating temperature of 675°C, hydrogen and air flow rates of 500 and 1500 sccm respectively, the maximum power density is 480 mW/cm^2. The electrical efficiency and fuel utilization is 51.9% and 86.1%, respectively (Fig. 3).

(iii) An 18-cell stack with INER's cells was tested in the INER-II SOFC system with dilute or natural gases as fuel for more than 300 hours. The power output of the stack was around 500 W, as illustrated in Fig. 4, while the reforming conversion efficiency was over 99%.

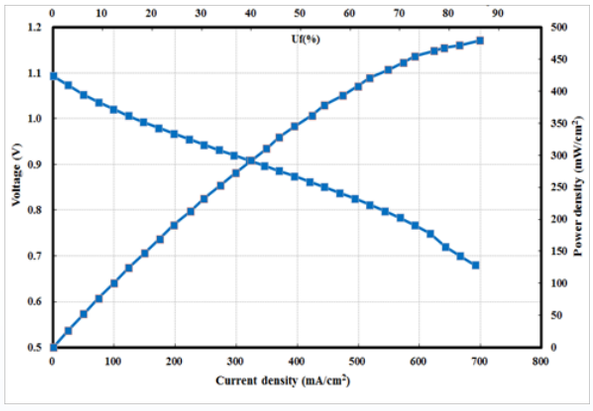
(iv) A thermally self-sustained kW-class SOFC power system was assembled, installed and tested at the China Steel Cooperation. The results indicated that the power output reached 852 watts, while the fuel utilization rate and electrical efficiency were 50.37 % and 36.72 %, respectively(Fig.5).



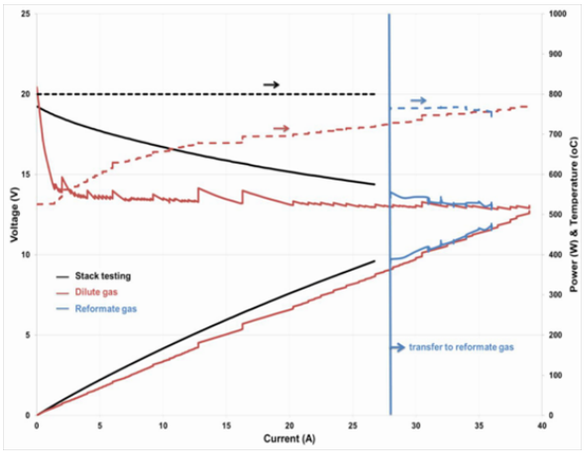
▲ Fig. 1 The performance curves of the 30-cell stack



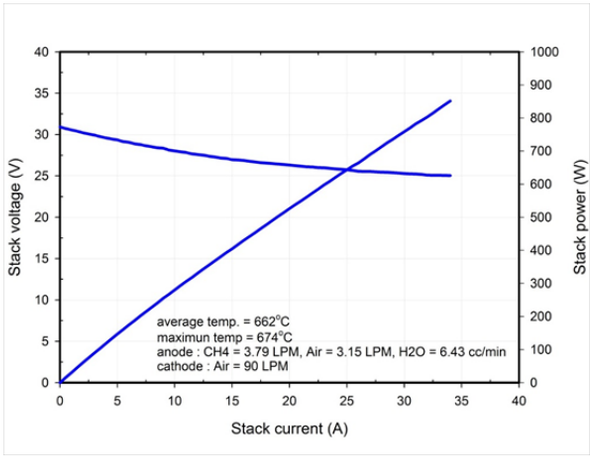
▲ Fig. 2 The durability test result of a 3-cell stack



▲ Fig. 3 I-V-P curves for cell under optimum conditions acquired by Taguchi method



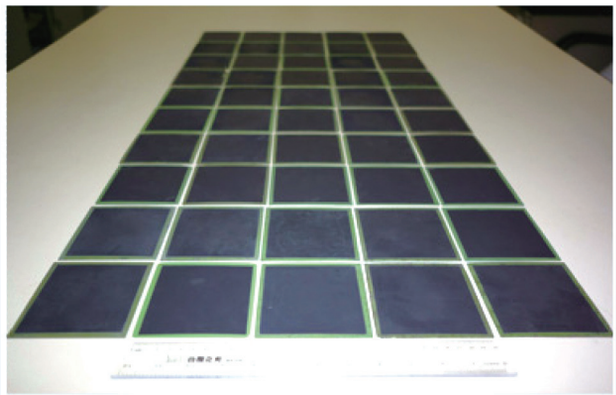
▲ Fig. 4 Performance curves for a SOFC system



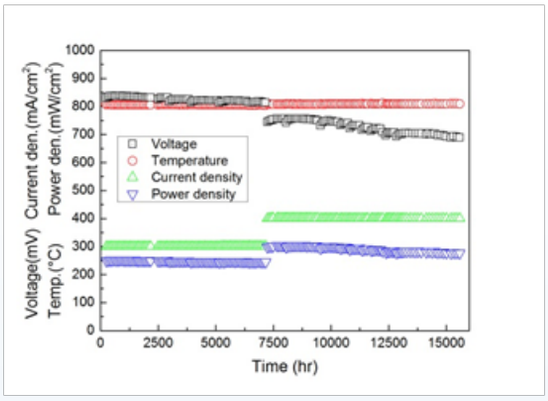
▲ Fig. 5 Performance curves of Elcogen stack in the SOFC system

(2) Technology development of the broad-temperature ceramic substrate supported solid oxide fuel cell and the materials (by Tai-Nan Lin)

Fabrication processes for the conventional YSZ-series ceramic cells with nearly 100 % production yield were well established. The performance ranged from 24 W up to 30 W for every single cell. In 2014, we successfully fabricated 50 pieces of YSZ-based cells with commercial size of 10×10cm^2 (Fig. 6). The long-term durability test has been carried out and completed for 15,000 hours with a degradation rate less than 1%/kh (Fig. 7), evidencing the stability of INER's fabrication techniques. INER was devoted to the technology and patent authorization to local industry, specifically the membrane electrode assembly techniques. A contract was officially signed with the Leatec Corporation on January 16, 2014. Now, the Leatec has possessed the core techniques to fabricate the SOFC MEA.Scale up processes will undergo afterwards (Fig. 8). Close relationship between INER and Kyushu University in Japan was established with mutual research collaboration. In 2015, a memorandum of understanding (MOU) between the INER and Kyushu University has been signed for further joint collaborative work. (Fig. 9).

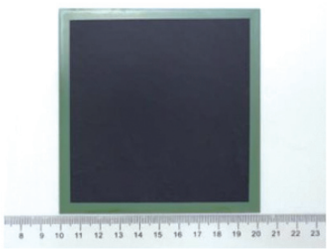


▲ Fig. 6 The small-scale cell production at INER

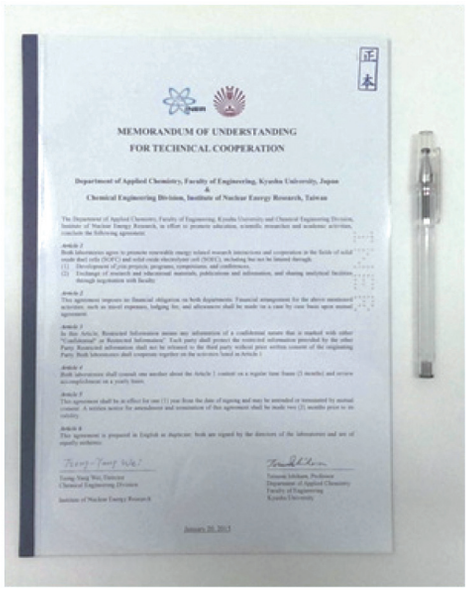


▲ Fig. 7 The 15,000 durability test result of the cell

▲ Fig. 8 (a) The green tape fabrication via patent authorization to Leatec Corp.



▲ Fig. 8(b) cell product under patent authorization from INER to Leatech corp.



▲ Fig.9 The memorandum of understanding for technical cooperation between INER and Kyushu university

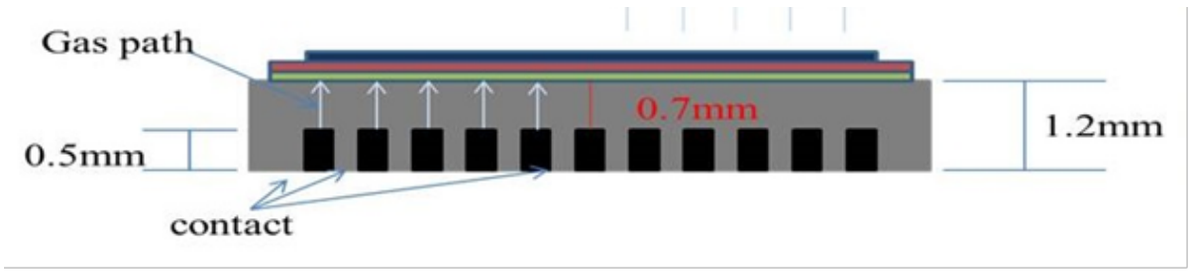
(3) Development of cells with metallic substrate and relevant materials using plasma spraying technique (by Chang-Sing Hwang)

Two manufacturing processes, leveraging colloidal and compression molding methods, were developed to produce porous metal substrates employed in fabricating plasma sprayed Metal-supported Solid Oxide Fuel Cells (MS-SOFCs). In the leveraging colloidal method, a porous 1.2 mm thick substrate with high permeability, as shown in Fig. 10, was obtained. The ventilating holes with 0.5 mm and 1.8 mm in depth and diameter, respectively, were uniformly distributed with a density of 5 holes/cm^2 on the back side of substrate. These ventilating holes acted as quick channels for introducing hydrogen to anode and exhausting water from anode during cell operation. Figure 11 shows that the 5x5cm^2 MS-SOFC cell with these ventilating holes can deliver 1161, 1013 and 676 mW/cm^2 at 750, 700 and 650^{o}C, as well as 0.8, 0.77 and 0.65 V, respectively, under the standard cell test procedure.

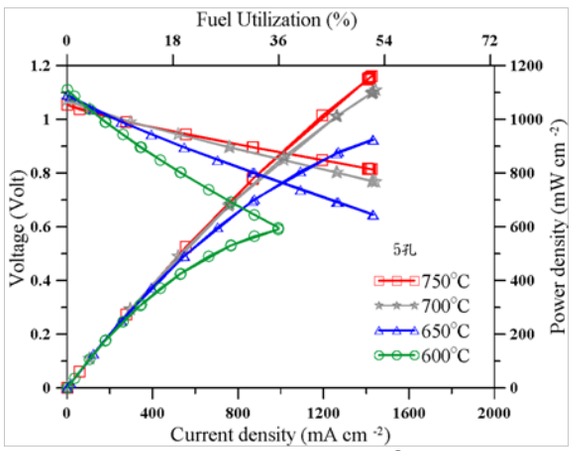
In the compression molding method, the manufacturing processes, including spray drying, compression molding and sintering, were developed and constructed to produce porous molybdenum-containing nickel-based super-alloy substrate. The open circuit voltage (OCV) of this cell is higher than 1.0 V, obtained at test temperatures ranging from 600 to 750°C, indicating that a fully dense layer of LSGM electrolyte is successfully fabricated via Atmospheric Plasma Spraying (APS) coating process. The measured maximum output power density (@0.77 V) of this cell, as shown in Fig. 12, has reached 1109 mW/cm^2 at 750°C under the standard cell test procedure.

The chromium-contained ferritic stainless steels are widely employed as metallic interconnect in intermediate-temperature solid oxide fuel cells. However, the chromium content of these steels would cause obvious degradation phenomena, due to the chromium-poisoning of cathode and oxidation of interconnect. Therefore, APS process was used to produce protective lanthanum-strontium-manganese (LSM) coatings on the surfaces of Crofer 22H, Crofer 22APU and SS441 steels. The obtained LSM layers reveal relatively dense microstructure and high purity of crystallography phase, due to the employed process parameters. After about 4,932 hours

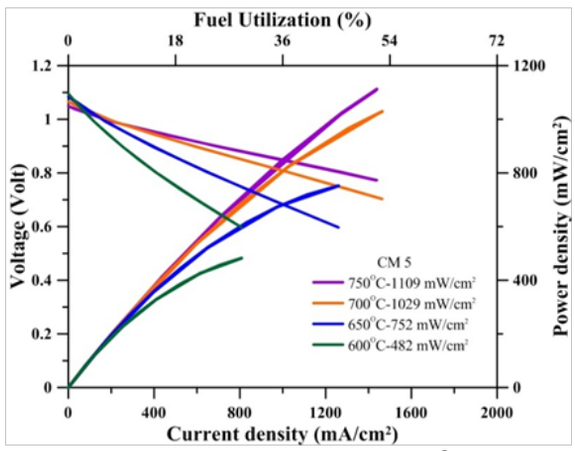
of ageing test at 800°C in air, the initial and final area specific resistance (ASR) values of the coated Crofer 22APU sample with pre-oxidation treatment are 1.91 and 5.13 mΩcm^2, respectively. As shown in Fig. 13, the increasing rates of ASR of these coupons are 1.28, 0.65 and 1.28 μΩcm^2/hr for Crofer 22H, Crofer 22APU and SS41, respectively. These values are all much lower than the threshold value of 2.5 μΩcm^2/hr, which is obtained from the criterion of interfacial resistance and the service life-time for SOFC interconnect (100 mΩcm^2/40,000 hrs).



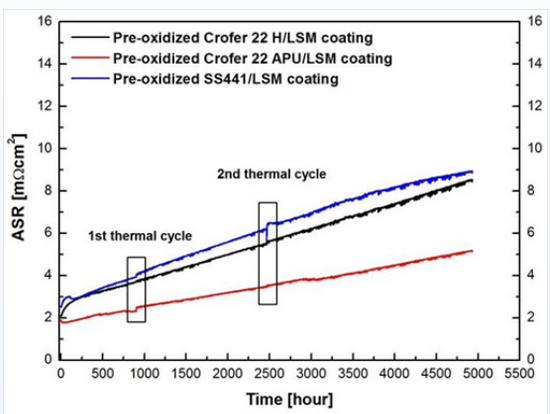
▲ Fig. 10 The schematic diagram of porous metal substrate manufactured by leveraging colloidal method with ventilating holes on the back side.



▲ Fig. 11 I-V-P results of a 5x5 cm^2 MS-SOFC cell with ventilating holes on the back side of substrate.



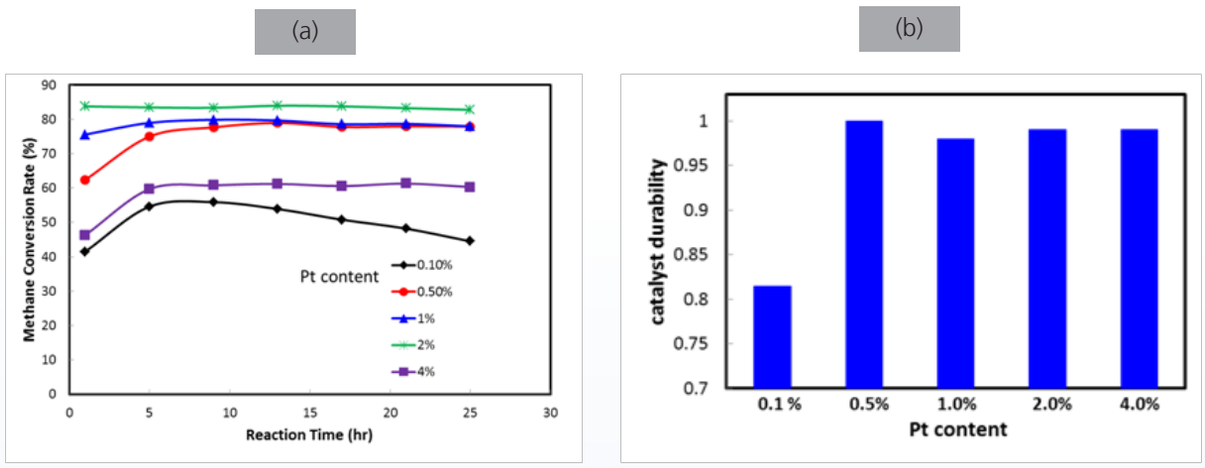
▲ Fig. 12. I-V-P results of a 5x5 cm^2 MS-SOFC cell, using a compression molding porous plate as substrate.



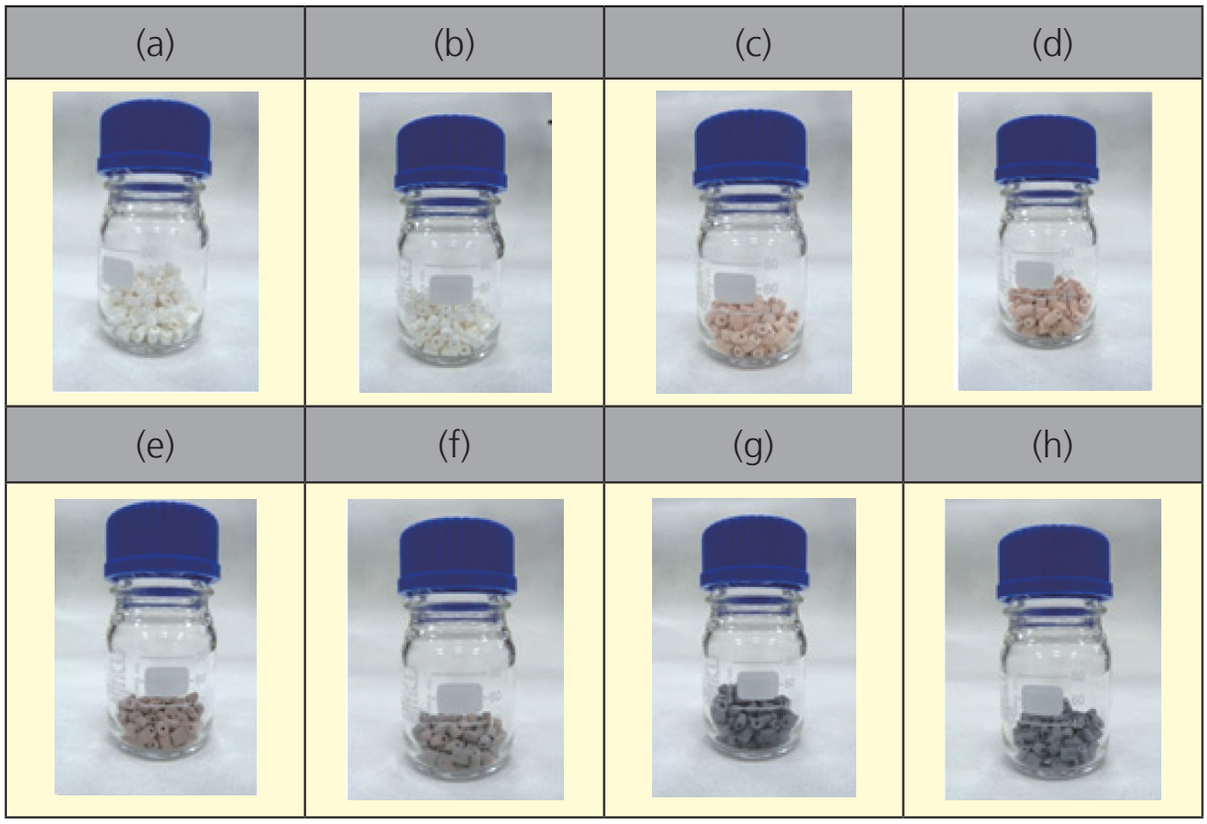
◀ Fig. 13 Long-term ASR measurement results of LSM-coated Crofer 22 H, Crofer 22 APU and SS441 coupons.

(4) Development of fuel reformers and reforming catalysts (by Ning-Yih Hsu)

Natural gas reforming catalyst is a critical technology for SOFC system. With the innovative invention of ring-shape supported catalyst, properties of various combinations of catalysts and their conversion rates of methane were analyzed. It was found that the ceria (CeO_2)-assisted Pt catalyst coated on the α-Al_2O_3 support, i.e., Pt/CeO_2/α-Al_2O_3, was able to significantly eliminate the carbon accumulation problem in the traditional commercial catalysts. Comparisons of the methane conversion rates of reforming catalyst with platinum content of 0.1%, 0.5%, 1.0%, 2.0% and 4.0% are shown in Fig. 14(a). When the platinum content is less than 1.0%, platinum particles cannot be fully distributed on the support surfaces. As methane molecules are effectively adsorbed on the surface of the platinum particles, a methane conversion rate can be enhanced and remains fairly stable. Considering the methane reforming reaction by a catalyst with a platinum content of 0.1%, platinum particles can be at hydrogen-rich positions, where Ce (IV) is reduced to Ce (III). Catalyst promoter (CeO_2) will lose the function of oxygen storage to cause carbon deposition, resulting in the decreased methane conversion rate. However, 4.0% platinum content is too high to cause the particle aggregation. The oversized platinum particles result in poor catalytic performance. A ring-shape support and various compositions of a ring-shape supported catalyst will be significantly different in appearance as shown in Fig. 15. The pure white α-Al_2O_3 turns to rice white by adding 12% CeO_2. Successive addition of 0.1 or 0.2% platinum nanoparticles to prepare the reforming catalysts are shown in Fig. 15(c) and (d). Due to low platinum concentrations, platinum nanoparticles coated on the support surface with a monolayer structure absorb light at 250-500 nm. We will see the complementary color of red. However, if the platinum concentration is increased to 0.5, 1.0, 2.0, and 4.0%, on support surfaces formsa multiple-layer structure of platinum nanoparticles, and the appearance becomes dark. Considering the cost and durability, the catalyst with 0.5%Pt/12% CeO_2/α-Al_2O_3 yields 79% of methane conversion rate, and can react for 25 hours while maintaining its reactivity of catalyzation.



▲ Fig. 14 Comparison of (a) methane conversion rates and (b) catalyst durability of ring-shape supported catalysts with various Pt contents.



▲ Fig. 15 Appearances of(a) α-Al_2O_3 (b) 12% CeO_2/α-Al_2O_3 (c) 0.1% Pt/12% CeO_2/α-Al_2O_3 (d) 0.2% Pt/12% CeO_2/α-Al_2O_3 (e) 0.5% Pt/12% CeO_2/α-Al_2O_3 (f) 1.0% Pt/12% CeO_2/α-Al_2O_3 (g) 2.0% Pt/12% CeO_2/α-Al_2O_3 (h) 4.0% Pt/12% CeO_2/α-Al_2O_3

3. Perspective

The SOFC key technologies are being continuously transferred to the domestic industry, facilitating the formation of a complete industrial supply chain consisting of up-, middle-, and down-streams. The inclusion of mobility and system integrating capability from the industry sector will accelerate the formation of the SOFC industry clusters.

In the future, efforts will be paid to the following categories: design 3~5 kW SOFC power generating system with an overall efficiency higher than 85%, assist the industry to move forward to mass production of cells, develop atmospheric plasma spray technology for protective coating on interconnect, manufacture mid-temperature (650~750°C) reforming catalyst etc. It is expected that Taiwan can play an essential role in the global SOFC market.

4-2-4 Technology Development of Clean Carbon as Sustainable Energy (CaSE)

Yau-Pin Chyou/Ching-Tsung Yu /Po-Chuang Chen/Yi-Shun Chen/Ching-Ying Huang /Hsiu-Mei Chiu/Kuo-Hsin Lin

Introduction

National Energy Program-phase II (NEP-II) has been launched since 2014, to be devoted to R&D on energy safety, energy efficiency and clean energy. The action represents one of the options to implement the guidelines for industry development and to fulfill the requirements for economic development, environmental protection and social justice.

This work focuses on clean carbon-based energy technologies under the framework of the Carbon Reduction and Clean Coal Focus Center of NEP-II, and consists of two tasks: (1) Commissioning of an integrated test facility for clean carbon system, including gasification, warm/hot gas separation and clean-up, carbon capture, system design and optimization technologies, and (2) Carbon capture at elevated temperature and reutilization.

R&D Achievements

(1) Development of gasification technology

The gasification test facility has been commissioned for operation at 700-900°C. In addition, the gas analysis system has been built to analyze the composition of outlet syngas from gasifier, for which the concentrations of CO, CO_2, H_2, and O_2 in syngas were measured and calibrated. The effect of various operation parameters on the composition of syngas will be carried out in the work. A preliminary test result of gasification with air is shown in Fig. 1-1.

The system-level simulation model for synthetic natural gas (SNG) production based on gasification technology has been built in present study, for which the commercial chemical process simulator, Pro/II® V8.1.1 was implemented to evaluate the system efficiency of NGCC plant. To convert carbonaceous fuel to SNG by gasification technology, it can reduce the risk for imported liquefied natural gas (LNG) due to the limited storage capacity of natural gas in Taiwan, which is about two weeks at this moment. The results show that the efficiency in either case of SNG or mixture of SNG and syngas are both around 54%. The study shows a possible way of converting coal to SNG in Taiwan. Fig. 1-2 shows the simulation processes flow diagram of a typical NGCC power plant. Furthermore, some domestic industry (e.g., pulp and paper industry) has been interested in recycling the process residues, which can undergo gasification process for generating syngas, then recovering its thermal energy. For this type of application, combustion technology for syngas (or hydrogen-rich gas) is crucial and resides in the scope of the CaSE project. The project team has been interacting with academic and industrial partners for planning the development of syngas applications, and the patent of "A burner for hydrogen-rich gas," jointly developed by INER and academics, has won a silver medal award in the Invention Contest of 2014 Taipei International Invention Show & Technomart.

(2) Development of Gas Clean-up Technologies

The exhibited technology consists of two categories. The first one is advanced gas filtration technology in moving granular bed filter (MGBF). Development of the moving granular bed filter system was targeted at operation under the high-temperature environment of 500°C. In 2014, commissioning the hot model of

three-dimensional granular bed filter (GBF) with the sub-systems (trommel screen system) was finished (in Fig. 1-3), which exhibited granule screen efficiency higher than 98%. The facilities supply the high-temperature environment for experimental study under 500°C, in which the collection efficiency was higher than 90% at 500°C.

Secondly, desulfurization technology was developed for the removal sulfide compounds of gas emissions at elevated temperature. Porous inert supported metal oxide was used as sorbent for desulfurization reaction at elevated temperature, which is a potential technology for reduction of gas contaminant emissions. In previous work for comparison of desulfurization performance by various metal oxides, Fe_2O_3-based desulfurization sorbent exhibit superior sulfur capacity and high chemical stability. Therefore, Fe_2O_3-based material has been chosen for further study in this field. In this year, the study is focused on developing a large-scale production apparatus (as shown in Fig. 1-4.) for desulfurization sorbent, and performance test further leads to atomically synthesis fabrication. The expected goal is achieved for large-scale production of 0.5 kg desulfurization sorbents per day.

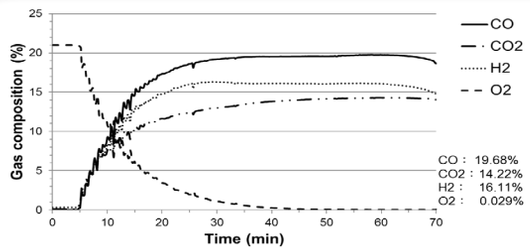
(3) Development of Carbon Capture Technology at Elevated Temperature

The aim of this study is to develop CaO-containing CO_2 sorbent in the elevated temperature range (600-800°C). The CaO-based sorbent has caught much attention due to its high CO_2 capture capacity, environmental friendliness, low costs and wide operation temperature. In our previous work, Ca/Al LDH (layered-double hydroxides) sorbents have been synthesized and it showed better stability than commercial CaO as well as limestone. Furthermore, pilot-scale production of Ca/Al LDH was also developed. The goal of this year is to modify the composition of sorbents to mimic natural limestone and establish the operation parameters of 10 kW fixed-bed reactor. Figures 2-1 and 2-2 show the CO_2 capture performance of INER's sorbents. Although the capture capacity was dropped after modification with magnesium, the contents were much close to natural limestone. Additionally, it also exhibited good stability during long-term cyclic test.

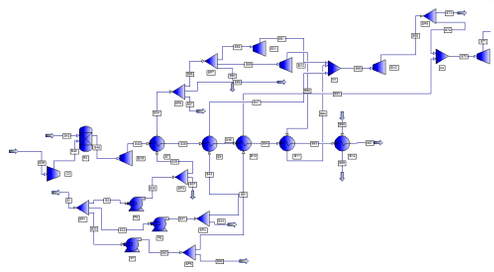
Testing data of Ca/Al LDH and commercial $CaCO_3$ sorbents at the 10 kW reactor (seen in Figure 2-4) were shown in Figure 2-3. It is obvious that cyclic stability of Ca/Al LDH is better than the counterpart of commercial $CaCO_3$ in all tests, which also means that it possessed robust resistance against sintering. Beside this, the operation parameters of the 10 kW fixed-bed reactors were also established. In the future, various types of CO_2 sorbents fabricated by this technique will be employed to fixed-bed and fluidized-bed reactors, for evaluating the capture capacity and long-term stability of these sorbents. The goal is to gradually establish key technologies of CO_2 capture and eventually to commercialization.

Prospect (or Future Work)

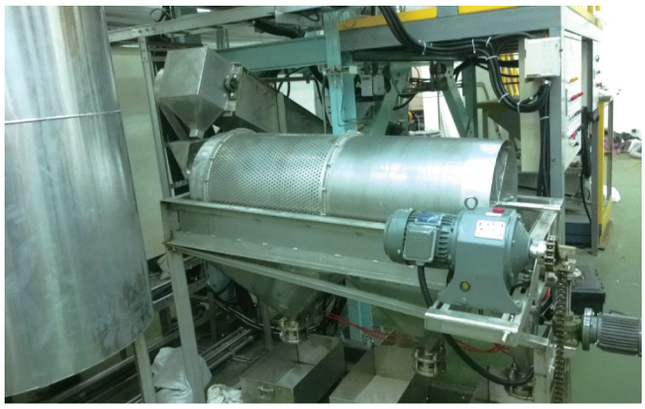
The concluding remarks from a recent National Energy Conference proposed important activities on carbon reduction and clean coal, such as to introduce clean coal and carbon reduction technologies, and to formulate research project on "Carbon Capture, Use and Storage (CCUS)" with schedule and progress. The gasification and related technologies developed in the work have features of feedstock flexibility, low emission multiple applications, etc., and play a major role in key clean coal technologies. Industry has shown interest in multi-production based on gasification and practiced a feasibility study plan. The working team will cooperate with industry to pursue follow-up efforts for mitigating greenhouse gas emissions from sustainable development viewpoints. It is expected that this strategic planning will establish the essential foundation for technologies needed to fulfill the policy of energy saving and carbon abatement.



▲ Fig. 1-1. Typical test result of gasification with air

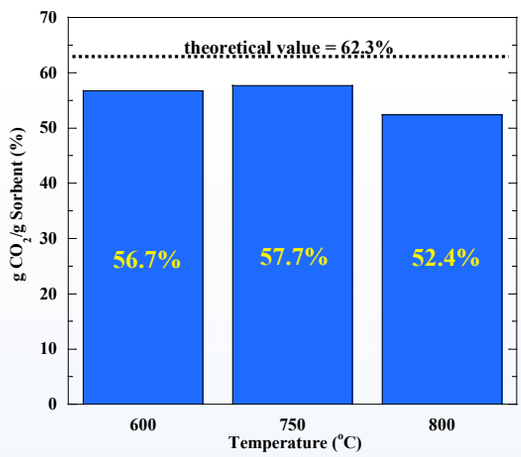


▲ Fig. 1-2. Simulation processes flow diagram of a typical NGCC plant

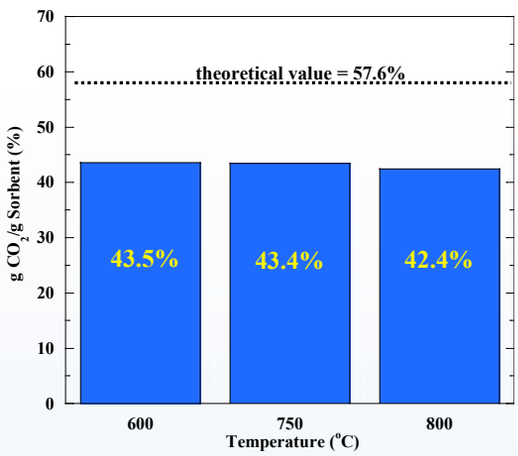


▲ Fig. 1-3. Trommel screen system

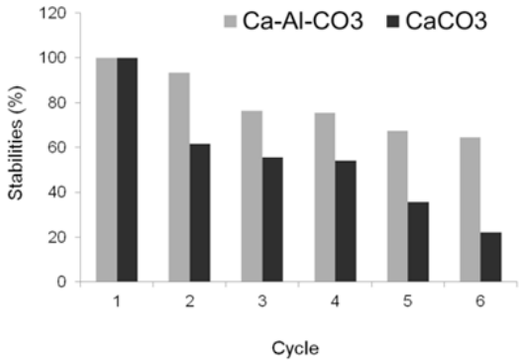
Fig. 1-4 Large-scale desulfurizer production equipment ▶



▲ Fig. 2-1. Performance data: INER's sorbent of Ca/Al LDH



▲ Fig. 2-2. Performance data: INER's sorbent of Ca/Mg/Al LDH



▲ Fig. 2-3. Cyclic testing data of Ca/Al LDH and $CaCO_3$ at 10 kW reactor

▲ Fig. 2-4. 10 kW fixed-bed CO_2 capture reactor

4-2-5 Development and Application of Autonomous Power Control and Management Technology for a Distributed Power System

Kuo-Yuan Lo, Tsung-Chieh Cheng, Yih-Der Lee, Yung-Ruei Chang.

In recent year, INER actively develops renewable energy, such as wind, solar, and biomass, for power generation. However, due to the intermittent and uncertain characteristics, high penetration of renewable power generation will cause dramatic impact to the operation of bulk electric power system. INER establishes a hundred-kW-scale microgrid demonstration site and develops power control and management technology for a microgrid to provide possible solutions. The objective of this work is to demonstrate the power control and management technique for a microgrid with more than 20% penetration rate of renewable energy sources. Through the execution of this work, resources integration among governments, academics, research institutes, and industries can form the opportunities not only to offer the component supply chain of developed countries, but also to create the market of developing countries.

INER is currently developing autonomous power control and management technology, with important R&D achievements shown as follows:

Development of Distributed Power System and Intelligent Control Technology

The first Active-Power dispatched microgrid has been built for Taiwan Power Company (TPC) to develop the virtual power plant as shown in Fig. 1. INER microgrid can receive and execute the dispatching command from TPC Taoyuan Branch by the communication protocol of DNP 3.0 as shown in Fig. 2. Also, the load and generation information is recorded by the high-voltage/low-voltage work station as shown in Fig. 3. In Fig. 4, it shows the EV charging schedule design and EV charging platform, for which real/reactive power control are realized for INER microgrid by integrating energy storage system and charging pile.

Development of Power Electronics Technology for Distributed Energy Resource

The circuit simulation of static switch system is built by PSIM software. It is verified that the power converter is capable of cutting the grid within 2 cycles for the microgrid system. The prototype of static switch is

developed with DSP controller which can sense 6 voltage signals and output 6 control signals. Figure 5 shows the test result of the prototype integrating converter and battery system. It can be found that the system is capable of riding through the mode-transfer during transition period of time. In addition, the mechanical parameters of the power converter are given to design the 3-D thermal simulation by FDS software as shown in Fig. 6.

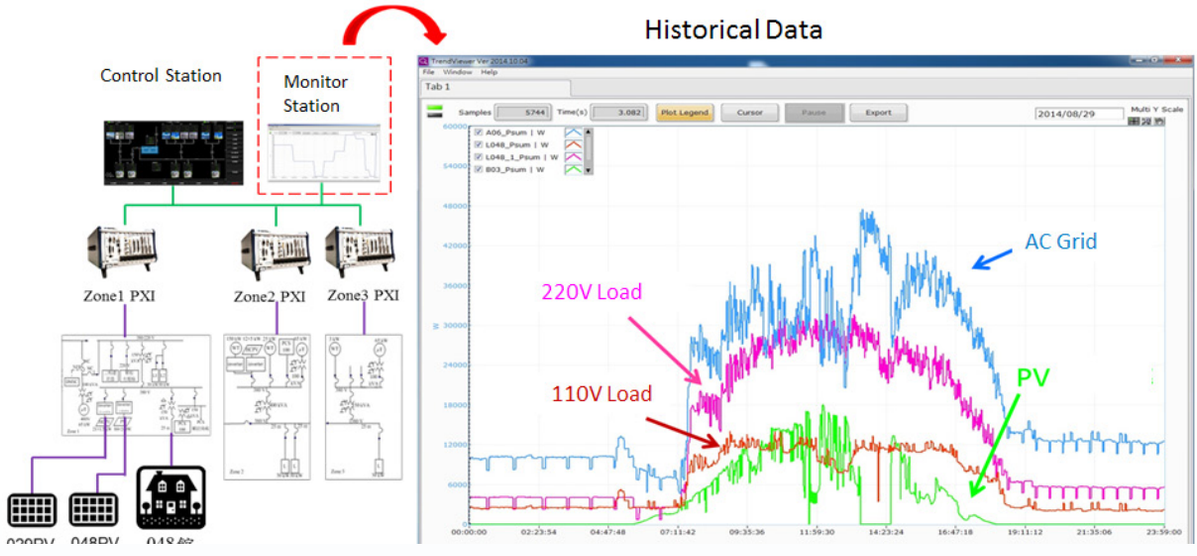
Development of Multi-agent Integration Platform Technology for Distributed Energy Resource

The state-of-the-art international standards for the communication and information structure of distributed energy source power have been studied in recent years. The entities and interfaces of INER microgrid are identified according to IEEE 2030 standard. The distributed energy source power communication and information structure designed by IEEE 2030 standard is shown in Fig. 7. Then, the JADE (Java Agent DEvelopment Framework) platform is realized for multi-agent system structure and performs the optimal and visual electricity marketing scenarios in the microgrid system, as shown in Fig. 8. This multi-agent system, which is also called the conceptual testing platform of implementing multi-agent systems in smart grid, provides implementing analyses with the microgrid controller of INER. In the future, electricity market developments and key trends for Taiwan will be taken into account in the multi-agent system and its testing scenarios to realize the autonomous electricity marketing of the microgrid.

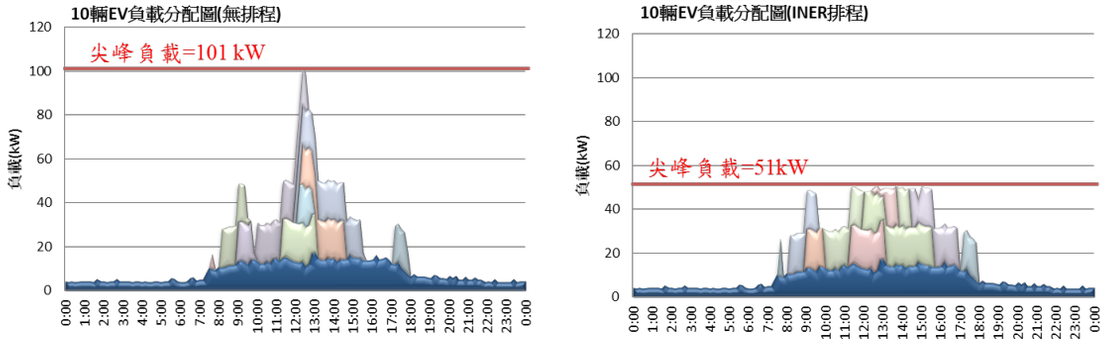
The development of microgrid technology allows distribution network to cope with more power generation from renewable energy. The microgrid technology can be widely implemented in the offshore islands, remote communities, and small cities, to enhance the power quality, stability, and reliability of their regional grids. In the short-term, INER microgrid will be connected to an actual Taipower distribution feeder and complete the microgrid demonstration site for stable operation. Regarding to the med-term and long-term benefits, the operation of this demo site can create business models for the microgrid industries in off-shore islands application. With system standardization and the completion of packaging, INER plans to promote microgrid as the role of increasing energy independence, providing stable energy supply, and reducing carbon emissions.

▲ Fig.1 The first Active-Power dispatched microgrid

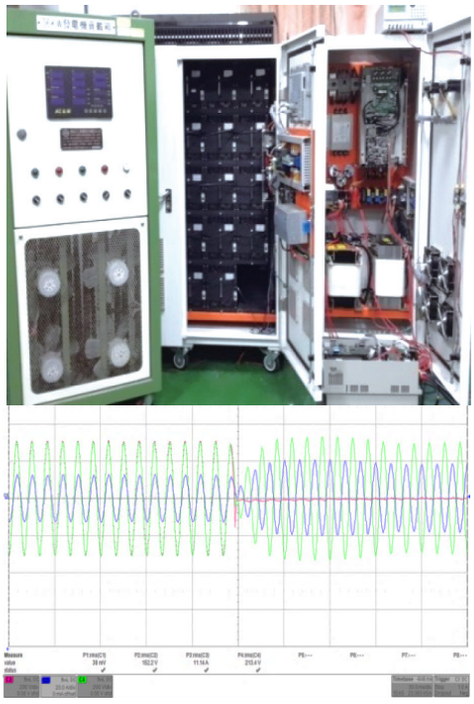
▲ Fig.2 Microgrid power dispatching test with TPC



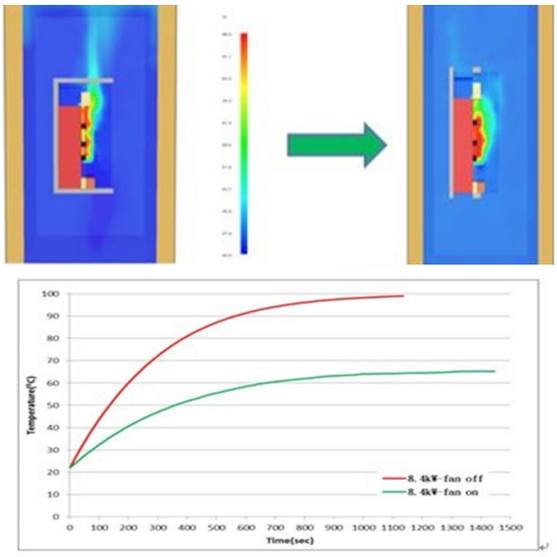
▲ Fig.3 Continuous 24hr test with 048 building and distributed Power System



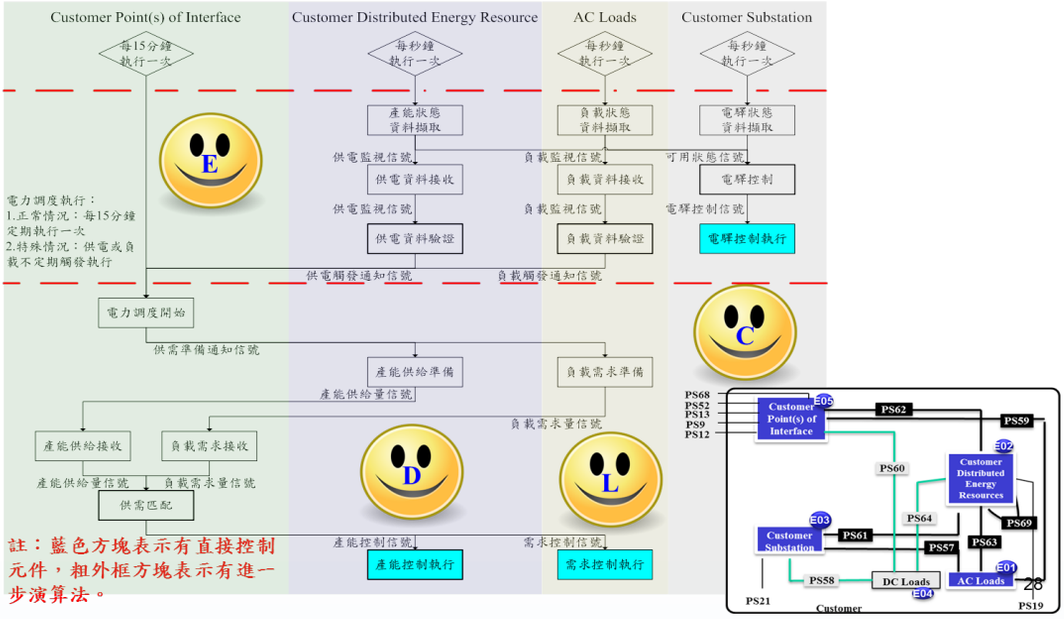
▲ Fig.4 Design of EV charging schedule



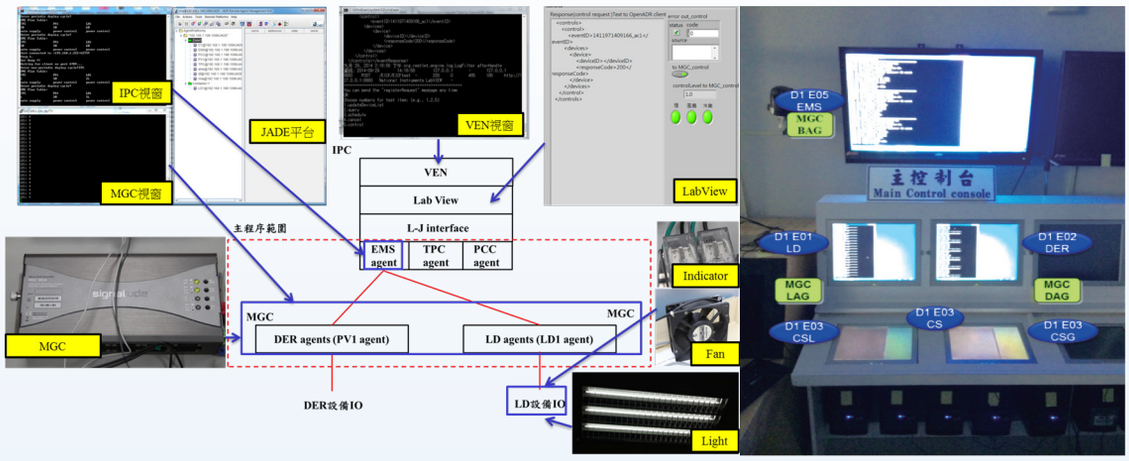
◀ Fig.5 Static switch system integrating converter and battery system



▲ Fig.6 Thermal simulation for power converter by FDS software



▲ Fig.7 Identification of entities and interfaces for INER microgrid according to IEEE2030 standard



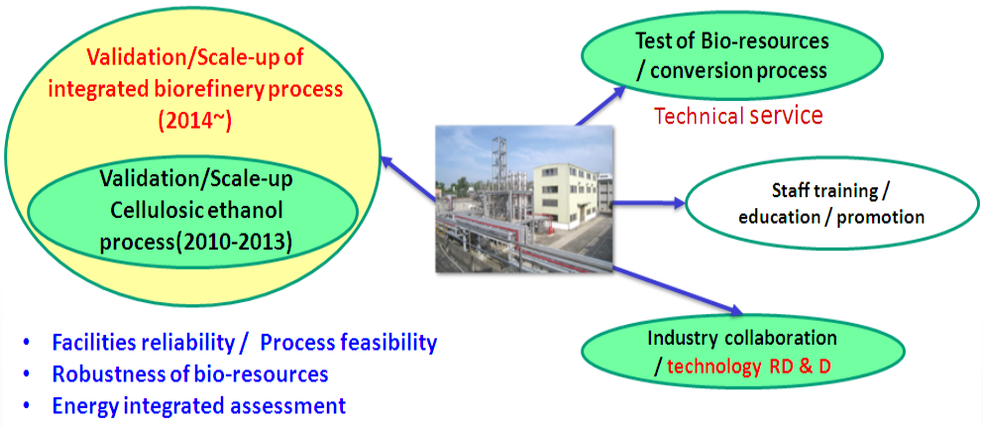
▲ Fig.8 Design of multi-agent system platform and apply to distributed energy resource

4-2-6 An industry promotion platform for cellulosic ethanol and the development of value-added biomass refining technology

Chwei-Huann Chiou

1. Introduction

This R&D program is in compliance with national policies on promoting biomass energy and green energy for reducing the dependence on petroleum, lowering carbon dioxide emission, and establishing emerging low-carbon industries. It advances the development of cellulosic ethanol and biorefinery technologies, using non-food biomass as the raw materials for commercialization. Cellulosic ethanol technology is a proactive and challenging biomass conversion technology, and its core-technologies can be extended to biorefinery for producing bio-materials and bio-chemicals. The tests on unit performance, process stability, scale-up validation, and system improvement have completed in the pilot-scale cellulosic ethanol research platform of the Institute of Nuclear Energy Research (INER) since it started operating in 2010. The capabilities of operation and conceptual design of mass-production process are built accordingly, and the operating data can also be the basis for evaluating the production cost, energy benefit, and carbon-emission benefit if such a plant is designed. These outcomes could help establish commercialized cellulosic ethanol or biorefinery technology, converting agricultural and forest residues into bio-fuels or bio-based chemicals, so that the increase of low-carbon industries, energy diversity, and carbon dioxide reduction can be achieved then. Starting from year 2014, a consecutive four-year program has been initiated for optimizing the cellulosic ethanol manufacturing process for commercialization and developing biorefining process for producing bio-chemicals. Its main development plan is shown in Figure 1.



▲ Figure 1. The strategic development plan for commercialization

2. Major achievements

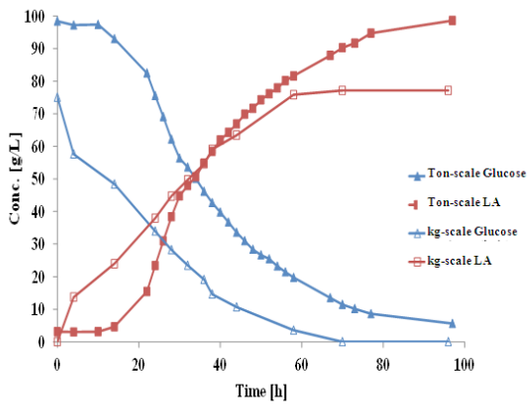
This program is extended from the former "R&D of cellulosic ethanol mass production technology" program. It will extend the technologies and information accomplished at the former program, such as cellulosic ethanol validation test platform, process development and design, pilot plant basic design, and operating data, into a biorefinery technology platform. The major achievements include the following items:

(1) Steady operations of the whole plant: The ton-scale pilot plant can be run continuously for 2 ~ 4 weeks. It was operated mainly with the simultaneous saccharification and co-fermentation (SSCF) biochemical process, and the hybrid SSCF process HSSCF as well.

(2) Establish competitive and featured cellulosic ethanol conversion process: This program is the rare one that focused on developing the mass-production process for converting rice straw, the most abundant lignocellulosic material in the world, into cellulosic ethanol. The production technology for converting sugarcane bagasse and wood chips, which are plentiful in subtropical region, were also developed. Through SSCF biochemical process, it is estimated that one ton dry rice straw, bagasse, and wood chips can produce maximum 200 L, 220 L, and 240 L cellulosic ethanol, respectively.

(3) Validation of cellulosic lactic acid mass-production process: The cellulosic lactic acid fermentation in a ton-scale reactor has been completed and validated. Both lactic acid production concentration and glucose conversion efficiency have reached commercially applicable levels of 99 g/L and 96%, respectively. An amount of 220 ~ 250 kg cellulosic lactic acid can be produced form one ton dry cellulosic feedstock (Figure 2).

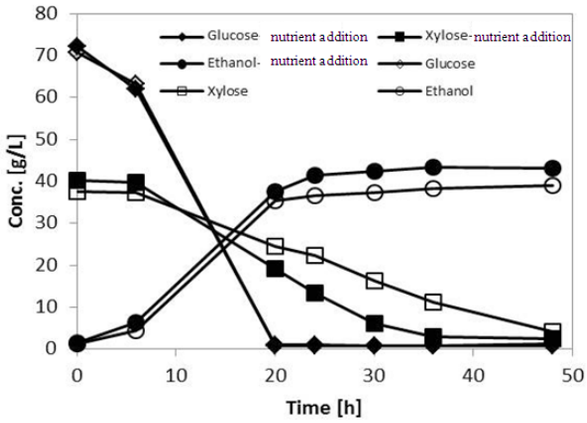
(4) Integration and design of commercialized cellulosic ethanol production process: Mass and energy balance calculations of a cellulosic ethanol plant have been proceeded, based on the pilot plant's operations with SSCF process and reasonable layout plan. Thus, the process for treating 100 tons feedstock per day has been integrated and conceptually designed, and its energy benefit and cost analysis have also been implemented, so as to estimate the requirements for plant site, equipment and facilities. These results can be the major references for engineering design for building demonstration or commercial plants.The features and achievements of the developed biochemical process include the following items:



▲ Figure 2. Schematic process flow diagram of cellulosic lactic acid's esterification reacting distillation

(1) Establish the tailor-made industry service platform that can assess the suitability of biochemical process according to the feedstock's composition: SSF, SSCF, and HSSCF processes all can be used for converting cellulose into ethanol. The conversion technology and equipment used for mass production validation is determined according to the compositional characteristics of the raw material. Mass and energy balance and economic benefit evaluation are implemented, based on the operating data, and can be provided as a reference for industrial input then.

(2) Improvement of the cellulosic ethanol co-fermentation process: Various feedstocks, such as rice straw, bagasse, and wood chips, have been tested with SSCF process, and the operating costs have been reduced to increase the process competitiveness. The enzyme loading in enzymatic hydrolysis process has been decreased by 33%, while the conversion efficiency deviated less than 5%. Ethanol fermenting time can be decreased from 48 hours to 36 hours by adding 0.03% urea nutrient in the enzymatic hydrolysate using Y600 co-fermentation yeast, and the resulted ethanol concentration can be 40 g/L, while the conversion efficiency is 75%. An energy beneficial and competitive mass-production process of cellulosic ethanol can be established, since both enzyme dosage and fermenting time can be decreased by 33% (Figure 3).

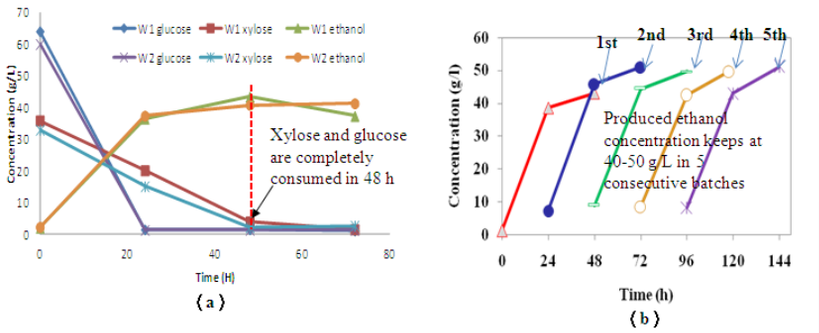


▲ Figure 3. Comparison of nutrient addition for improving HSSCF process

The features and achievements of the fermentation yeasts development include the following items:

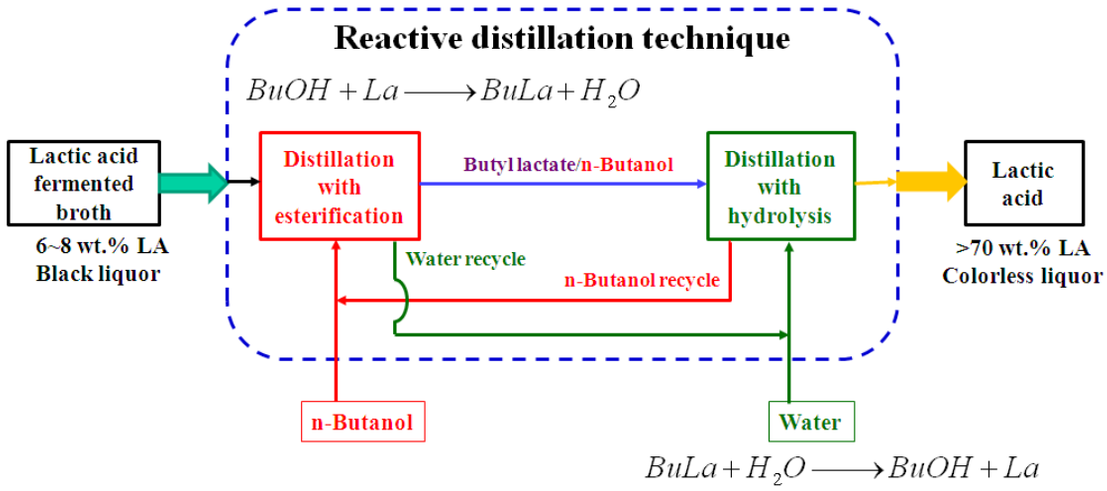
(1) Improvement of the ethanol co-fermentation yeasts: The co-fermentation yeasts' tolerances of temperature and inhibitors are increased through mutation screening and evolution engineering technologies. Under non-detoxification condition, the produced ethanol concentration can still be higher than 40 g/L and the xylose utilization rate is maintained above 1.5 g/L/h and consumed completely within 48 hours in the fermentation tests on various feedstocks' hydrolysates generated by the ton-scale equipment. The results of the produced ethanol concentration can be kept at 40 ~ 50 g/L during 5 times repeated co-fermentation tests, which shows that the co-fermentation yeasts developed by this program can be used in high-inhibitors hydrolysates from different feedstocks, and can maintain high fermentation efficiency and stability (Figure 4).

(2) Development of cellulosic lactic acid strains: More than 40 lactic acid bacteria have been screened in this program to select 3 strains with high optical purity and high conversion potential. They are L-lactic acid strain, D-lactic acid strain, and L-lactic acid co-fermentation strain, respectively. Their products' optical purities are higher than 99% and conversion efficiencies from glucose to lactic acid are more than 95%, therefore, all these strains have potential for commercial applications.



◀ Figure 4. Tests on the co-fermentation yeast's tolerance (a) and stability (b) to the hydrolysate

R&D achievements of the separation, purification, and analysis technologies for cellulosic lactic acid: The lactic acid fermentation broth produced from non-food biomass is different from that via starch- or sugar-crops, which contains a lot of impurities and dark shade. This program has developed a new separation and purification method (Figure 5), which can purify cellulosic lactic acid through the combined processes of esterification conversion and hydrolysis-distillation reaction. A bench-scale system for processing 30 L broth has been set up. After purification, cellulosic lactic acid concentration can be 88%, amount of impurities meets specifications, and the overall recovery can be 70%, of which the results have reached the threshold for commercial applications.Achievements of industrial platform promotion include the following items:



▲ Figure 2, Cellulosic lactic acid production validated in kg- and ton-scale fermenters

(1) Construction of domestic biorefinery industries supply chain: After years of implementation,this program has joined domestic industries, academia and institutes to construct a complete supply chain, including feedstocks supply, technologies establishment, equipment manufacture, biology technology, whole plant's engineering design, benefit assessment, and sales channels, that all have already built a complete cooperation structure.

(2) Technology commercialization: This program has successfully signed a biorefinery technology transfer contract with Malaysian Cymao Plywood Company. It includes 6 cellulosic ethanol core technologies with 5 relevant patents, and the total licensing fee is 60 million NTD. Cymao will use its wood wastes as the raw material, and may build a verification biorefinery plant in a couple of years.

(3) Promoting the collaboration with domestic engineering company for biorefinery plant design: Since domestic feedstocks and market are limited, to promote the bio-fuels or biorefinery technology abroad becomes a necessary trend. However, the technologies can be consolidated internally if the core technology and prototype design are kept domestic. This program promotes the establishment of partner relationship with domestic engineering company, so that its full plant design and construction capabilities can be combined with INER's biorefining process conceptual design and pilot plant operating experiences to help build commercial plants. INER will also sign technology-transfer contracts with the investors. Such a mutual beneficial cooperation can help promote turn-key mode to domestic and abroad markets, and expedite commercialization of the biorefinery technology.

3. Perspective

Cellulosic ethanol technology has reached the industry-promotion stage. One technology-transfer contract has been signed, and it will then start to practically build the plant. This program will face the problems of equipment scale-up, mass-production process validation, and demand for building commercial plant larger than 300 tons per day. Therefore, this program is planning to establish the design of a production line for processing 300 tons feedstock per day, it can then be expanded to 3 ~ 4 lines for meeting commercial plants' demand for more than 1000 tons feedstock per day. In these years, international biofuels process design and integration has gradually adopted the biorefinery concept, and emphasized multi-technology integration for full utilization of biomass resources and increasing products' added-value. Recently, many international programs have targeted the drop-in biofuels development, and chosen the bio-aviation fuel as prior goal, which coincide with this program's planning. Currently, R&D of the drop-in biofuels technology is still in the beginning stage, so it is a good opportunity for this program to start at the same point.

4-2-7 Capability Establishment and Assessment for Energy Technology Policy and Industrial Policy

Fu-Kuang Ko

1.Introduction

Institute of Nuclear Energy Research (INER) formally established Center of Energy Economics and Strategy Research in January, 2014. The purposes of the center are to continuously develop human resources, enhance research on energy economics and provide strategy recommendations. The center consists of four divisions, including energy system, energy economics, energy strategy and energy information and statistics. It is an interdisciplinary team of 28 research staff, who focus on the following research fields: energy policy and strategy, energy database platform, developing and maintaining the construction of national 3E (energy, economy and environment) evaluation model. Besides reinforcing the development of energy engineering models, energy economic models, and the corresponding application analyses, the center also emphasizes on promoting the communications and understanding of energy issues for the public.

2.Research Achievement

• The analysis about achieving CO_2 emission reduction targets of industry

The CO_2 emission from industrial sector is larger than other sectors in Taiwan, so it always plays an important role in national carbon reduction. Therefore, the Taiwan government proposed CO_2 emission reduction targets in 2011: the CO_2 emissions will be 125 million tons in 2020, while reducing to 107 million tons in 2025. They are 3% and 17%, respectively, less than the emission in 2010, i.e., 129 million tons. In order to discuss if the emission targets will be suitable, MARKAL model is utilized to analyze the electricity cost and opportunity cost of industry sector, for the collocations of electricity and industry technologies, to achieve the targets.

The results show that the following two collocations can achieve the CO_2 emission reduction target in 2020: (1) while the annual energy efficiency improvement of industry technologies is less than 2.5%, it needs to expand more liquefied nature gas (LNG) and renewable energy usage for reducing the coal-fired electricity generation to a level below 13% in Taiwan, or (2) under the present policy about imported LNG and renewable energy, the annual energy efficiency improvement of industry technologies must be larger than 4%. To reach the target in 2025, it needs: (1) efficiency improvement larger than 2% annually and reduction of coal-fired electricity generation (about 4%), or (2) 5% annual improvement rate with the present policy of LNG and renewable energy.

The results show that for the collocations with expanded LNG and renewable energy, the extra costs of electricity consumption are between 73.4 billion NTD to 214.4 billion NTD, which are 14% to 40% respectively of the social welfare in 2012 (504.4 billion NTD). Under the present policy of LNG and renewable energy, with the opportunity cost of industry technologies being between 31 billion NTD to 63.2 billion NTD, the ratios are 6% to 12% respectively of the social welfare in 2012. All costs are listed in Table 1.

From the results mentioned, the costs for achieving the emission targets are very expensive, and the targets should be adjusted. For example, if the target values are 138 million tons (2020) and 140 million tons (2025), which are 10.4% and 30.8% larger than original targets, it needs the collocations of 2% annual industry energy efficiency improvement and the present policy of imported LNG and renewable energy.

▼ Table 1: The extra costs of electricity consumption and the opportunity costs of industry technologies

The extra costs of electricity consumption under expanded LNG and renewable energy usage				
Annual industry energy efficiency improvement (%)	Excess costs of electricity consumption in 2020 (billion NTD)	The proportion related expenditure of social welfare (2012)* in 2020 (%)	Excess costs of electricity consumption in 2025 (billion NTD)	The proportion related expenditure of social welfare (2012)* in 2025 (%)
0.5	175.8	33	-	-
1	149.7	28	-	-
1.5	83.1	15	214.4	40
2	73.4	14	186.1	34
The opportunity cost of industry technologies under announced LNG and renewable energy policies				
Annual industry energy efficiency improvement (%)	Opportunity cost of industry technologies in 2020 (billion NTD)	The proportion related expenditure of social welfare (2012)* in 2020 (%)	Opportunity cost of industry technologies in 2025 (billion NTD)	The proportion related expenditure of social welfare (2012)* in 2025 (%)
4	31	6	-	-
5	45.9	8	63.2	12

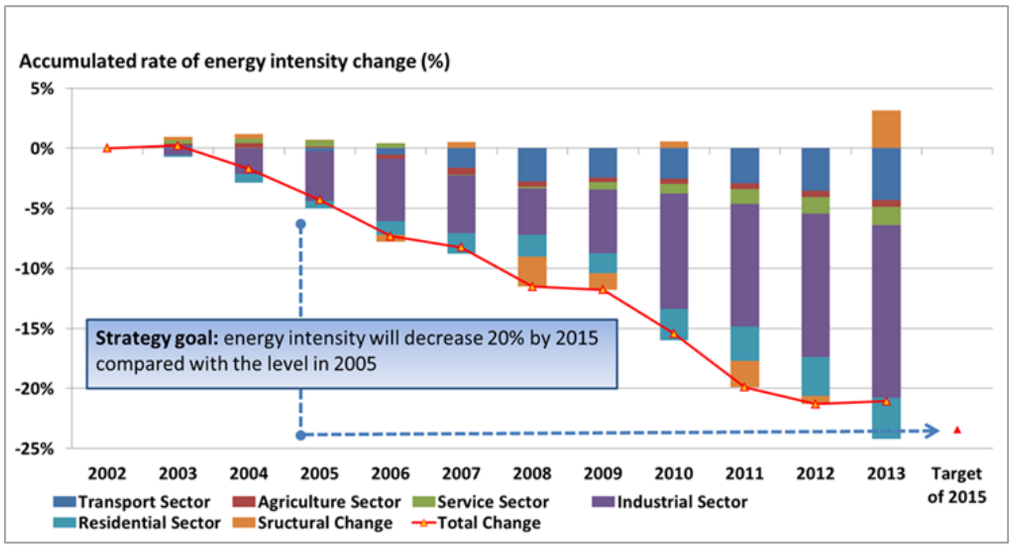
*: The social welfare in 2012 is 504.4 billion NTD

• Taiwan's changing energy intensity trend- A decomposition analysis

In 2008, the government of Taiwan passed the energy policy: Taiwan's Sustainable Energy Policy. In the policy, the goal is to improve energy efficiency by more than 2% annually, so that energy intensity (EI) will decrease 20% by 2015 compared with the level in 2005. Supplemented by further technological breakthroughs and proper administrative measures, energy intensity will decrease 50% by 2025. From Fig. 1, it is observed that the total energy intensity decreased by 21.1% for the decade, and expected to successfully achieve the target of 2015 according to the declining trend. By the index decomposition analysis which decomposes the total EI changes into two effects, i.e., the structural change and the sectorial EI change, we have the following conclusions.

(1) Structural change: The total EI increased by 3.15% due to industrial transformation. Transforming Service Sector to Industrial Sector has made the EI deteriorate, although low-EI manufacturing industry (electronic parts manufacturing) grew quickly over the past years. In addition, the study found the industrial transformation toward high-EI industry has influential impact to EI than other industry. For instance, when the share of chemical materials manufacturing increases by 1% in Taiwan's GDP, the total EI will worsen by 17.4%.

(2) Sectorial EI change: This change implies the energy efficiency improvement of industry and is also the main reason of total EI decreasing over the past few years in Taiwan. The total Sectorial EI decreased by 24.2%, including Industrial Sector (-14.4%), Transport Sector (-4.3%), Residential Sector (-3.4%), etc. In addition, when we assume that the industry structure of Taiwan keeps constant, we found that improving energy efficiency of high-EI and high energy consumption industry will be the most effective means to decrease total EI in Taiwan. In summary, we suggest that government should not only focus on improving energy efficiency of high energy-consuming industry, but also keep tracking high-EI industry and supervise its energy efficiency improvement. Therefore, the GDP structure of Taiwan should be transformed to Service Sector, high value-added industry, Service-oriented Manufacturing Industry and other low-EI industry, so that the total EI will continue to improve for meeting the strategic goal of 2025.

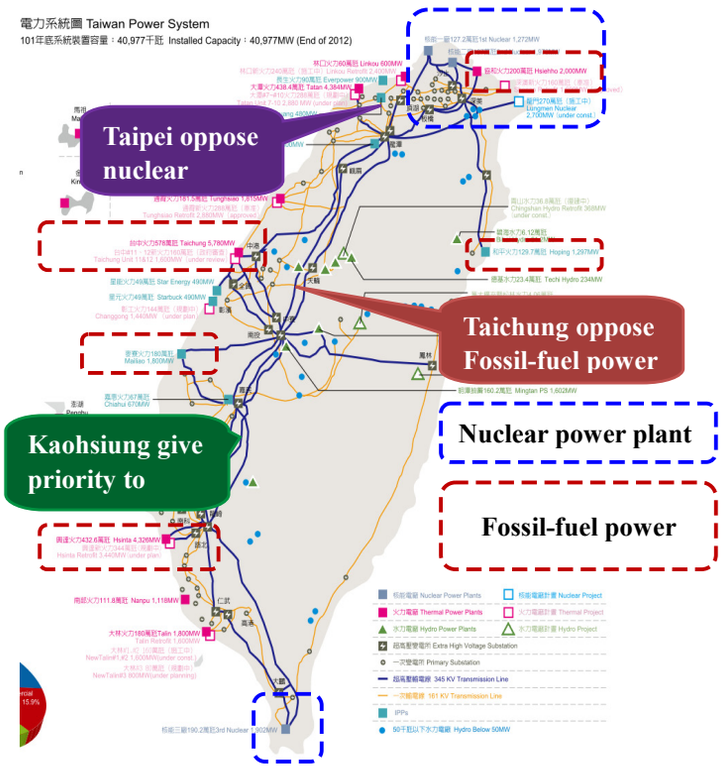


▲ Figure 1: Index decomposition analysis of energy intensity change of Taiwan (Base year: 2002)
Data Source: National Accounts (SNA93) from Statistical Bureau (R.O.C) and Energy Balance Sheet from Bureau of Energy (R.O.C); Depicted by INER

• Consumer willingness-to-pay for electricity price: Results from focus groups

The main purpose of this study is to find out whether consumers are willing to pay a surcharge for green energy after Fukushima nuclear disaster. In order to facilitate public participation in energy policy-making process, focus groups were the primary method adopted in the project. We invited 54 participants across various groups, including the public, environmentalists, electricity experts and industry representatives. These forums feature an exploratory study on the public attitude and willingness to pay for electricity and green energy. Based on participants' cognition of the demand and supply of electricity, this research investigates each group's electricity usage behavior, such as motives, decision-making process, information source, and decision factors. With the design of an interactive spreadsheet in four variety situations, this study hopes to elicit public preference and factors for energy use.

Results showed that: (1) Most of respondents were willing to pay a premium in line with the cost, and demonstrated a regional difference according to the distribution of nuclear power plants or fossil-fuel power stations. Respondents in Taipei value environmental protection much more than electricity price, and have the highest willingness to pay for renewable energy; respondents in Taichung accept nuclear power much more than fossil-fuel power, because of air pollution, and hope to receive subsidies from government; respondents in Kaohsiung prefer to reduce nuclear energy and increase renewable energy, but still want to maintain the current electricity price. As for the information source about energy issue, compared to government authority and NGOs, most do not trust Taiwan Power Company.(Fig. 2) (2) Among SMEs (small and medium-sized enterprises) and large enterprises, there are great differences in measures to cope with electricity price increasing; SMEs passed the cost to consumer, while large enterprises have more energy-saving equipment and technology to adapt it.



▲ Figure 2: Taiwan power system and public attitude

3. Prospects

INER will continue to focus on the long-term trend and perform in-depth analysis. Furthermore, we will evaluate the uncertainty by using statistic methods or sensitivity analysis. On the other hand, corresponding to the needs of communities, including correct energy information and participation in energy policy, the achievement of energy research and useful energy information are diffused through the energy information platform (EIP). We will extend public participation in energy policy-making process in order to strengthen the rationality in policy implementation.

4-2-8 Development of wind turbine technology

Chin-Cheng Huang, Wei-Nian Su, Wen-Jeng Lai, Yan-Ting Lin

1. Introduction

Comparing to the large wind turbine industry, the small-and-medium wind turbine companies in Taiwan possess better competitiveness internationally. However, technology improvement on the wind turbine system integration as well as its system verification and certification are still required. After the development and implementation of the 25 kW and 150 kW wind turbine systems, INER is actively involving in the development of the 2nd generation 150 kW wind turbine system. In other words, INER is the only domestic institute with the capability of design, system integration, operation, and design assessment of small-and-medium wind turbine systems. INER is struggling to establish the domestic technology for the large and offshore wind turbine system, based on the existing small-and-medium wind turbine technology.

2. Achievement

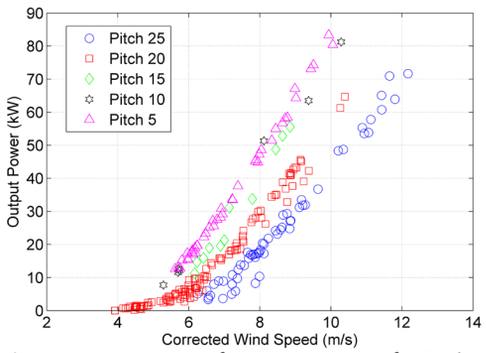
2.1 Development of small-and-medium wind turbine technology: Assembly, installation, and test operation of the 2nd generation 150 kW wind turbine

INER initiated the project for developing the 2nd generation 150 kW wind turbine in 2011. In accordance with the requirement of IEC 61400-1 Class IA, the design process was finalized in 2013 and moved into production. The 2nd generation 150 kW wind turbine was assembled in early 2014 (Figure 1) and tested with the 200 kW dynamic testing platform (Figure 2) at the laboratory. In July 2014, the system was successfully installed on top of the 50 m lattice tower at campus (Figure 3) and undergone control system tuning. An opening ceremony and technical conference for the 2nd generation 150 kW wind turbine was held in October 2014. Finally, the preliminary power performance test was conducted as shown in Figure 4.

▲ Figure 1:Assembly of 150 kW turbine system

▲ Figure 2:Ground test of 150 kW turbine system

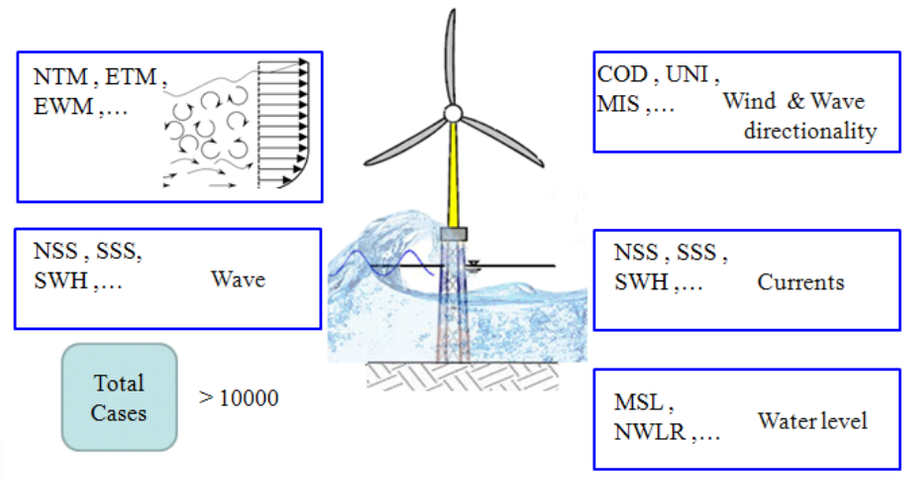
▲ Figure 3:Installation of 150 kW turbine system



▲ Figure 4: Power performance test of 150 kW turbine system

2.2 Development of large wind turbine technology: Analysis of the design load in accordance with IEC offshore guideline

Using NREL 5 MW virtual wind turbine with jacket support structure as the reference wind turbine, the design load cases were defined in compliance with the requirement of IEC 61400-3 (Figure 5). Combining wind, wave, and sea current conditions, the extreme loads as well as fatigue loads were calculated and analyzed (Table 1). By this way, the design evaluation technique of offshore wind turbine can be established in the near future.



▲ Figure 5:IEC design load cases

Table 1:Extreme and fatigue loads on NREL 5 MW wind turbine

	Extreme Load: ETM		
	1A	1B	1C
Blade falpwise moment (kN-m)	18350	17210	15970
Shaft thrust (kN)	1144	1108	1041
Shaft torque (kN-m)	6133	5922	5620
Shaft bending (kN-m)	13730	12650	11410
Tower thrust (kN)	1205	1121	1015
Tower bending (kN-m)	14170	12960	11670
Base thrust (kN)	3728	3750	3702
Base moment (kN-m)	141900	132900	13050

	Fatigue Load		
	1A	1B	1C
Blade falpwise moment (kN-m)	5065	4577	4094
Shaft thrust (kN)	221	197	174
Shaft torque (kN-m)	842	751	653
Shaft bending (kN-m)	6168	5566	4954
Tower thrust (kN)	274	246	219
Tower bending (kN-m)	4459	3936	3405
Base thrust (kN)	1695	1676	1665
Base moment (kN-m)	36358	33827	31401

3. Future Work

Utilizing the developed 150 kW wind turbine platform, development of the fault detection and warning system can be achieved in the near future. It is expected to implement these systems on the large wind turbines and domestic technology can be greatly improved. As to the large and offshore wind turbine technology, the international standards such as IEC 61400-3 were primarily developed, based on the European site conditions. Typhoon and earthquake are the unique regional environmental conditions in Taiwan, for which these impacts should be studied and analyzed in order to increase the reliability and safety of domestic offshore wind turbine operation.

4-3 Research and Development of Radiation Application

Wuu-Jyh Lin, Shiou-Shiow Farn , Kuan-Yin Chen

In 2014, the nuclear medicine and high-end medical devices by the fields of Radiation application at INER were focused on:

1. Diagnostic Nuclear Medicine: (1) A novel Gallium-68 radioisotope generator which is simple designed, easily operated and suitable for various hospitals and research institutes, is to provide the public better clinic diagnosis in the field of nuclear medicine and increase social welfare, also is to win an international award. (2) Developed the dissolution method of target material Y-89 stable isotope and developed a new radiofluorinated compounds TAUF1 which is a TAU protein imaging agent. (3) Colorectal cancer image reagent: The radiation signal of In-111-labeled sulfonamide derivatives were significantly increased in HCT-15-induced xenografts tumor proved that CA9 was a potential CRC serum biomarker for diagnosing CA9 expression in CRC clinical practice. (4) Development of PLGA biodegradable and multifunctional microspheres: From animal data shown, this is a potential drug for liver therapy. (5) Alzheimer's disease image agent: establishment of silico virtual screening techniques for new drug, two candidate chemicals have been proven to penetrate BBB and bind to amyloid plaque by in vitro test.
2. Targeted Therapeutic Nuclear Medicine: (1) Passive targeted therapeutic drug: phase 1 clinical trial of Re-188 liposome in treatment of metastatic late stage patients has been approved by TFDA and IRB at VGHTPE. The Phase I clinical trial of Rhenium-188-Liposome is ongoing at Veteran General Hospital-Taipei. Aims of the trial are to evaluate safety, tolerance and preliminary efficacy of the therapeutic radiopharmaceutical. (2) Active targeted therapeutic drug: Possessing the bi-function of radiotherapy and chemotherapy ^{188}Re-liposome- Fcy- hEGF/5-FC has more therapeutic potential on EGFR over-expressing tumor cells. (3) Radioembolization: The CMC documents for a new drug, Re-188MN-16ET/Lipiodol for treatment of hepatoma, had written and evaluated by radiopharmaceutical production center for promoting its application for hepatoma treatment. The research team obtained Silver reward of 2014 Taipei International Invention and Market Exhibition by its unique pattern and market potential, because of the brilliant idea, and also gained the 11th National Innovation Award.
3. Service of Molecular Imaging Platform: The only radio and molecular image platform in Taiwan to provide radiation technology and molecular imaging services, more importantly, the platform collaborated with NRPB projects helps local institutes and universities for the development of novel drugs. With the assistance of this platform, The goal of this platform is promoting potential new drug to acquire TFDA approval and enter clinical trial in a shortest period and become a global molecular imaging and drug development leader at the same time.
4. Radiopharmaceutical Linker Synthesis and Analytical Techniques: (1)An Improved Synthesis of di-Boc-NOTA-Bz as bifunctional chelating agents to serve for imaging agent for PET is develpoed. (2)The metabolites of

F-18-Flumazenil (^{18}F-FMZ), the PET imaging agent for GABA receptor in the CNS, there were 2 metabolites resulting from hydrolyzed of ethyl group of FMZ in rat in both of hepatic microsome and liver homogenate enzyme system were identified.

5. Novel Nano In Vitro Diagnostics(IVD): The effectiveness of Co-60 irradiated modification of Nano IVD for detecting EB virus, with features of easy to use, rapid and low detection limits, has been verified by analysis of 50 healthy subject's and 50 patient's samples from Mackay Memorial Hospital. The Nano IVD can be used to detect EB virus titer with cancer risk assessment, the sensitivity is 0.88 and specificity is 0.84.
6. High-end Medical Imaging Devices and 3D tomoDR Technology: Key technologies for molecular imaging devices and 3D tomo-DR are developed, including the researches of high-speed medical image processing, solid-state photonics imaging probes, limited angle 3D reconstruction of low-dose imaging, radiology instrumentation, radiology device testing, and medical radition dose evaluation. Establishment of these techs is to fulfill the need of developing new and world-wide competitive radiation-based medical imaging devices. The most important goal of this project is to lead / help local industries to step in the area of medical imaging devices and to build their own high c/p value products.

In 2013, the fields of Radiation application at INER have got great achievements research achievements including 28 patents, 31 journal papers, 92 international conference papers and internal reports. The purpose of our research was to establish the commercial technology of local nuclear medicine in Taiwan to cost down medication and to maintain the health welfare of our countrymen.

The strategies of the new drug development for radiation application research were to cooperated with private companies, academic or research institutions and medical centers for the purpose to coordinate with government policy for mutually beneficials, the expansion effects of the research and development, and professional integration, development drugs with commercial potential and value to accelerate the development of health care. We focused on the development of diagnostic drugs for hepato-cellular carcinoma, lung cancer, neuroblastoma cell tumors and center neurological diseases this year. In the future, the research and development will actively promote not only the clinical application of the drugs, but also extend research directions toward more innovative drugs.

For the high-end medical devices R&D team, lots of high techs were involved in developing practical radiation application technologies, such as semiconductor-photosensor-based image detectors, physical models and algorithms of imaging system, and Co-60 irradiated medical devices. With the developed patentable technologies and the established platform for high-end medical device development, the aim is to cooperate with the existing/developing domestic industrial chain and achieve commercialization in the future.

Both of the new drugs and medical devices development of the fieblsare not only upgrade the nuclear medicine industry in Taiwan, but also safeguard the health of citizens. Integrated the sub-development technology continues to visit and exchange medical and potential vendors, combined with the institute and university, to develop a prototype system-wide cooperation and technology into the spindle, helping domestic medical imaging equipment timber industry thrive. Moreover, promote the local biotechnolgy developments in Taiwan to compete international market competition.

4-3-1 The Research and Development of Nuclear Medicine and Medical Instrument and Apparatus Application

4-3-1-1 Cyclotron Produced New Radioisotopes for Generator Research and Development

Jenn-Tzong Chen

The Application for New Generator Isotope Produced by Cyclotron and Application project has successfully applied the process optimization model developed in the subproject to the mother radionuclide production process. Mother radionuclide of Ge-68/Ga-68 generator is produced from the proton irradiating on target. The high energy proton is accelerated from 27keV of the ion source of TR30/15 cyclotron up to 30MeV, mother radionuclide Ge-68 is produced after proton irradiating. Daughter radionuclide Ga-68 generated from the mother nuclide can be produced in the PET centers without cyclotron or related facilities nearby. Ga-68 generator is composed of a generating column and citrate salt eluent. The generating column includes part of packed ion exchange resin with glucose and amino function group bonded in order to adsorb and desorb Ge-68 and Ga-68 radionuclide. Ga-68 product is desorbed from the column by adding citrate salt as the eluent. This optimized process modeling honored received the Nurnberg IENA gold medal award 2014.

In the non-generated cyclotron produced radioisotope studies, we developed the target material of Zr-89, stable isotope Y-89 preparation method. This preparation method can successfully transforms Y-89 metal into solution. Solution form of Y-89 is the base of the target material of Zr-89 prepared by electro deposition or plating technique. Zr-89 is a worldwide newly developed PET radioisotope, with 3 days half-life represents an ideally immuno-PET nuclide for imaging studying monoclonal antibodies labelled Zr-89 accumulation and biodistribution. Y-89 is the only stable isotope of all Yttrium isotopes. The average positron emission energy is 396.9keV, its translational energy is lower than fluorine-18, therefore provides higher resolution imaging property, is one of the ideal PET radionuclide for immune-PET imaging.

In radioisotope application studies, fluorine-18 produced from liquid target system has been successfully applied in some radiofluorination reaction studies. One of the new radiofluorinated compounds is TAUF1 which is a TAU protein imaging agent. [F-18]TAUF1 is founded to cross blood brain barrier in normal mouse. In brain tumor mice model imaging studies, the uptake of [F-18]TAUF1 in brain is higher than normal mice. We also found in the same model, [F-18]TAUF1 uptake is higher than [F-18]FLT and [F-18]FET. [F-18]TAUF1 imaging studies in Alzheimer's disease transgenic mice model, will be undertaken next year.

The research and development of cyclotron produced radioisotope honored won an internal award on Ga-68 generator optimization model. Discovered an new radiofluorinated molecular TAUF1 with brain TAU protein imaging ability, and the development of Y-89 liquid form heralds the advent of immuno-PET isotope Zr-89 in Taiwan.

1. A Novel Gallium-68 Radioisotope Generator

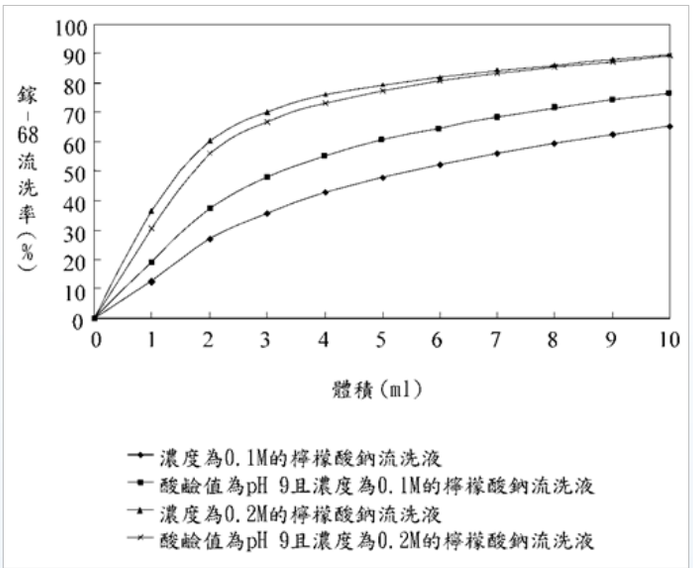
Ming-Hsin Li

In recent years, gallium-68 generator to flourish in the international market, and are subject to drug researchers and clinicians attention, particularly the use of radioactive elements in the biochemical markers (radiolabelling). Due to the emergence of small peptide molecules, raise interest in this kind of gallium-68 nucleus, its half-life (77.7 minutes) shorter for these peptides pharmacokinetics, and reduce patient radiation

problems. In addition, trivalent metal ions and gallium-68 easy with DOTA peptide conjugates of derivatives make direct radiolabeled reactions.

In summary, a Ga-68 radioisotope generator and a method applied in the same in accordance with the present invention are characterized by the use of an organic resin (i.e. ion-exchange resin with glucamine groups) and its selective absorption for Ga-68 in comparison with Ge-68 to generate Ga-68 nuclide. In combination with a citrate eluent, it can prevent the formation of metal ion liquid waste in the reaction so as to reduce potential environmental pollution threats effectively. In addition, the Ga-68 radioisotope in the form of Ga-68 citrate can be transformed into that in the form of Ga-68 hydrochloride, which is more generally used, by combining the generator with a transforming column. It prevents further complication to users from the non-regular product. The apparatus in accordance with the present invention is simple designed, easily operated and suitable for various hospitals and research institutes to provide the public better clinic diagnosis in the field of nuclear medicine and increase social welfare.

▲ Gallium-68 Radioisotope Generator



▲ elutriation rate of Ga-68(%)

4-3-1-2 The Status of New Diagnostic Molecular Imaging Agents Development at INER

Tsai-Yueh Luo

Depending on the clinical applications, radiopharmaceuticals can be divided into two categories, diagnostic and therapeutic one. The major characteristics of diagnostic radiopharmaceutical are combining the usage of SPECT (or PET) and the emission of gamma ray from radioisotope to get the distribution image in the body for disease diagnosis. In order to extend the research in this field and raise the medical quality in Taiwan, it is researcher's obligation to develop the competitive and new potential radioisotopes and radiopharmaceuticals for the diagnosis and therapy of local diseases.

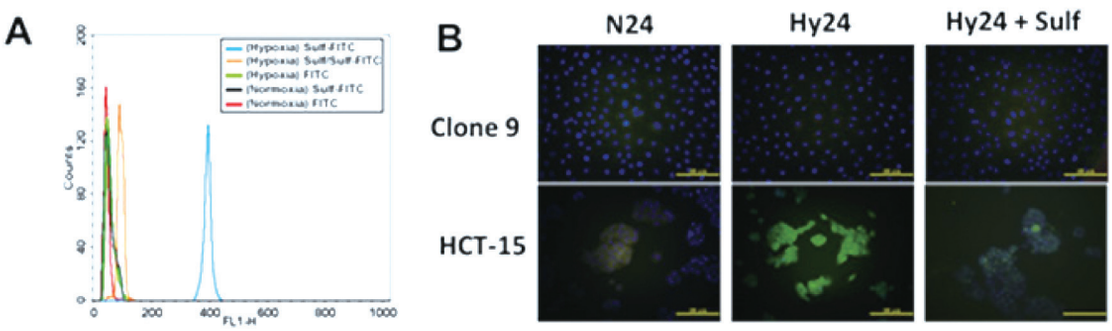
Colorectal cancer (CRC) is known as a common malignant neoplasm worldwide. Carbonic anhydrase IX (CA9) was considered to be one of the best cellular biomarkers of hypoxia. CA9 inhibitor was proven to reduce tumor growth. We initiated a study to establish radio-isotope labeling with sulfonamide derivatives (CA9 inhibitor) and evaluate its potential as a tumor biomarker. The signal of 111In-labeled sulfonamide derivatives were significantly increased in HCT-15-induced xenografts tumor site as compared with control groups. We considered that CA9 was a potential CRC serum biomarker for diagnosing CA9 expression in CRC clinical practice. PLGA (poly-lactic-co-glycolic acid) was chosen as the material to make the biodegradable microsphere. We established the microsphere manufacturing and analytical techniques. 111In (90Y)-PLGA- microsphere were evaluated in hepatoma rat model via transarterial embolization. Preliminary animal data showed the potential as a therapeutic agent for liver cancer. Virtual screening not only provides valuable insight in which amyloid imaging tracers bind to the fibril, but also opens new opportunities for drug design. In this year, we established in silico virtual screening techniques and applied in the new drug development for Alzheimer's disease.

1. Tumor Hypoxia Imaging Agent 111In-Labeled Sulfonamide for Diagnosing Tumor Hypoxia in Colorectal Cancer in HCT-15-Induced Xenografts

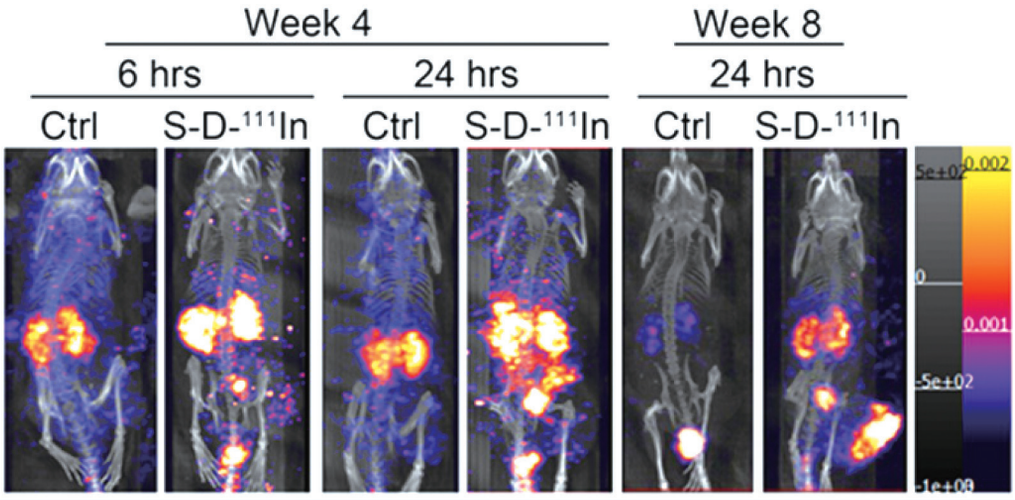
Shiau-Shiun Guan , Chun-Chia Cheng

Colorectal cancer (CRC) is known as a common malignant neoplasm worldwide. Epidemiological studies have showed that the incidence of colorectal cancer is increasing over the past several decades. Therefore, an early and accurate diagnosis of colorectal tumor is urgent to increase the therapeutic effects and survival rate. Hypoxic microenvironement is the common situation in solid tumors, including CRC. In addition, Carbonic anhydrase IX (CA9) participated in a variety of biological processes, including pH regulation, cell adhesion, proliferation and transformation, and considered to be one of the best cellular biomarkers of hypoxia. Studies have indicated that CA9 inhibitor such as sulfonamide can block CA9 activation, and hence reduce tumor growth consequently. Therefore, we aimed to detect the expression of CA9 in serum and tumor of different stage of CRC patients and utilize sulfonamide derivatives as a probe with 111In labeling for CRC nuclear medical detection in vivo. First, CA9 expressional levels were detected in the collected sera and tissues of patients with CRC to evaluate CA9 as a reliable biomarker of CRC. Results revealed that serological CA9 were correlated with the tissue CA9 levels in colorectal patients as an overexpressed biomarker. We further found that the expression level of CA9 in tumor was correlated with the stage of CRC. Moreover, the in vitro assay showed that the cell viability of colorectal cancer cell (HCT-15) were increased and induced CA9 overexpression in hypoxia condition (24 and 48 hrs). Then, we confirm the interaction between sulfonamide derivatives and CA9 in vitro under hypoxic condition by using the flow cytometry and mass spectrometry assays. In order to detect the hypoxic distribution in CRC animals, the hypoxic reagent was injected into HCT-15-induced tumor

xenografts for in vivo fluorescent imaging detection. The result revealed that hypoxic signaling significantly accumulated in tumor area. The distributions of hypoxia in several organs of HCT-15-induced xenografts were also detected. Tumor tissue possessed higher fluorescence signal as compared with other organs. Finally, the 111In-labeled sulfonamide derivatives were utilized for CRC detection in HCT-15-induced xenografts. The radioisotope signaling was significantly increased in tumor site as compared with control groups. In conclusion, we considered that CA9 was a potential CRC biomarker, and suggested that measurement of serum CA9 can be a potential tool for diagnosing CA9 expression in CRC clinical practice. In addition, the radioisotope-labeled sulfonamide derivatives may be applied in nuclear medicine imaging for diagnosing tumor hypoxia of CRC patients in order to improve the radiotherapy efficiency and to overcome the side-effects derived from radiotherapy.



▲ Sulfonamide-FITC interacted with CA9 in hypoxic HCT-15 cells. (A) Sulfonamide labeled with fluorescent FITC was used to bind to HCT-15 cells detected using flow cytometric assay. The results indicated that Sulfonamide-FITC bound to hypoxic HCT-15 cells which overexpressed CA9 protein. (B) Sulfonamide binding assay was used to observe that sulfonamide bound to CA9-overexpressed HCT-15 cells using a fluorescence microscopy. The results revealed that sulfonamide specifically bound to HCT-15 cells in hypoxia for 24h (Hy24) compared to the cells incubated in normaxia for 24h (N24). Hy24+sulf, cells in hypoxia for 24h treated with both sulfonamide-FITC and sulfonamide.



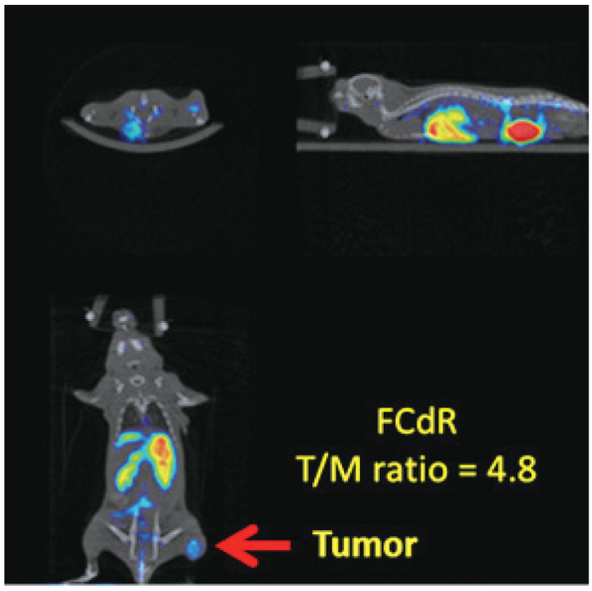
▲ The detection of tumor hypoxia in HCT-15-induced tumor xenografts using nuclear imaging technique. HCT-15 cells (2×106) were subcutaneously inoculated into the right flank of nude mice for 4 week and 8 week to establish a CRC xenograft model. The sulfonamide (sulf)-DTPA-111In was injected into mice for 6 and 24 hrs and the tumor hypoxia was detected by using a Nano-single photon emission computed tomography/computed tomography (NanoSPECT/CT). DTPA-111In was used as a control reagent. The result demonstrated that the tumor hypoxia imaging agent S-D-111In accumulated in bigger tumor induced for 8 weeks with higher CA9 expression compared to smaller tumor induced for 4 weeks, indicating that this agent was reliable for diagnosing tumor hypoxia.

4-3-1-3 The Development of Radiolabeled Imaging Agent for Lung Cancer

Yu, Hung-Wen

1. Evaluation of Radiofluorinated Nucleoside ^{18}F-FCdR as A Proliferation Imaging Probe in A Lung Tumor Xenografts

This study aims to evaluate a novel radioiofluorinated thymidine analog ^{18}F-FCdR as a probe for imaging tumor in LL/2 lung carcinoma-bearing mouse model. FCdR was labeled with F-18 and was prepared in high radiochemical purity (>95%). Biological characterization studies of ^{18}F-FCdR including PET/CT imaging were performed. The results of PET/CT imaging indicated that ^{18}F-FCdR clearly delineated the tumor lesion in LL/2 lung carcinoma-bearing mouse with tumor-to-muscle ratio of 4.8 at 1.5 h post injection (Figure 1). In this study, the radioiodinated ^{18}F-FCdR was successfully prepared with high radiochemical purity. ^{18}F-FCdR was highly accumulated in the tumors and is demonstrated as a potential radio-probe for clinical tumor imaging.



▲ The PET/CT image of mice bearing LL/2 lung carcinoma after injection of ^{18}F-FCdR.

4-3-1-4 Radiopharmaceutical Synthesis and Analytical Techniques Research and Application

Chen, Wei-Hsi

Owing to the community pace is faster and faster, living stress of the people is increasing, and also the trend of population is aging in Taiwan, resulting in the central nervous system (CNS) symptoms case is increasing quickly. In order to diagnosis of the CNS disorder correctly using positron emission tomography (PET), it was estimated 3.74% for the annual growth rate in 2015~2016 of PET market demand. It is an important issue to develop new PET imaging agents to supply the medicine requirement. In 2014, we had designed and synthesized a new macrocyclic amino-tricarboxylic acid linker: NOTA derivative, which was labeled with positron nuclide, F-18, after coordinated to aluminum, furthermore carboxylic acid group coupled with the target peptide to serve for imaging agent for PET. Compared with other analogue compounds, the important breakthrough was that both of the carboxylic acids were protected and only one retained the ability to couple with amine or alcohol group in the target bioactive molecule selectively. The procedures to synthesize NOTA ligand linker had been set up and the product was characterized. On the other hand, the metabolites of F-18-Flumazenil (^{18}F-FMZ), the PET imaging agent for GABA receptor in the CNS, in both of hepatic enzyme system (rat liver microsome and liver homogenate) were identified. The results showed that there were 2 metabolites resulting from hydrolyzed of ethyl group of FMZ in rat liver microsome biosystem. But there was only 1 metabolite in rat liver homogenate which was methyl transesterization product of FMZ.

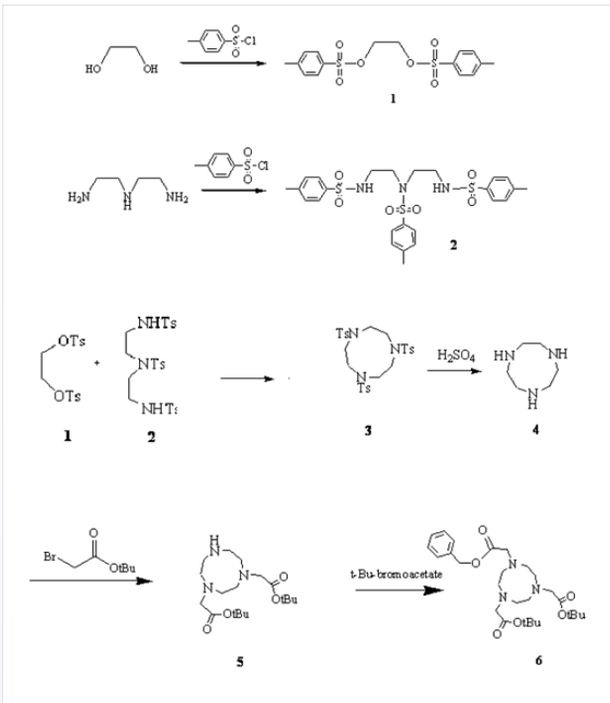
1. An Improved Synthesis of di-Boc-NOTA-Bz as Bifunctional Chelating Agents

Lin, Sheng-Lun; Chang, Yu

Recently, aluminum-fluorine bonded labeling among non-carbon-fluorine type has been attracted much attention, and lot of research for the coupling of 1,4,7- triazacyclononane- 1,4,7-triacetic acid (NOTA) and Al-18F have approached, such as NOTA is first binded peptide molecule, then labeled with Al-^{18}F to test image and biodistribution in vivo, simultaneously, the labeling efficiency with different substituted NOTA derivatives for Al-18F were compared.

To employ the binding identity of NOTA with Al-18F, we could design the coupling of NOTA derivative and molecule with bioactive side chain to yield the potent bioactive molecule, then labeled with Al-^{18}F for further imaging test. Due to non-selective protection reaction for three carboxylic group, the coupling reaction of NOTA derivative and bioactive molecule would obtain many of side, causing low yield, complexity in experiment and high cost. If we could first protect two carboxylic group, the other naked carboxylic group would easily and selectively bind to amino group and alcohol.

About the synthetic method and characterization of 1,4,7-triazacyclononane-1,4- dicarboxylic acid di-tert-butyl ester-7- benzyloxycarbonyl as bifunctional chelating agents. First, diethylenetriamine was protected with tosyl chloride to afford N,N′,N″-tris(p-toluenesulfonyl)-diethylenetriamine 2. Then 2 was reacted with 1,2-bis(p-toluenesulfonyl)-1,2-ethanediol 1 also protected with tosyl group, and cesium carbonate as base to form 1,4,7-tris(p-toluenesulfonyl)-1,4,7- triazacyclononane 3. The Ts protection of 3 was removed under concentrated sulfuric acid, to produce the desired product 1,4,7-triazacyclononane 4. The synthesis of Bis-t-butyl NOTA 5 was undertaken by coupling of 1,4,7-triaza- cyclononane 4 and tert-butyl bromoacetate. The substitution reaction of compound 5 was performed by using benzyl-2-bromoacetate to afford the final product di-Boc-NOTA-Bz 6. All of the above compounds were characterized by NMR and mass spectra.



▲ Synthetic Pathway of di-Boc-NOTA-Bz 6 as Bifunctional Chelating Agents

4-3-1-5 Development of Key Technologies of Advanced Clinical Nuclear Imaging Instruments

Hsin-Chin Liang

The project includes two sub-terms of work, which are "Development of high-performance medical image processing technology", "Development of solid-state photonic imaging probe technology". Based on INER's radiation imaging technologies, nuclear imaging technologies are applied to healthcare and livelihood use through the project, to meet the national biotech policy and the needs of domestic ICT industries. In the project practical and commercialization capable radiation applied technologies, such as high-speed image processing calculations and solid-state photonic imaging probes are developed. With the developed patentable technologies and the established high-end medical device development platform, it is expected to facilitate the domestic industry and to achieve commercialization of the project outputs. The main achievements in 2014 are depicted as follows.

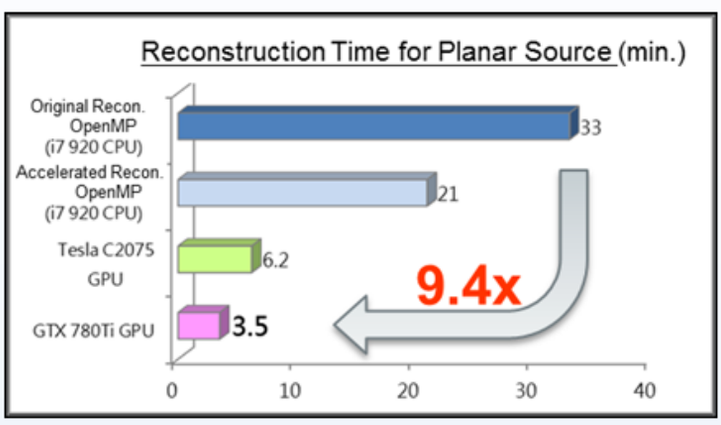
1. Research of High Performance Medical Image Processes: Acceleration of Iterative Reconstruction for Symmetric-Oblique-Detector PET System

Yu-Ching Ni

Recently, improvements of medical images rely on advances of image reconstruction techniques, and there is a tendency to combine accurate corrections and system physical models together. According to the devices and medical image processes, system-specific properties can be found with various corrections and modeling methods. However, due to the complexity of the heavy processing and time-consuming computations, high performance image processing has become a crucial solution to achieve high quality medical imaging.

To solve the computation issue caused by the unique geometry and interactive calculations, we developed a dedicated high performance reconstruction algorithm for the Symmetric-Oblique-Detector PET system. By addressing performance bottlenecks and adapting the reconstruction process to massive parallel computing, the reconstruction algorithm was modified and implemented for acceleration. With verification on different data sets, it was confirmed that our method can efficiently increase the system performance on image reconstruction.

The results show the reconstruction time of a plane source. For the most time-consuming case, the computation time could be reduced form 33 minutes to 3.5 minutes, which is about 9.4 times faster. The example shows our up-to-date result of our researches for high performance medical image processes. Further researches for improving the accuracy and performance on radiography and medical image processes are still on-going, for providing a reasonable image quality and processing time in clinical use.



▲ The test results show that the reconstruction time for planar source. In the most time-consuming case, the computation time could be reduced form 33 minutes to 3.5 minutes, which is about 9.4 times faster.

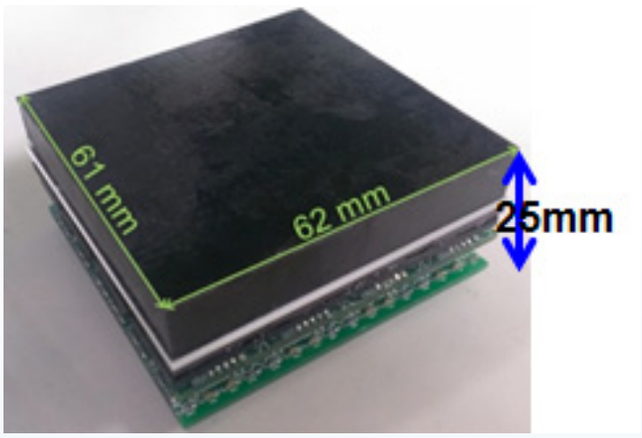
2. Research of Key Techniques of Solid-State Photonic Imaging Probes

Hsin-Chin Liang

Nuclear imaging devices have been showing their market potential recently. In order to fulfill the market demands of next-generation products, a new imaging detector is necessary. The advantages with compact, low-power consumption, and magnetic-insensitive of the solid-state photonic devices make the imaging detector technology base on them an essential key for developing the advanced nuclear imaging devices. In this project, the mature PMT-based technology and results from basic researches on solid-state photonic elements were integrated to establish our own solid-state imaging probe technology, and also the key points to improve the performance specifications were researched, to lay the foundation for the successful development of medical imaging devices.

The most important technical progress this year (2014) is successfully establishing the technique of continuous-expansion imaging area and improvement of the front-end signal processing speed. With the technology development and integration, a solid-state photonic imaging detector with an effective area larger than 2×2 inch-square (actual area of 38 cm2, the industrial regular need is meet!) was successfully developed. The pixel size of the detector can reach 1.6 mm or smaller, which shows its competitiveness for the development of mature commodity. The technical results this year were contributed to the imaging detector fabrication and micro-current pulse signal operation, which are essential basic abilities for developing imaging scanner of a new-generation nuclear imaging device.

Through the results, the establishment of signal manipulation techniques for the solid-state photonic devices was presented. To achieve the tech-necessaries for developing commercialization-competitive scanners, dead-gap-less packages and miniaturization/high-density electronics are essential engineering issues. Therefore, further improvements on the optical manipulation techniques and research on parallel high-density electronics are required. It is expected that the complete solid-state photonic devices based imaging detector technology makes our team capable of developing the world-wide competitive, new-generation molecular imaging devices.



▲ The latest developed solid-state photonic devices based imaging detector, with an effective area of 38 cm2 and pixel size of 1.6 mm.

4-3-2 Development of Nano Diagnostic and Therapeutic Radiopharmaceutical Technology and Their Applications

Te-Wei Lee , Shu-Pei Chiu , Wei-Chuan Hsu , Chih-Hsien Chang , Po-Yen Liu , Kuan-Yin Chen

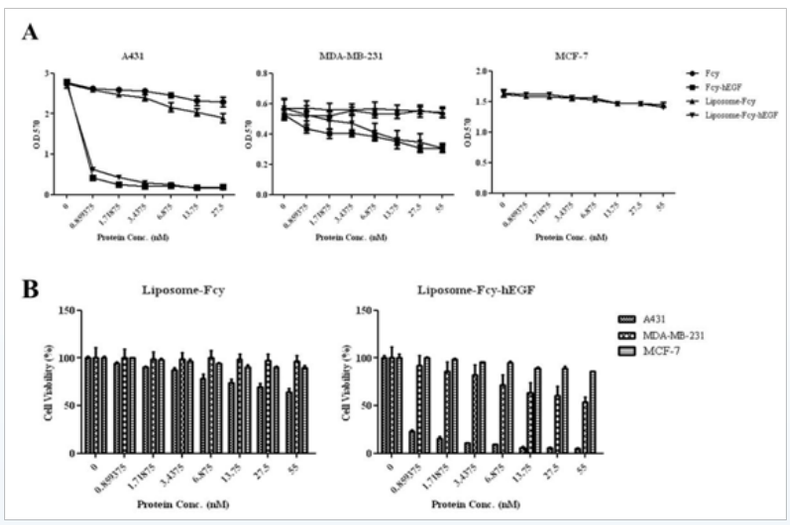
1. Foreword

The Project, entitled "development of nano diagnostic and therapeutic radiopharmaceutical technology and their applications" covers three main topics, including (1) nano diagnostic radiopharmaceuticals (2) nano therapeutic radiopharmaceutical (3) carbon nano tubes as early phase NPC diagnostics. The aim of this project is to develop a new therapeutic or diagnostic nuclear medicine, and in order to reach clinical trials. And meet the requirements of cancer therapy; fulfill the applications of nuclear energy in human health care.

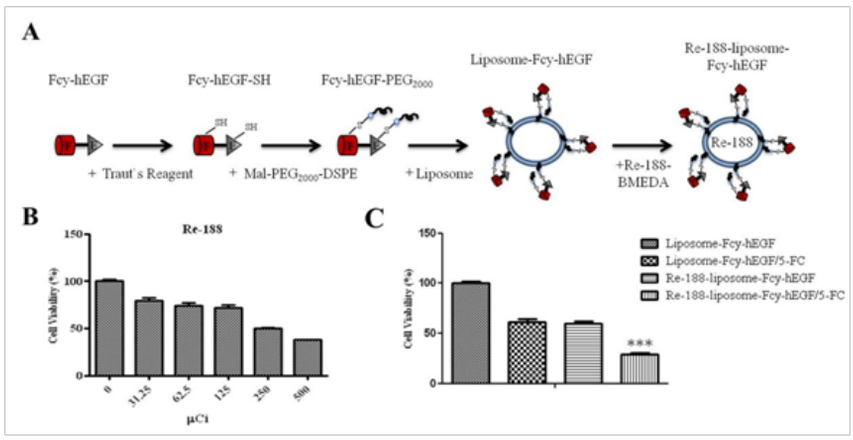
2. Achievement

(1) Development of Novel Targeted Radio-Nano-Liposome for Cancer Therapy and Diagnosis

The yeast cytosine deaminase fused with human EGF (Fcy-hEGF) combined with 5-fluorocytosine (5-FC), Fcy-hEGF/5-FC, prodrug system had been demonstrated that an EGFR-bound Fcy localizes to tumor tissue, where it selectively converts 5-FC to a 1000-fold more toxic chemodrug, 5-FU to inhibit the growth of cancer cells. The purpose of this study is exploring combination of radiotherapy and chemotherapy by incorporating this Fcy-EGF/5-FC prodrug system and Rhenium-188 (^{188}Re) with liposome for diagnosis and treatment of EGFR-overexpressing cancers. Liposome-Fcy-hEGF/5-FC can preferentially suppress the viability of EGFR-overexpressing cancer cells. Moreover, the ^{188}Re-Liposome-Fcy-hEGF/5-FC reveals a better cytotoxic effect for cancer cells than the treatment of liposome-Fcy-hEGF/5-FC or ^{188}Re-liposome-Fcy-hEGF alone. We have selected a potential EGFR-overexpressing cancer radio- and chemo-therapeutic or diagnosis drug successfully and the further pre-clinical animal studies will be performed recently.



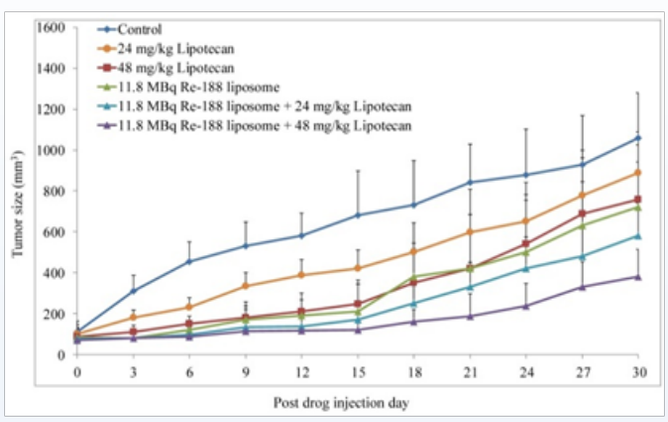
▲ Cytotoxicity of liposome-Fcy-hEGF/5-FC and liposome-Fcy/5-FC. The results showed that liposome-Fcy-hEGF specifically inhibits the viability of A431 cells, which is EGFR-overexpressing cancer cell line (A, B).



▲ Schematic diagram of conjugation of ^{188}Re -liposome-Fcy-hEGF (A). Cytotoxicity of ^{188}Re for A431 cells is dose-dependant manner (B). Cytotoxicity of ^{188}Re-liposome-Fcy-hEGF/5-FC for A431 cells. The results showed that ^{188}Re-liposome-Fcy-hEGF/5-FC has significant cytotoxic effect than the treatment of liposome-Fcy-hEGF/5-FC or ^{188}Re-liposome-Fcy-hEGF alone (C). ***, P <0.005.

(2) Preclinical Studies of ^{188}Re-liposome and Lipotecan in Combination Cancer Therapy

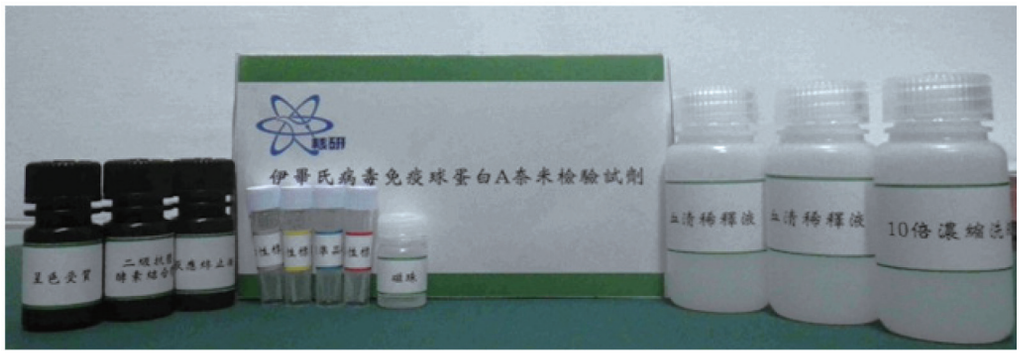
Lipotecan (TLC388), a synthetic analogue of camptothecin with potential antineoplastic and radiosensitizing activities. Lipotecan has been considered having not only the antineoplastic property but also as a radiosensitizer. Thus, we proposed that the combination of Lipotecan and ^{188}Re-liposomes will enhance the therapeutic effect. The Huh-7 subcutaneous transplantation tumor animal model was established to evaluate the antitumor activity of ^{188}Re-liposome combined with Lipotecan (^{188}Re-liposome + Lipotecan) treatment compared with monotherapy (^{188}Re- liposome or Lipotecan). Mice were administered via intravenous injection with ^{188}Re-liposome (11.8 MBq, 2/5 maximum tolerated dose (MTD), Lipotecan (48 mg/kg, 2/5MTD) and normal saline as blank control. To evaluate the targeting and localization of ^{188}Re-liposome in Huh-7 tumor-bearing mice, biodistribution was performed. Tumor growth and body weight were measured to evaluate the antitumor effect. After intravenous administration of ^{188}Re-liposome, radioactivity in tumors was 5.03±0.21 %ID/g at 24 h, the tumor/muscle ratios is 15.71±0.56 at 24 h. In the study on therapeutic efficacy, the tumor-bearing mice treated with ^{188}Re-liposome + Lipotecan group showed better mean tumor growth inhibition rate (MGI=0.36, n=6) than those treated with radiotherapeutics of ^{188}Re-liposome (MGI=0.681, n=6) and chemotherapeutics of Lipotecan (MGI=0.717, n=6). The synergistic tumor regression effect was observed with the combination index (CI) exceeding 1 (CI=1.36) for combination therapy. These results suggest that Lipotecan may be usefully integrated into the ^{188}Re-liposome treatment of Huh-7 tumors, with potential benefits resulting from increased tumor cell radiosensitization.



▲ Therapeutic curves for Huh-7 subcutaneous tumor animal model after administering of drugs by i.v. injection

(3) Development of an IVD for EBV Clinical Diagnosis by INER

The development of In Vitro Diagnostics (IVD) improves enormously with advanced modern medicine. By non-invasive tests, doctors read the diagnostic data soon and the related risks will decrease. Epstein-Barr virus (EBV) is a human herpesvirus and strongly associated with development of nasopharyngeal carcinoma (NPC). Over the years, Institute of Nuclear Energy Research (INER) combines the Carbon Nanotubes (CNTs) modified with carboxyl group and Fe3O4 on the surface by Co-60 irradiation as a substrate and diagnosis techniques to develop in vitro diagnostic kit. We use the antigen-coated CNTs to react with IgA antibody in serum sample with the Enzyme Immunoassay, radioimmunoassay or chemiluminescence Immunoassay for evaluating the cancer risk of Nasopharyngeal Carcinoma. The patent "Preparation of magnetic CNTs with irradiation" was approved by R.O.C and the patents "Quantitative analysis of a functional group on the surface of a solid material" were approved the U.S. and R.O.C. We also cooperated with Otolaryngology, Pathology and Hematology departments of Mackay Memorial Hospital for in vitro diagnosis. We collected the clinical specimen of healthy person and patient for examination by our kit. The test results indicated that the sensitivity is 0.88 and the specificity is 0.84. Furthermore, General Biologicals Corporation (GBC) executed a MOU (Memorandum of Understanding) with INER. This kit has many advantages like rapid, convenient and low detection limit are benefit for early detection of Nasopharyngeal Carcinoma and track the therapy in patients. This project is expected for developing more diverse test reagent with the purpose of promoting the qualities of life.



▲ EB virus in vitro diagnostic kit of magnetic CNTs.

▲ The R.O.C patent "Preparation of magnetic CNTs with irradiation" and the U.S. and R.O.C patents "Quantitative analysis of a functional group on the surface of a solid material".

	INER	Commercial product 1	Commercial product 2
AUC	0.92	0.91	0.92
Sensitivity	0.88	0.88	0.96
Specificity	0.84	0.8	0.8

▲ Comparing the clinical sensitivity and specificity of different EB virus diagnostic kits.

3.Prospect

The purpose of this project is to develop nano-radiopharmaceutical from bench to beside. Currently, the clinical trials of "^{188}Re-Liposome for internal radiotherapy drug" are proceeding. ^{188}Re-Liposome is the first nanotargeted radiotherapeutic drug for cancer translated into the human clinical trials in the world. We have finished Phase 0 trial in 2013 and Phase I trial is ongoing. "EBV IgA detection kit" was compared with commercial products and based on the results to improve process. We expect the development of "INER Rhenium-188-Liposome Injection" will have contributions in enhancing the health quality of people in Taiwan.

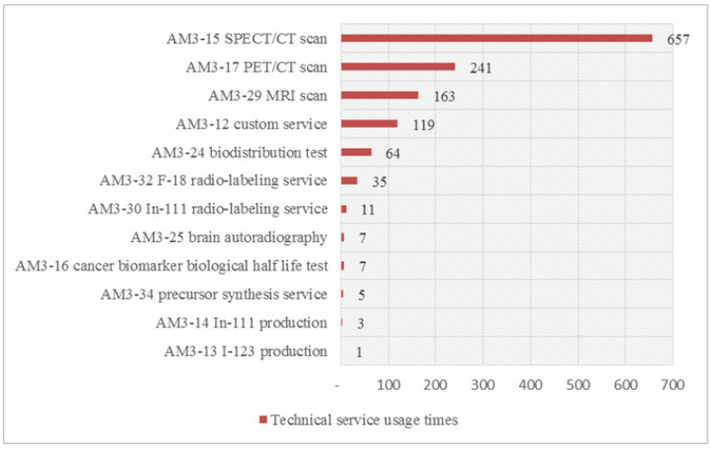
4-3-3 Business Operation of Radiation Applications and Molecular Imaging Platform

Wang, Mei-Hui

The business operation of radiation applications and molecular image platform in 2014 has been the third year of a five-year National Research Program for Biopharmaceuticals. Therefore, we evaluated the fueling engine of biotechnology and pharmaceuticals by analyzing the industrial value chain. Based on the analysis report on the trend of biotechnology in US from the past 60 years, the driving force of biotechnology growth has been focused on innovation drug and new indication. In our platform, we combined the niche of academics and the core technique of platform, which promoted the development of new drugs. In the core service of the platform, high efficiency of the innovative process allows the release of manpower to the new market innovation.

The accomplishment highlights in this year were presented in various aspects. First were the applications of nanoSPECT/PET/CT/MR integration system, especially on lung tumor and hepatoma research. Moreover, in the cooperation of NHRI, we fulfilled the F18 radio-labeling, purification and purity analysis of cannabinoids, and further examined the molecular image, bio-distribution quantification, and pharmacokinetic in vivo by using nanoPET/MR integration system. With special academic status and research innovation, we developed the method of F18 radio-labeling in steroid, which hasn't been published in scientific study. Based on this new developed technique, we successfully finished the molecular image, bio-distribution quantification, and pharmacokinetic test on steroid drug in the cooperation of TMU. Through establishing the optimized MRI pulse sequence of normal rat brain, we studied the effect of long-term light or dark cycle on the expression of serotonin transporter and receptor in molecular image and won the oral and poster prize in 2013 and 2014 annual meeting of SNM in Taiwan, respectively. In cooperation with ITRI and NTU, the peptides for bone regeneration and nasopharyngeal carcinoma targeting were studied on their bio-distribution and pharmacokinetics. Among them, the research of the peptide on nasopharyngeal carcinoma targeting won the first poster prize of annual meeting of SNM in Taiwan.

We will focus on the significant disease with regional predilection in Asia and strengthen the international competitiveness through playing an enthusiastic role in the integration and cooperation of the upper, middle and lower stream of biotechnology. Moreover, we exploit the "all Taiwan brain" advantages and opportunities of NRPB to screen and assist the development of potential new drugs. The goal of this platform is promoting potential new drug to acquire TFDA approval and enter clinical trial in a shortest period and become a global molecular imaging and drug development leader at the same time. Following the remarkable increase of peptides with tumor targeting property, our platform will develop the core technique of precursor synthesis and radio-labeling for tumor-targeting molecule to meet the requirement and commit to assist the development of drugs into clinical trials. This platform will base on the established software, hardware and facilities of radiation applications and professional team cultivated by INER to maximize the benefits for each "research group", "pre-clinical group" and "clinical group" and supply the service of radiation application in biotechnology and pharmaceutical which is still lacking in our country.



▲ The amount of the distribution of technical services over the years

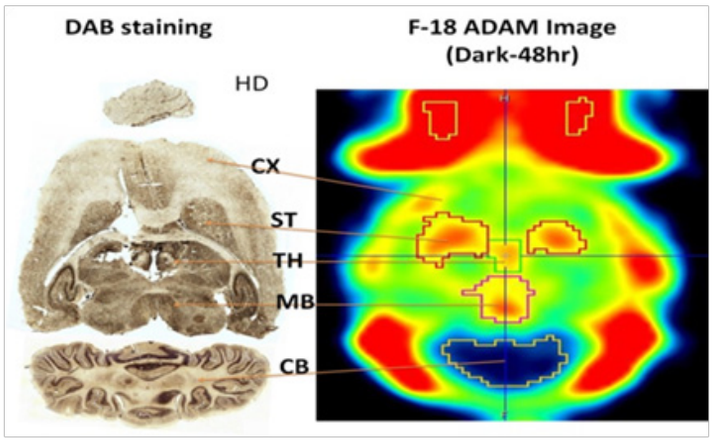
4-3-3-1 The Biodistribution Study of F-18-ADAM

Chien, Chuan-Yi

Serotonin transporter (SERT) is crucial in management of patients with major depression. It also reported to be related to daily rhythm with higher uptake in dark phase than light phase. N, N-dimethyl-2-(2-amino-4-[^{18}F] fluorophenylthio) benzylamine (i.e. 4-[^{18}F]-ADAM) has been served as a SERT specific PET radioligand. The study was undertaken to observe changes of SERT activity in different brain regions including the Harderian gland after periods of dark and light on status using 4-[^{18}F]-ADAM PET.

Twelve Sprague-Dawley rats (aged 6-8 weeks, weighted 200-250g) were raised in 48h consecutive light and dark phases (n=6 for each phase). The rats were then scanned 30min with nanoPET/CT 1hr after 1mCi of 4-[^{18}F]-ADAM intravenous injection under 5% isoflurane anesthesia. Imaging data were reconstructed and analyzed by In Vivo Scope and PMOD software and expressed as specific region-to-cerebellar uptake ratios (SURs). Immunohistochemical stain (IHS) and Western blot assay (WBA) were also applied to verify presence and quantity of SERT in corresponding brain regions. Results: Our preliminary data revealed a trend yet not statistically significant of increased 4-[^{18}F]-ADAM uptake in the striatum, thalamus and midbrain in the dark group compared to that of the light group. The averaged SURs in Harderian gland were 5.23$\pm$0.45 and 5.14$\pm$ 0.93 in the light and dark groups respectively. Results of IHS and WBA were consistent with imaging findings. However, there was no significant uptake of SERT in Harderian gland using both IHS and WBA.

The central SERT changes might be not apparently affected by daily rhythm as evaluated by 4-[^{18}F]-ADAM PET. The commonly found high uptake in the Harderian gland is more likely due to nonspecific accumulation which is also not associated with the light/dark rhythm.

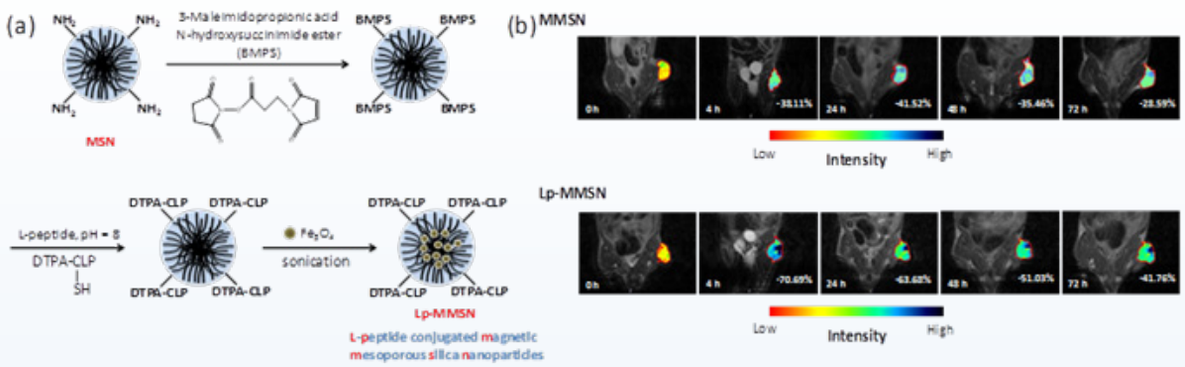


▲ SERT Distribution in Brain Region by Immunohistochemical staining and F-18 ADAM

4-3-3-2 Multifunctional Magnetic Mesoporous Silica Nanoparticles with L-peptide as a Targeted Magnetic Resonance Imaging Contrast Agent for Nasopharyngeal Carcinoma

Chen, Po-Jung

In this study, a new imaging mesoporous silica nanoparticle is reported with exceptionally excellent targeting efficiency and magnetic resonance imaging, which was constructed by embedding iron nanoparticles into porous silica, following conjugated L-peptide targeting peptides through covalent bridges (Lp-MMSN). The X-ray diffraction analysis showed the six diffraction peaks assigned to the characteristic iron oxide structure and the superconducting quantum interference device analysis showed the high correlation of magnetization. For in vivo study, the Lp-MMSN showed significant increase of MR signal at tumor site compared with pure MMSN. In MTT assays, the results showed high cell viability (over 80%) in the high concentration of Lp-MMSN, indicating a successful design of highly-cytocompatible nanoparticulate platform capable of providing cell-specific targeting and nano-imaging modalities for biomedical applications.



▲ (a) Schematic illustration of the synthesis and structure of the L-peptide conjugated magnetic mesoporous silica nanoparticles (Lp-MMSN). (b) The magnetic resonance images show the tumor boundary. Subtraction images were calculated as the 4h, 24 h, 48h and 72h post-injection image minus the pre-injection image.

4-3-4 The Developmental Status of Therapeutic Radiopharmaceutical ^{188}Re-MN-16ET/Lipiodol

Luo, Tsai-Yueh ; Kuo, Yu-Ming

The goal of this project is to develop a new therapeutic radiopharmaceutical ^{188}Re-MN-16ET/ Lipiodol and promote its application for hepatoma treatment. Rhenium-188 (^{188}Re) is an important dual-functional radioisotope for nuclear imaging and targeted radionuclide therapy. ^{188}Re has the following characteristics:(1) eluting from homemade tungsten-188 /rhenium-188 generator which can be used for up to six months; (2) emitting 155-keV gamma photon suitable for imaging; (3) decay with 2.12-MeV beta particle suitable for therapy; (4) suitable half-life (16.9 hrs.) for radiopharmaceutical research. The pre-clinical evaluation in hepatoma animal model demonstrated the potential of ^{188}Re-MN-16ET/Lipiodol in hepatoma treatment.

In 2014, we had written the CMC documents for ^{188}Re-MN-16ET/Lipiodol and evaluated by radiopharmaceutical manufacturing center. Eighteen copies of Standard operation procedures related with the manufacturing and quality-control procedures were issued and routinely used in 2014. The mass-production of GMP-graded synthetic environment for the raw material, MN-16ET, was established and regularly supplied for the following formulation study. In this year, we also establish the analytical methods to evaluate the metabolic pathway of ^{188}Re-MN16-ET/Lipiodol from the bio-specimen. The experimental results demonstrated that Re-MN-16ET dissolved in lipiodol phase could prohibit it metabolize from liver enzyme. We further identified the existence of M1and M2 metabolites in the liver specimens and drew the possible metabolic pathways. To extrapolate the radiation absorbed dose of ^{188}Re-MN-16ET/ Lipiodol from animal model to human dose is an important technique for clinical trial design. We performed the radiation dosimetry evaluation in this year which will be an important reference for the clinical dose estimation.

This project obtained Silver reward of 2014 Taipei International Invention and Market Exhibition and gained the 11th National Innovation Award in 2014. The research team have filed to center for drug evaluation for clinical trial consulting in 2014. After file review and meetings, we received many positive affirmation and recommendations. Researchers arranged three batches of the trial production which followed PIC/S-GMP norms in 2015, and the GLP radiation toxicology study will finish in the first quarter. After preparing all the files above, the clinical trial application will be filed to the Ministry of Health and Welfare in 2015.

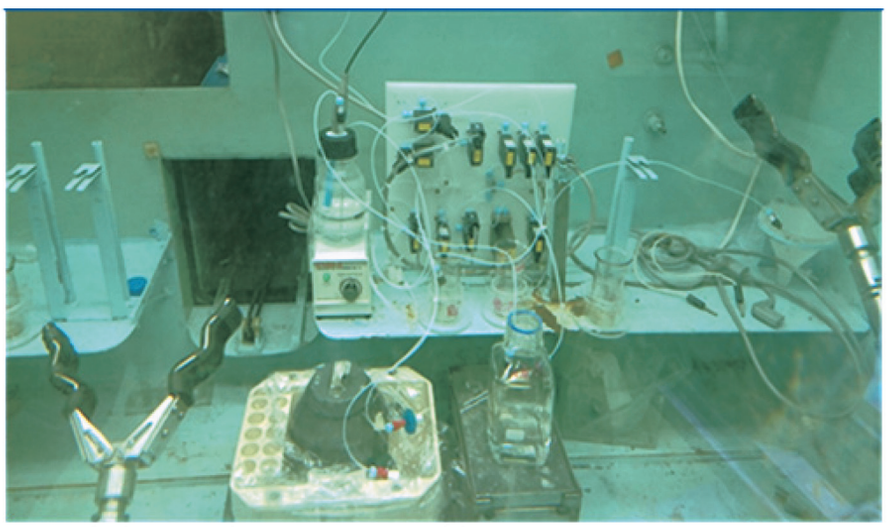
▲ The honorable rewards of 2014 Taipei international invention and market exhibition and 11th national innovation award obtained by Re-188 MN-16ET/Lipiodol project.

4-3-4-1 Establishing the Semi-automatic Preparation Technique for Tungsten-188/ Rhenium-188 Generator in Lead Cell

Tang, I-Chung

This report record generator core processes - alumina column filled and simplify the complicated job of lead chamber, completed in a single-room solution to adjust the pH value, the generator flow adsorption column wash, etc., significantly reducing the risk of the manufacturing process. After the completion of the generator can be obtained by analyzing 100% rhenium-188, metal ion levels below 10ppm, with quality similar to the old process.

This technique not only reduces the cost of development of the generator and process risks, provide better after the completion of the relevant signs and animal needs.



▲ The new semi-automatic manufacturing platform for W-188/Re-188 generator in the hot cell.

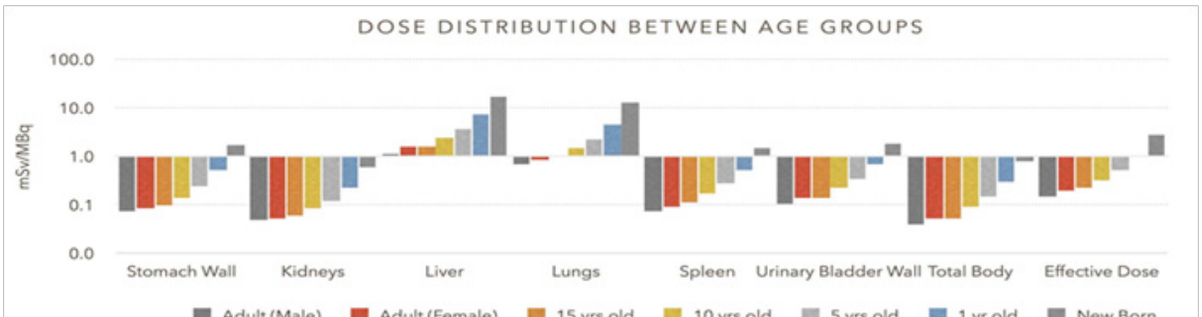
4-3-4-2 Dosimetric Studies of a New Radiopharmaceutical ^{188}Re-MN-16ET/Lipiodol for Hepatocellular Carcinoma Treatment

Chang, Su-Jing

We can evaluate whole body dose distributions with mathematical models and methods to obtain internal exposure data. Gathering with the time-activity curve of injection data and S-values derived from MIRD computational human phantoms, the dose distribution of a subject would obtain by OLINDA/EXM (FDA 510(k) – K03396). The injection data has been normalized to the percentage of injected dose per gram tissue. The following figure shows the dose distribution between age groups.

Furthermore, the Monte Carlo particle transport method will be applied in addition to detailed dose distribution in the next step. Monte Carlo calculation produces outstanding detailed and accurate results with the realistic voxel phantom, which usually constructed using the CT or MR images of human body. Till now reference realistic voxel phantom does not exist in Taiwan, but we still can refer to voxel phantoms developed

by other countries, like Korean Typical Man (KTMAN), pediatric phantoms by university of Florida, and etc., to engage with the characteristic of a tumor in our calculation. It can provide to the project more information through IRB reviews.



SUMMARY BY ORGAN SYSTEM

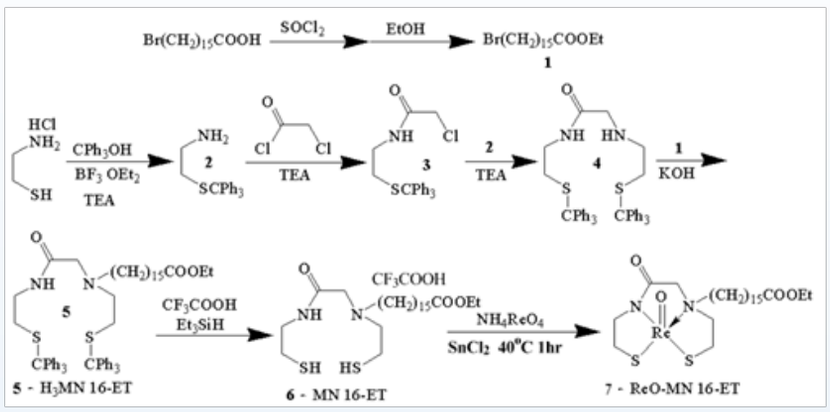
Category	Adult (Male)	Adult (Female)	15 yrs old	10 yrs old	5 yrs old	1 yr old	New Born
Stomach Wall	7.43E-02	8.44E-02	9.89E-02	1.45E-01	2.55E-01	5.23E-01	1.74E+00
Kidneys	4.96E-02	5.41E-02	5.97E-02	8.55E-02	1.27E-01	2.31E-01	6.19E-01
Liver	1.17E+00	1.60E+00	1.60E+00	2.48E+00	3.76E+00	7.49E+00	1.79E+01
Lungs	6.83E-01	8.44E-01	1.03E+00	1.48E+00	2.31E+00	4.66E+00	1.31E+01
Spleen	7.59E-02	9.27E-02	1.13E-01	1.78E-01	2.84E-01	5.33E-01	1.47E+00
Urinary Bladder Wall	1.1E-01	1.45E-01	1.45E-01	2.24E-01	3.57E-01	7.02E-01	1.86E+00
Total Body	4.11E-02	5.32E-02	5.33E-02	9.08E-02	1.52E-01	3.08E-01	8.28E-01
Effective Dose	1.56E-01	2.00E-01	2.24E-01	3.33E-01	5.18E-01	1.04E+00	2.78E+00

▲ Dose distribution between age groups for 188Re-MN-16ET/Lipiodol

4-3-4-3 New Synthetic Method of Non-Radiation Standard for ^{185}ReO-MN-16ET

Lu, Kuei-Lin; Chang, Yu

MN-16ET (6) can bind with Re-185 to form the stable complex. 16-Bromohexadecanoic acid is esterificated to get ethyl 16-bromohexadecanate (1). 2-Mercaptoethyl hydrochloride is protected by triphenylmethanol to get 2-[(Triphenylmethyl)thio]ethylamine (2). Compound 2 is reacted with chloroacetylchloride to form N-[2-((Triphenylmethyl) thio)ethyl] chloroacetamide (3). Compound 2 is reacted with 3 to form N-[2-((Triphenyl-methyl)thio)ethyl][2-((triphenylmethyl)thio) ethylamino] acetamide (4). Compound 1 and 4 were reacted with potassium hydroxide in acetonitrile to give N-[2-((Triphenylmethyl) thio)ethyl]-3-aza-18-ethyloxy-carbonyl-3-[2-((triphenyl-methyl)thio)ethyl] octadecanamide(H3-MN-16ET, 5). We perform the de-protect reaction of Compound 5 to give MN-16ET (6). Compound 6 is reacted with Ammonium perrhenate to get Compound 7 (ReO-MN-16ET) . Compound 1 to 7 were characterized by NMR.



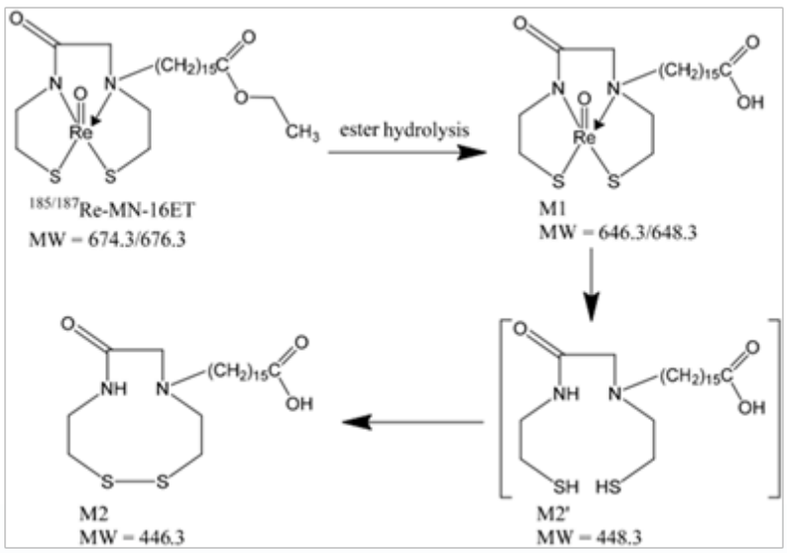
▲ Synthetic Pathway of Non-Radiation Standard for 185ReO-MN-16ET

4-3-4-4 Metabolism Studies of Re-MN-16ET and Re-MN-16ET/Lipiodol in Liver Tissue

Chen, Wei-Hsi

In this study, a reverse phase (C18) HPLC-tandem mass spectrometry methodology was employed to understand the metabolism mechanism of ^{188}Re-MN-16ET. The results demonstrated that Re-MN-16ET almost be consumed (> 99%) within 90 min in rat liver homogenate but only around 80% be transformed into metabolites within 120 min in rat liver microsome. There were 2 metabolites, M1 and M2 discovered in both liver enzymatic system. The mass-charge ratio of protonated M1 molecular ion ($[M+H]^+$ m/z) was 649. M1 was referred to the carboxylic acid form of Re-MN-16ET. The other metabolite, M2 with $[M+H]^+$ m/z = 447, was referred to de-ReO and disulfide compound derived from M1 according to fragmentation spectra. The ethyl ester of Re-MN-16ET was enzymatic hydrolyzed to M1 which was more hydrophilic and partition more in aqueous, then released ReO from N2S2 ligand to form M2.

The experiments result demonstrated that only 2% of Re-MN-16ET was consumed within 90 min of Re-MN-16ET/lipiodol incubated with rat liver homogenate. We suppose that Lipiodol prohibited Re-MN-16ET from reacting with enzyme. Re-MN-16ET/Lipiodol could be a suitable dosage formulation for the further clinical trial.



▲ The identities and pathway scheme of enzymatic reaction for Re-MN-16ET in the liver enzymatic systems

4-3-5 Next Generation 3D Imaging Technology for Medical Instrumentations and Applications

According to Taiwan government economic policy on high-end medical devices, our project was funded based on INES's radiation experiences and industry-academic-medical cooperation, for settling up a development environment for medical device products, and help overcome the funding gap for Taiwan ICT industries. Key technologies on system developments, radiation dose assessments, and product inspection and verification researches are in progress. Implementation outcomes are expressed as follow:

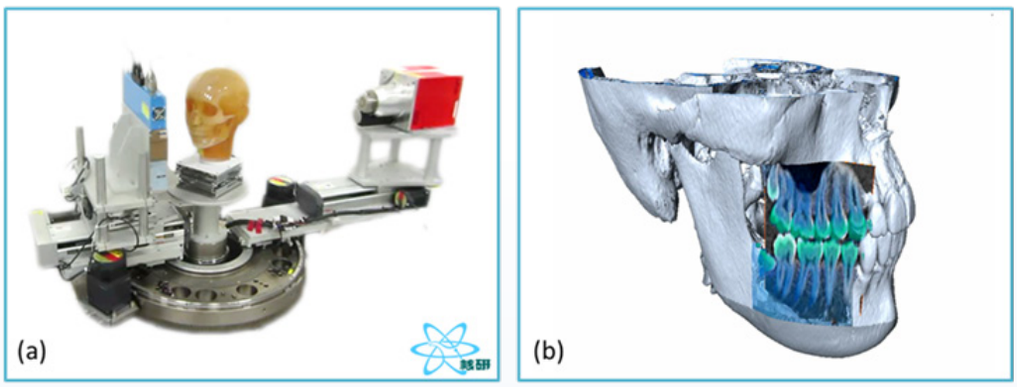
4-3-5-1 Multi-purpose X-ray Imaging Simulator for Radiography Device Development

Tseng, Sheng-Pin

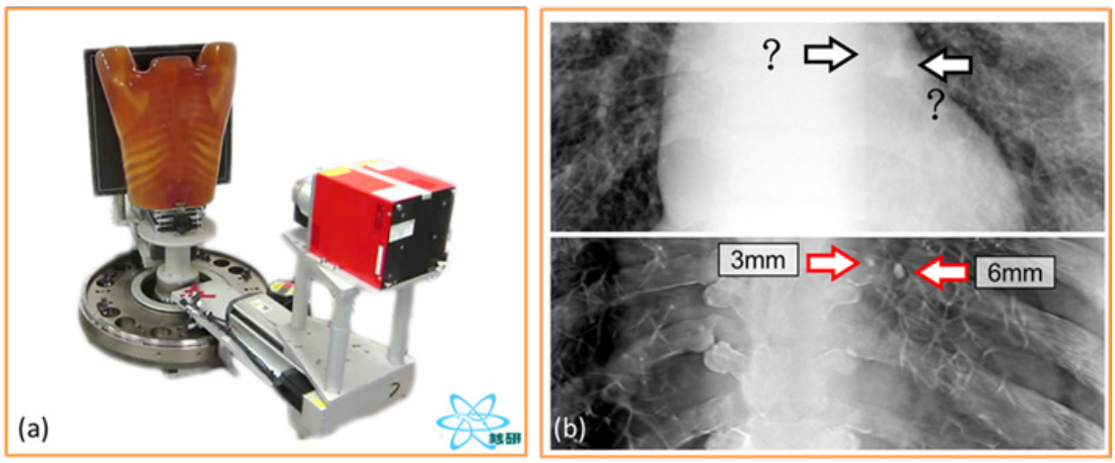
To make up the demand gap of radiation imaging and dose experience for Taiwan radiography industries, a Multi-purpose X-ray Imaging Simulator, designed by Institute of Nuclear Energy Research (INER) Atomic Council, R.O.C., was developed for supporting local industries to develop their new x-ray imaging system or component products. The simulator design concept was focused on reducing product development time and costs. It is expected to enhance the independent R&D abilities of Taiwan medical X-ray imaging device industries.

INER Multi-purpose X-ray Imaging Simulator is a flexible and reliable multi-axis kinematic system. Clinical applications such as dental radiography, mammography, chest radiography, orthopedic radiography and interventional fluoroscopy can be simulated under 2D, 3D and asymmetric scan modes. The simulator has two main purposes. The first purpose is for proof-of-concept. Initial x-ray imaging results can be acquired with the simulator before the completion of the product prototype. Clinician users can be involved in the product development as early as possible. The second purpose is for the link test between components and systems. After the integration of test components into the simulator, the system performance can be acquired in advance and the feedback can rapidly be provided to component manufactures for design optimization.

Currently, at least six scan modes have been implemented on INER Multi-purpose X-ray Imaging Simulator, which provides a platform for design/manufacturing process optimization and system performance demonstration. With the simulator, the whole picture of the products under development can be predicted at the product design stage. Time and Costs on prototype development and modification of medical x-ray imaging devices can be reduced.



▲ INER Multi-purpose X-ray Imaging Simulator for dental radiography. (a) Example of proof-of-concept on dental CT imaging. (b) INER cone-beam CT processed concept image.



▲ INER Multi-purpose X-ray Imaging Simulator for chest radiography. (a) Example of proof-of-concept on chest x-ray imaging. (b)Top: With conventional 2D chest radiography, two tumors cannot be detected. Bottom: With patented INER low-dose x-ray 3D imaging technique, two tumors can be distinguished.

4-3-5-2 Establishment of Testing Technology of Medical Devices in Radiology

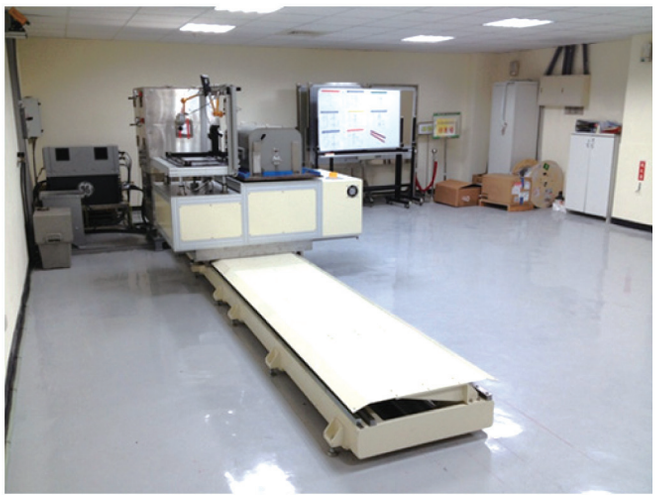
Yuan, Ming-Chen

The purpose of this project is to develop the testing technology of the Taiwan TomoDR based on international standards, and make sure that the products meet the design/control concept of ISO 13485 specification requirements during the manufacturing process. Quality of products is the life of medical device development. Therefore, quality means competitiveness. In this project, we set up several testing capabilities in basic safety and essential performance for establishment of diagnostic radiology medical devices, and help to bring together domestic testing capabilities and strengthen radiation safety in the environment to provide full capabilities for the testing of medical devices in radiology.

In this year, we aim to establish domestic safety testing environment of medical devices in radiology, and couperate with domestic research institutes to develop the radiation testing techniques and the shielding environment for measuring electrical safety, including electromagnetic compatibility and radiation protection testing of electrical safety laboratories. However, the results of the above experimental evaluations can be used as later testing requirement which can help improve radiation detection environment of domestic medical devices, implement testing infrastructure of radiation dose and beam quality output in the laboratory in accordance with IEC 60601-2-54, and mainly focus on the prototype in this project which will be needing X-ray spectrum for radiation detection environment as the standard testing environment for later use. In addition, according to the IEC 62494-1 and AAPM TG-116 report, we will use the medical X-ray machine in the laboratory to establish the correspondence between the dose and pixel value and to provide feedback exposure index as a reference to operate digital radiography system, in order to achieve the optimized purposes of medical images and radiation doses.

Currently, the medical device industry in radiology has been comprehensively developed by the government, but it is facing obstacles in the moving process because of the lack of experience and the ability in detection and verification methods and the dependence on foreign resources. All is time-consuming and extremely costly. Therefore, this project set up several technologies of basic safety and essential performance, which bring together domestic testing capabilities to strengthen domestic radiation safety in the environment to provide full capabilities for the testing of medical devices in radiology.

▲ Evaluation and testing of radiation protection shielding



▲ The testing track and implements of medical device

5 Appendices

Current Major R&D Activities

In order to avoid subjective judgments and self-complacency, the INER encourages all units to engage in external evaluation in the spirit of establishing a culture of continuous advancement. The award-winning records of INER participating in the evaluation by higher authority or external organizations or facilities during the year are outlined as following.

1. Organizational performance re-affirmed:

The institute is the sole government agency in 11 suceeding years to obtain the Defense Industrial raining Storage System awards and the 'blue chip' employer of the Ministry of Interior alternative R & D program.

2. Awards and active promotion of technology development

(1) "Solar Bluetooth Keyboard Prototype" was awarded one gold medal prize at the US Pittsburgh International Trade Show (INPEX) and one silver medal prize at the SWISS Genèva International Exhibition of Innovations respectively.

(2) One gold medal as well as one bronze medal prizes at the Germany Nürnberg International Trade Fair (IENA): Gold medal: "Process parameter assessment method for the solid target for gallium (Ga)-68/germanium (Ge)-68 generator."Bronze medal: "Quantification method for remaining liver function and novel liver receptor imaging agent."

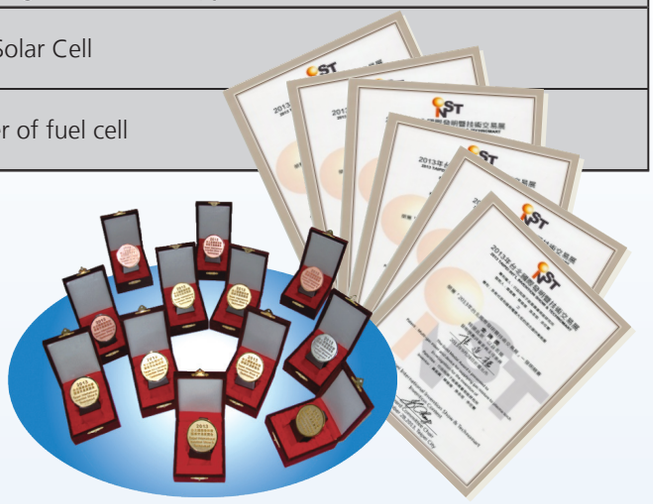
(3) Won Technology Invention Award and Technology Transfer Contracts in 2014 Taipei International Invention Show and Trade Show. oblained five gold, six silver and two bronze medals, total of 13 medals in 2014 Taipei International Invention Show and Trade Show. During the exhibition; signed with 7 companies for "Contract of Technology Licensing and Co-development" and "Latter of Intemt to Cooperate and Joint Research Contracts".

(i). Number of awands in Invention Show & Techno mart during three years (101-103)

YEAR	Total	Platinum	Gold	Silver	Copper
2012	12	1	4	2	5
2013	12	0	7	1	4
2014	13	0	5	6	2

(ii) Listing of awards list in 2014 Taipei International Invention Show & Technomart

Type of Award	Patent title
Gold Award	1.Process to Produce Fine Ceramic Powder through a Chemical Reactor with Powder Collection Device
	2.A Method of Energy Spectrum Analysis for A Bank of Sodium Iodide(NaI) Detectors
	3.A Passive Sunlight Collection for Solar Lighting
	4.Liver-receptor imaging injection, dispensing method and pharmaceutical composition thereof
	5.Kit for preparation of nano-targeted liposome drug in combined radionuclide therapy and chemotherapy
Silver Award	1.A method for preparing a xylose-utilizing strain of Saccharomyces cerevisiae and the Saccharomyces cerevisiae
	2.Combustion device for hydrogen-rich gas
	3.Structure of double anode layers on a metal substrate for a solid oxide fuel cell and the production method thereof
	4.Frame using interior connectors for holding highly-concentrated solar cells
	5.The radioactive mixture and its manufacturing method
	6.One pot processes of preparing multifunctional liposome drug for imaging, delivery and targeting in cancer diagnosis and therapy
Bronze Award	1.Series Module of Plastic Solar Cell
	2.A plate type fuel reformer of fuel cell



▲ Director-General Ma (first from right) and Vice President Wu (second from right) in 2014 Taipei International Invention Show & Trade Show

(iii) Listing of contract manufacturers in 2013 Taipei International Invention Show & Trade Show

Item	Company	Signing title	Class
1	Yulon Energy Service Co., LTD.	Energy Management System	Technology Licensing
2	Lion Young Co., Ltd.	Low level radioactive waste concrete container	Technology Licensing
3	Tatung Co.	Technique of Energy Management Control Strategy	Technology Licensing
4	EVERPHOTON ENERGY COUPORATION	Solar cell micro receiver packaging technology	Technology Licensing
5	JIA JIE Metal CO., LTD	A technique for producing high alumina refractory brick from recycling aluminum dross	Technology Licensing Patent Licensing
6	Ying Tang Sustainable Services Co., LTD.	Sunlight Indoor Lighting Devices Used in Plant	Technology Licensing Joint Development
7	Edison International Energy Inc.	Technology of SOFC power system	Early participation

◀ Group photo with Contract Manufacturers in 20142014 Taipei International Invention Show & Trade Show

(4) "The development of new therapeutic radiopharmaceutical, ^{188}Re-MN- 16ET/Lipiodol, for hepatoma treatment"project gained the 11th National Innovation Award from Institute of Biotechnology and Medicine Industry.

(5) "Distinguished Contribution Award "of National Program on Nano Technology: the Project, entitled "development of nano diagnostic and therapeutic radiopharmaceutical technology and their applications" was outstanding performance and awarded as the Distinguished Contribution Award at the 2014 Taiwan Nano Exhibition.

3. Help industries to expand the markets:

(1) The International Marketing of Radiopharmaceuticals: There have been 1,571 doses of radiopharmaceuticals sold to Brazil, India, Chile and Lebanon from January through October 2014 which is better than 2013 (474 doses).

(2) New niche for exploiting the industrial applications:The production technique related to the epitaxial growth of III-V compound semiconductor can be applied to other optoelectronic components so as to open up the utilizations in optoelectronic integrated circuits and to realize the benefits of semiconductor device miniaturization for exploring new industrial application fields.

(3) Decreasing fuel consumption: The technology of utilizing radioactive organic waste solvents as an auxiliary fuel for incineration was developed. It helps to decrease the diesel consumption as well as to treat the organic waste on operating a radioactive solid waste incinerator.

(4) Energy saving and environmental protection polymer solar cell: A new generation product with low energy consumption, less pollution, low cost, manufactured by using the full solution, non-vacuum continuous process, can be applied to 3C or vehicles, also combined with living environment, to reach energy saving, power generating function, and to achieve the environmental protection benefits.

(5) Low-carbon cellulosic ethanol process: A cellulosic ethanol production process has been developed with the net GHG emission of about 35g CO_2 e/ MJ ethanol, which is 60% lower than that of gasoline production.

(6) Combustion device for hydrogen-rich gas: This patented-design is suitable for the combustion of hydrogen-rich gas (e.g., syngas) , in which the robust flame-stabilization mechanism effectively cuts down the vessel size; at the same time, the hot-spot zones are subdued and the NOx as well as CO emissions is decreased.

(7) Meeting the International Quality of Radiopharmaceuticals: The Radiopharmaceutical Manufacturing Center of INER has been qualified on PIC/S GMP compliance by Taiwan FDA to provide high-quality radiopharmaceuticals by strict quality management system.

(8) The theranostic radiopharmaceutical approved for Phase I clinical trial:The application for"A phase I, open-label, dose-escalation study to determine the maximum tolerance dose (MTD) and to evaluate the safety of ^{188}Re-BMEDA-liposome in patient with primary solid tumor in advanced or metastatic stage" had been approved by TFDA and Taipei Veterans General Hospital Institutional Review Board on 103/7/3 and 103/9/29, respectively.

(9) On-going supply of Radiopharmaceuticals: Providing short half-life radioisotope Injections and cold kits for domestic hospitals. The service network covers all oven Taiwan are.

(10) Development of new radiofluorination technique: the radiochemical purity of F-18-CB1 antagonist was > 99%. The results showed that the drug accumulated mainly in liver, and less tham three times of background level in brain. The biodistribution of this new compound is better than most commercialized drugs.

(11) Make sure the dose accuracy: Complete the only graphite calorimeter prototype, which directly provides dose standard to domestic 120 Medical Accelerator to ensure the dose accuracy of 1.2 million patients a year.

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