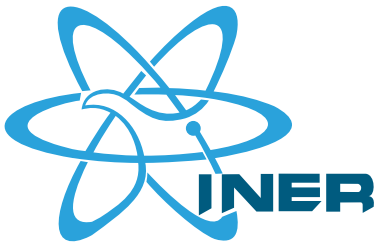
ISSN: 1812-3155

Institute of Nuclear Energy Research
Atomic Energy Council, Executive Yuan

2012 Annual Report

Published in June, 2013



Institute of Nuclear Energy Research
Atomic Energy Council, Executive Yuan

2012 Annual Report

Published in June, 2013


行政院原子能委
核能研究
歡迎蒞臨
WELCOME
核能研究所
Institute of Nuclear Energy Research

Institute of Nuclear Energy Research
Atomic Energy Council, Executive Yuan

2012 Annual Report

Contents

1 Preface

Competitiveness Roots on Competent Execution
- An Institute in Transformation -

The Institute of Nuclear Energy Research (INER) was first established in 1968 as a designated organization to pursue research on atomic energy, energy development and radiation applications. Aiming at providing technology solutions for national energy security, environmental protection and public health, over years INER set visions on becoming a worthy and competitive institute deserving public support and international recognition.

Transformation of the institute set sail as INER in recent years devotes research momentum into the renewable energy and environmental protection arena. Research groundwork for photovoltaic systems, advanced solar cells, solid-oxide fuel cell, direct methanol fuel cell, wind power, cellulosic ethanol fuel, environmentally friendly plasma applications, clean carbon technologies, intelligent micro-grid technology etc. were rooted and preliminary contributions started to emerge. These match well with the planned government organizational reform that INER be transferred to the Ministry of Economic and Energy Affairs. Accordingly the institute will soon be renamed as Institute of Energy Research (InER).

I would take this occasion to summarize a few milestones achieved in 2012 with regard to such transformation that go beyond conventional nuclear science & technologies. On photovoltaic power area, INER developed a photovoltaic power (HCPV) system with a concentrator ratio of 1,000 and 31.7% in conversion efficiency. Our HCPV system and associated laboratories have been certified by Underwriters Laboratories (UL), TAF and also Beijing Jianheng CGC. On solid oxide fuel cell, a self-sustaining system has been validated for 54.9% fuel utilization, 35.1% electric efficiency, and 760 W output. MEA development verified 38% low degradation rate per kW-hr in laboratory. On wind power, we will aim at developing 2nd generation 150 kW turbine and MW grade system in the long term. In carbon reduction efforts, the power uprating for two domestic nuclear power plants delivered considerable electricity production with zero carbon release. A total of additional 480,000 tons of carbon dioxide emission is now being avoided annually.

For environmental protection, a variety of environmentally friendly plasma coating technologies has been innovated and put forward to industrial production. We coded 22 cases of

industrial technology transfer and 20 cases of supervisory industrial services. The plasma coating technologies nurtured in INER have actually fostered the technology core for a thriving domestic plasma coating industry. On recycling of waste material, INER has developed plasma sintering technology to transform aluminum smelting slag into high-grade refractory products. One commercial processing company has built a 3,000-ton daily capacity plant using this technology.

On biomass cellulosic ethanol and biomass refining technology, INER is engaging strategic alliances with domestic and foreign research organizations in search for advancements promising to energy efficiency, environmental protection and economic viability. Our bio-refining test platform and technical services are available to support development of the emerging green energy industry and the high value-added petrochemical material industry.

Moreover, on renewable energy system development, a 20kW solar photovoltaic system and 100kW energy storage system has been integrated with an INER-designed micro-grid system to regulate distributed intermittent renewable energy sources. This integrated micro-grid system has demonstrated its functionality on power switching and control and the economy for practical industrial applications.

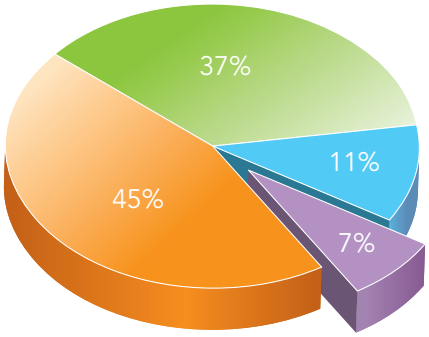
Transformation definitely will bring along changes, or in a way, challenges. We believe that competitiveness to meet new challenges in this global race for technology innovation comes from creativities and devotion by every member of the institute. More importantly the institute must as a whole commit to pursuing competent execution on each and every project at hand. And only with competence in project execution and competitiveness in technology innovation, InER can bring to life the vision of becoming a worthy and competitive institute deserving public support and international recognition.

As a national research institute, we commit ourselves to serving the needs of the nation and to conforming to governmental policies on energy research. Tasks on policy study of energy economy and guiding of technology development directions constitute two pivotal missions InER will look forward to undertaking.

Director-General

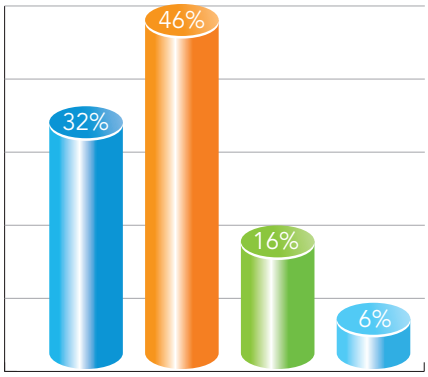
2 Human Resources and Budgets

(Time of data: December, 2012)



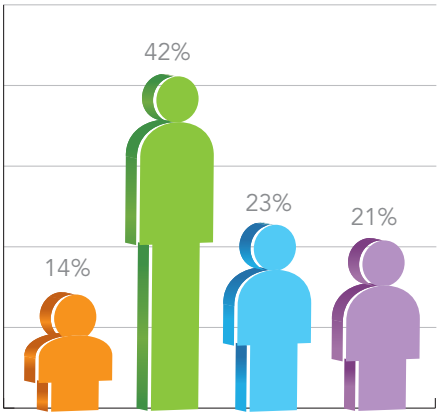
Manpower Distribution of INER

Research Staffs	367 persons (45%)
Technicians	297 persons (37%)
Administrative Staffs	89 persons (11%)
Other Staffs	60 persons (7%)
Official Staffs	813 persons



Statistics of Educational Background for Research Staffs

Ph.D.	118 persons (32%)
Master	169 persons (46%)
Bachelor	60 persons (16%)
Vocational School	20 persons (6%)
Research Staffs	367 persons



Statistics of Job Category for Research Staffs

Researcher	52 persons (14%)
Associate Researcher	152 persons (42%)
Assistant Researcher	85 persons (23%)
Research Assistant	78 persons (21%)
Research Staffs	367 persons

2012 Annual Budget

Unit：Thousand NTD

Administration and Safety	**1,327,805**	55.72%
Management, Operation and Maintenance	**111,365**	4.67%
R&D Programs	**805,876**	33.82%
Technology Promotion and Service	**137,905**	5.79%
Total	**2,382,951**	100.00%

3 Events of the Year

The direction of INER's technology development is base on the most interests of the national needs in every developing technology fields. We play midstream role to integrate upstream academic innovation research and downstream livelihood industry demand to form a complete value chain, and to the final technology transfer to the industry, and transformed into the people's livelihood and well-being, economic efficiency and social impact of scientific and technological achievements. The annual overall operating results compiled summarized of 2012 year as follows:

1. Effectiveness and Impact Assessment

(1) The Economic Benefits

- Technical service income: Total income of this year's technology transfer and technical services are 1.25 billion dollars.
- Enhance nuclear safety and operation efficiency: Implemented testing and test monitor job during the nuclear power plant's operation to prevent nuclear accidents, and extend the service life and economic benefits of billions of dollars.
- Reduce operating costs: To complete gantry power plant progress boiling water reactor containment heat flow analysis, the work offer more than a million dollars if commissioned abroad.
- Save decommissioning costs: The cost of development colloidal detergents is about 70 to 90 dollars / kg (including labor costs), and low prices than in the U.S. production of the same performance detergents ($ 5,000 / kg) future for the decommissioning of nuclear power plants will be able to save a lot of costs.
- Promote industrial upgrading: With the high-end imaging, medical supplies and industrial policy, to use the experience of radiation detectors and imaging technology to cross-domain cooperation with industry, academia, research and the medical profession area. Promote the upgrading of industrial technology and value-added of the domestic information and communications, optoelectronics, to fight for global medical imaging market.

(2) The Social Impact

- Increase local employment opportunities: Develop advanced welding technology, combine with domestic welding and related equipment industry, provide the domestic welding industry practitioners more jobs.
- Use of renewable resources, reduce environmental impact: Apply the plasma melting resources materials technology to counsel industry on how to produce advanced refractory made of aluminum smelting slag resources to reduce carbon emissions and improper waste disposal impact on the environment.
- Land resources conservation: Develop the hydrological and geological monitoring and assessment techniques for Environment, to provide technical support for environmental monitoring and assessment of the future decommissioning of nuclear power plants.
- Development of green waste reduction: Developed integration technology of solar thermal energy for evaporation and thin film distillation to reduce the use of fossil fuels to achieve the effect of carbon reduction. The hot commissioning handles 1.5 tons of high conductivity inorganic tritiated liquid waste.

- Enhance the efficiency of clean energy production capacity: The ratio of energy output and energy inputs of 2.5% caused by cellulosic ethanol process energy integration showing the energy efficiency.

(3) People's Livelihood and Well-Being

- To stabilize the supply and demand of domestic nuclear medicine: Provide diagnostic radiopharmaceutical for the heart, cancer, thyroid, nervous / spirit, cerebral vascular disease to domestic 51 hospitals and eight drug suppliers. This year provide domestic patients radiopharmaceutical diagnostic services to approximately 15 million people.
- Emergent production to replace imports drugs: Foreign production system of ECD, MIBI and other drugs for some reason can not be imported, in response to demand of the domestic hospitals, INER provide emergent production of 1,424 doses of the drug to resolve diagnostic needs of the domestic brain central nervous patients and myocardial infarction patients. Those doses can provide about 5,800 imaging services.
- Home-made high-end video medical material towards clinical trials: Self-developed high-end medical materials - breast positron photographic instrument has completed a technology transfer and reviewed by the Food and Drug Administration of the Department of Health and the National Taiwan University Hospital Institutional Review Board (IRB), The clinical trials will be conducted.
- Development of early diagnostic drugs: To develop biliary scan contrast agent and its logo formulations, to provide early diagnosis of biliary obstruction, in order to understand their health condition and offer the correct treatment.
- Develop the automatic synthesis box system, inhibit foreign monopoly: Completed Ga-68-DOTATOC radiopharmaceutical automatic synthesis box software systems, in line with the domestic cGMP validating and regulations, and no longer need to be imported the high price systems from abroad.
- Developed high-performance detection reagents: Developer radioimmunoassay EBV / NPC detection reagents it's detection limit is lower than conventional immunoassay hundred times. Unlike traditional ELISA test reagent, It is with the advantages of high sensitivity and high accuracy.

2. Status of Indication Matters

(1) Assist in the analysis of the support group board bolt breaking accident of the Nuclear Power Plant: Assist in the establishment of the bolt and the support plate finite element analysis model and parameter setting, correlation analysis 120 sets, and to solve probability risk of Nuclear Power Plant reactor pressure vessel support skirt bolt fracture.

(2) Dry storage earthquake safety study: Performed the study of the earthquake response of the dry storage facility, completed the design and construction of the simulation specimens, and expanded the series tests of the nature of the contact surface and the dynamic characteristics of the earthquake response to adjust the numerical model.

(3) Planning the decommissioning of nuclear power plants: Participated in the Nuclear Power Plant decommissioning planning, performed resource assessment and planning according to the decommissioning plan in order to participate in work at any time.

3. Policy and Administrative Support

(1) To attend the meeting, training and inspections of the Atomic Energy Commission , Department of Radiation Protection , Department of Nuclear Regulation, Department of Nuclear Technology , The property Management Bureau and Nuclear Power Plant for total of 252 times.

(2) To support the Atomic Energy Council receives radioactive steel 49 times, and receives abandoned radiation source 206 pieces. Support the AEC performs radiation safety to avoid the spread of contamination.

(3) To support the radiation detection of the import of fishery products: To support the relevant units to implement radioactive analysis tests of Japan's imports of food, feed, alcoholic products and export Russian fish products; liquor from Ministry of Finance, a total of 15,000 times.

(4) To integrate radiation disaster response capabilities: To help the emergency training of radiation accidents held at the U.S. Department of Energy's National Nuclear Security Agency (US DOE / NNSA), and to integrate domestic customs and radiation injury response technology and health care resources.

(5) To support the nuclear safety drill: To support the exercise of the Nuclear Safety No. 18 held by AEC, to complete the operation of the technical group and dose assessment of Radiation Monitoring Center in the north, To help script compilation and dose evaluation results output.

(6) To support the demands of the control system and equipment: To support maintenance and update of radioactive waste control system for Property Management Bureau, and to manufacture MERM-PE-HDB motor environmental radiation surveillance video 1 set for Radiation Monitoring Center.

4. The Key Contribution

(1) Nuclear Energy Technology Platform

- To developed autonomous nuclear digital instrument and control system platform: To develop SCS-2000 controller design of high reliability in cooperation with the United States HFC, the setup and installation test of the system platform has been completed and we will apply international standards IEC-61508 certification.
- Nuclear Grade Components Verification: Replace the license of "Nuclear Energy at the Same Level Product Components Verify Units Recognized Certificate", implement the verify plan of nuclear safety grade components to implement independent industrial applications of nuclear energy.
- To build a nuclear facility decommissioning technology: Complete the ZPRL decommissioning plan, apply for decommissioning permission, dismantling and finishing part of the reactor core internal components, donate to Tsinghua University to use for resource recycling purposes.
- To establish the only electric valve function assessment and verification testing technology platform of domestic nuclear power plants: Support the nuclear two, three and gantry power plants to complete the functional verification test during the overhaul and downtime period. We have completed 13 times overhaul and about 1,000 times electric valve test and tune for gantry Power Plant No.1 machine.
- To apply the risk assessment techniques to reduce testing costs of the nuclear power plant: Combine the processing strategy of piping degradation mechanisms to complete the assessment

and planning of the testing plan of the nuclear one, two, three plants during the risks inform operating period, and to reduce testing costs and personnel exposure dose.

- To establish technique for waste barrels nuclide concentration assessment and classification database of Orchid Island storage site: We accomplished classification of solid waste despite the limits of difficult environment and lack of resources. This technique can be fully utilized in the process of disposal of solid waste.

(2) Research and Development of Nuclear Medicine

- To refine the process of somatostatin receptor imaging agent for the Ga-68-DOTA-NOC: Effectively shorten the heating reaction time from 10 minutes to less than five minutes. The radiochemical purity is more than 98%.
- Develop the process of target type gold nano monoclonal antibody: To make use of radionuclide to produce flag technique. Can see the specificity accumulation performance of cells in vivo. It can be used in vitro detection methods for human body tumors. To use the characteristics of the thermal treatment by gold nanoparticles can enhance the effects of cancer treatment.
- Based on effective of multiple cancer treatment to assess the development of the probe: Through the animal tumor imaging, it is possible to see the tumor size, location, and the amount of the life and death cells in tumor of xenograft, including breast cancer, lung cancer and liver cancer.
- Development of nano cancer drugs "Rhenium-188 Liposome": "Rhenium-188 Liposome" was approved human clinical trials Phase 0 by the Department of Health in 101 years.
- The use of iodine 123-ADAM with single photon emission computed tomography: To assess prognosis for severe depression and to help detecting severe depression.

(3) Solar Technology

- Complete the development of 1,000 times concentrator module manufacturing technology: Photoelectric conversion efficiency is 31.7%. The technology of module design and module production has reached international standards, can effectively reduce module production costs. Concentrator solar cell modules gained certification of the United States (UL) system: INER's self-designed and production of concentrator solar cell modules gained certification of UL system on 11.10. 2012, will enable the industry to march into international market.
- Prototype production of image-sun position sensor and solar image tracking controller: Tracking accuracy is up to ± 0.04 percent. To build the experimental platform of the image-based sun position sensor which can be applied to large-scale Solar Tracker to increase the overall performance of the high concentrating solar power systems.
- Novel low band gap conducting polymer PBDTTT blended with PCBM (C70) solar cells: The energy conversion efficiency is up to 6.42%. (International highest efficiency of the same type solar cells is up to ~ 6%)
- The large area production technology of polymer solar cell: Useing ultrasonic spray technology to produce conducting polymer P3HT blended with the PC (60) BM large area polymer solar cell, spraying area is greater than 4cm^2, it's efficiency is up to 3.73%. The maximum efficiency of the solar cell internationally is up to 3%.
- Create a new translucent electrode process technology: The optimized efficiency is up to 2.8%, beyond the efficiency values of existing international same type of the ITO free solar cell.

(4) Fuel Cell Technology

- The performance of Plasma spraying metal supporting MSC Cell is exceeding the world standard: INER not only got a numbers of patents in Europe, America and Japan, but also got the platinum Gold Medal of the 2012 Taipei International Invention Show & Technomart by "solid oxide fuel cell and its production method". We signed the Cooperation Letter of Intent with domestic producers.
- The integrated device of the SOFC thermal components: Created the warming technology of SOFC power generation system by natural gas instead of a traditional electric method. The recombination rate of natural gas is more than 99%.
- To set up the unit cell multifunction detection device: To measure the overall performance of the battery unit, to simultaneously detect the transverse impedance of the cathode and anode layer and the characteristics of the partial area of the battery slice, in order to understand the difference of the partial area of the solar cell during unit testing.

(5) The Technique of Distributed Power Energy and Wind Energy Systems

- 20kW solar photovoltaic system: Completed the 20kW solar photovoltaic (PV) system and combined with grid system. Processed the technology testing of overall microgrid power control and the demonstration of the grid / silos smooth switching.
- 100kVA energy storage system: Completed stable running test of energy storage systems for eight hours a day for 15 consecutive days.
- Micro-grid power control technology: Demonstrated micro-grid islanding operation and the renewable energy penetration is greater than 10%. Our power control technology can reach that renewable energy generation facilities device capacity accounted for 20% of the micro-grid the partition generation system device capacity

(6) Environmental Plasma Technology

- The new energy-saving concept of flexible thin-film solar cell components combined with the home life: Completed Solar blinds modular exhibits of 1,000 × 1,000 mm^2 the window width comprising by 90, 100 × 100 mm^2 flexible thin-film solar cells. It was exhibited at the 2012 Taipei International Invention Show & Technomart, and was interviewed by electronic media at the scene.
- The development of novel structure and low cost solar cell: Replace the existing electron-doped layer with the introduced low-resistance metal copper-magnesium alloy to renovate the structure of productions. It gained Bronze Medal at the 2012 Taipei International Invention Show & Technomart.
- The energy-saving thin-film materials of flexible photovoltage and electrochrom: To achieve the basic specification of energy-saving integrated application. The photovoltaic efficiency of single junction silicon thin film is up to 6.67%, the open circuit voltage of double-junction thin-film photovoltaic is up to 1.48V, the discoloration rate of electroluminescent films is up to 60%. It can create energy-saving markets.
- Developed a long life plasma torches system: The cathode life is higher than traditional plasma torches 2 to 4 times. The maintenance cycle of 12 kW plasma torch is more than 3,000 hours. The technology has been transferred to domestic producers.

(7) Cellulosic Ethanol Technology

- Promote core technology of cellulosic ethanol for industrialization: To provided 16 items of bioethanol and biomass refining technology services to domestic industries, and to assist the domestic industries to establish a small pre-treatment and enzymatic hydrolysis experimental facilities.
- Completed an initiative of non-food cellulosic ethanol as a domestic biofuel: To assist in the National Science Council's plan to perform the bioethanol demonstration in Tainan's townships. We accomplished mixing of 2 kiloliters fuel alcohol with rice straw with CNPC 95 gasoline into E3 ethanol gasoline. This is the first use of second-generation non-food biofuels and has indicative significance.
- Make use of cellulosic ethanol technology to promote the development of non-food biomass chemicals: Have signed cooperation letters of intent with 3 possession and research units, and plan to develop the technology of fiber lactic acid and polyol productions. Cooperating with a petrochemical industry to develop the technology of petro-chemical process to convert biological method.

5. Convenience and communication services

(1) Guests visited our facilities a total of 90 times and 2,692 people in 2012.

(2) Participated in the 2012 Taipei International Invention Show & Technomart, with the demonstrative theme of "quality of life". We have five display themes, such as: smart micro-grid, green energy, solar energy blinds module, breast-specific positron emission tomography instrument, nuclear medicine research and development and applications. We also exhibited on the achievements of the derivative products which attracted many domestic and foreign guests and media to understand the results of government policy.

(3) Energy National Program for "Development and integration of key technologies of convert biomass into gasoline" was casted by Office of the Biomass Energy to participate in the 2012 Taiwan International Green Industry Show (TiGiS). It can help manufacturers and the public to understand the research conditions and to promote industrialization of technology.

(4) Nuclear medicine pharmaceutical center accepts phone and fax orders around the clock, and deliveries hospital's needs on-time. We handle the emergency orders in timely manner on holidays or at night. The process is accurate.

6. Value-Added and Innovative Measures

(1) Academic Achievement

- We submitted 136 reports for publication in foreign periodicals and 87 reports were accepted and published this year.
- Dr. Mao-chuan Li was invited by the International Journal of Electrochemistry communications as Paper Reviewer / Referee; he was invited by the European Fuel Cell Forum to be a member of International Board of Advisors, he was also invited by the American Ceramic Society to be an invited speaker at the 10th International SOFC Symposium. It means our SOFC-MEA accomplishments have received international recognition.
- Dr. Ging-Fang Shi was invited to serve as Paper Reviewer by Journal of Hydrology, and was invited to serve as Paper reviewer / Referee by Advances in Water Resources and Stochastic the Environmental Research and Risk Assessment.

(2) Technological Innovation

- Patent: We had 155 patent applications and patented 144 items.
- Participated in the 2012 Taipei International Invention Show & Technomart from September 20 to September 23 at the Taipei World Trade Center. The "Solid Oxide Fuel Cell and Its Production Method " was awarded the highest honor of Platinum Award in addition to receiving 4 gold, 2 silver and 5 bronze awards, a total of 12 medals.
- Development of wet substrate stripping process technology: Use of chemical etching solution with the speed to develop the technology of wet substrate peeling process which can significantly shorten component etching process.
- Development of positron emission tomography medical material with innovative imaging system model sophisticated quantitative accuracy: Use of the breast prosthesis to verify the accuracy of performance and quantitative, the horizons edge tumors quantitative accuracy increased by 30% than before treatment.
- Innovative applications of drugs: Rhenium-188 liposome (Body radiation therapy) and "The development of serotonin transporter imaging agent iodine-123-ADAM and it's application in the clinical of depression" participated in "The ninth National Innovation Award - Gakken group" organized by the Institute for National Biotechnology Industry in the ECCC (Health Planning Council) , and won the award.

7. The Growth of Professional process and Knowledge

(1) International Cooperation and Technological Exchanges

- Key technologies of microgrid of small and medium-sized wind turbine power converter control system: In April 2012, we signed a cooperation plan with Virginia Polytechnic Institute and State University (Virginia Tech University), having power-control convert design experience and international leading technology, to expand international cooperation network with joint research and development.
- Solar cell module long-term outdoor exposure test: Cooperated with the United States UL Lab to implement technical cooperation of solar cell modules long-term outdoor exposure test research at HCPV test point of Taitung University Sunshine Stations built by Kaohsiung Luchu MW HCPV demonstration farm and solar cell modules verification laboratory.
- Nuclear reactor safety assessment technology: Developed thin film lithium battery manufacturing technology in cooperation with Oak Ridge National Laboratory (Oak Ridge National Laboratory, ORNL). Sent delegates to the University of Nagoya, Japan, to participate in the research of thin film lithium battery manufacturing technology, and applied to the winch plasma coating platform to develop the flexible thin-film energy storage technology.
- Used the latest FAVOR program to develop reactor pressure vessel probability fracture mechanics analysis of the domestic nuclear power plant.
- Hot cell management technology: Established a pipeline of technical exchanges with the Idaho National Laboratory (INL) for future cooperation and partnership to enhance the management of the hot cell performance.
- Detection technology of nuclear fuel rods: Cooperated with the Los Alamos National Laboratory (LANL) to perform the spent nuclear fuel rods neutron measurements and Pu/U analysis.
- Cellulosic ethanol production technology: Cooperated with internationally renowned Novozymes

Enzymes Company to perform parallel testing for performance of enzymatic hydrolysis of rice straw pretreatment slag.

(2) Personnel Training

- Multivariate cultivate pipeline: This year, INER cultivated a total of 62 doctoral students and 118 graduate students for commissioned cooperation plan for the tertiary institutions in the country and for promoting the professional and technical capacity of the staff. In addition, INER organized a total of 265 sessions of education and training for a total of 4,963 participants in the current year, to enhance the research and development of energy.
- The Institute is the only award-winning public office of "Blue chip" employer for nine consecutive years awarded by the Defense Industrial Reserve Duty System and Military Training of the Department of Defense.

As a R&D institute, INER has been at the level of national laboratory. "Energy Security, Environmental Protection, National Health" are our visions. Not only implemented self-preparation of government reform policy but also plowed in forward-looking, integrated, large-scale and platform type plans. The core technologies are not readily available at home and abroad with the irreplaceable nature.

In response to the new challenges of organizational positioning adjustment, technology development direction will be guided by energy economy policy for the industrial economy and people's livelihood and well-being. Support the strategic planning of the energy policy in the R & D strategy. Support planning national energy technology development programs and the promotion of technological development. Develop atomic energy, new energy systems and systems engineering. Provide systems integration platform of innovative technology to promote the synergy and industrialization of technology.

3-1 Weld Overlay Repair Technology and Service for Nuclear Power Plant: INER a Pioneer in Asia

By Sheng-Long Jeng

More often than not the nuclear power plants of Taiwan Power Company (Taipower) had to call in urgent weld overlay (WOL) repair service from abroad in the past when a non-acceptable defect(s) was spotted with the reactor coolant piping system. Despite superb welding skills, local welding service firms were not well equipped with expertise to be qualified for the WOL repair jobs for in-service nuclear power plants. Taipower had no alternative but to rely on foreign welding service firms. That has long been a concern in terms of the operational safety and maintenance efficiency of nuclear power plants.

To address the above concern, the Institute of Nuclear Energy Research (INER), the sole government-funded institute for nuclear technology research in Taiwan, took the initiative to develop weld overlay technology and establish local repair service capabilities, so that Taipower can command timely technical support to ensure the operational safety of nuclear power plants. INER made the efforts to line up its staffs from the disciplines of materials science, mechanical and welding engineering, mechanics and quality assurance to work on the dissimilar and similar metal weld overlay repair technology and service program. It also secured working partnerships with a local welding service firm through an open selection process for on-site weld overlay repair operations and a foreign welding equipment company for the provision of welding apparatuses designed to the specific plant requirements.

As a first step toward the realization of the program goal of self-reliant weld overlay repair service for local nuclear power plants, INER contended with international competitors for the contract to perform pre-emptive weld overlays (PWOLs) of the pressurizer nozzle dissimilar metal welds of Manahan Nuclear Power Plant. INER and its welding team strove to have the temper bead welding and the weld design and analysis technologies established, and to get all the required documents of welding procedures and quality assurance in place to be qualified for the bidding. INER was awarded the contract in 2008. Prior to the execution of the contract, a crew of skilled welders and technicians were further trained with a mock-up so as to familiarize them with the plant site and to cut down their exposure to radiation.

In 2009, INER won another bid for the contingency contract-II to perform weld overlay repairs to the similar and dissimilar metal welds of reactor coolant system of Taipower BWR nuclear power plants, when necessary.

Both contracts were well executed, as briefly described below, and proved to be a great success.

PWOLs of pressurizer nozzle welds of Maanshan Nuclear Power Plant units 1 and 2

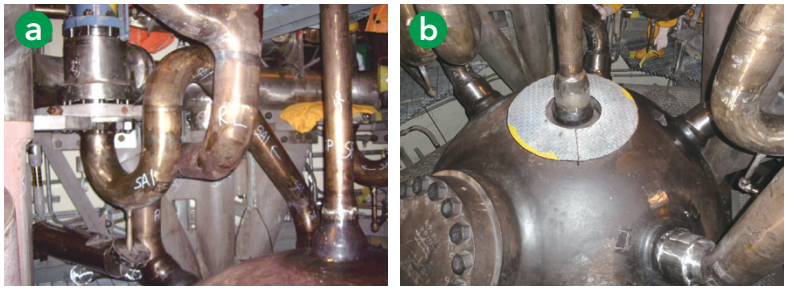
This contract was scheduled to be executed during the outages EOC 18 and EOC 19 of each unit from April 2009 to April 2011. Twelve nozzle-to-piping dissimilar metal welds were pre-emptively overlaid with nickel-based weld metal Alloy 52M for both units. The welding operations were carried out according to working plan by a crew of practised welders. All the PWOLs turned out to be of superb quality, passed the ultrasonic test with no need of repair. Compared to the similar jobs reported, this contract expended less working hours in on-site welding operations and registered lower staff radiation exposure. (Figs 1 and 2)

WOL of feedwater nozzle of Kuosheng Nuclear Power Plant unit 1

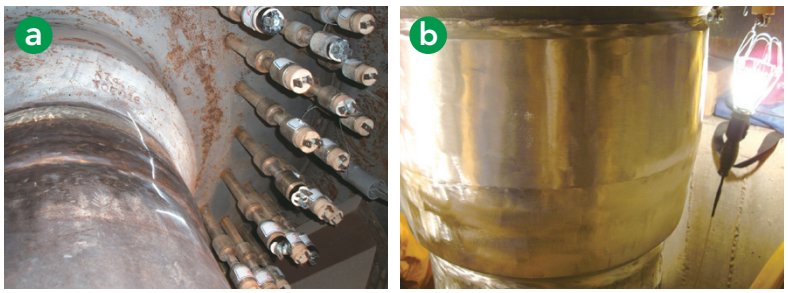
The Technical Support for Taipower Weld Overlay (WOL) Repair Contingency Contract (II) was to provide urgent weld overlay repair service for Chinshan and Kuosheng Nuclear Power Plants, when a non-acceptable defect(s) was detected on the reactor coolant piping system. The contract was valid from September 2009 through April 2012. In 2010, INER was asked to perform a WOL repair to the feedwater nozzle dissimilar metal weld N4B-F1 of Kuosheng Unit 1. A miniature weld head was employed with a specially-designed auxiliary to move the weld head track on piping (patent pending). (Fig. 3)

This repair welding campaign also had good success. It attested to the weld overlay repair capability INER and the welding team had established.

INER has already established WOL technology and repair service capability for both austenitic and dissimilar metal welds of reactor coolant systems of nuclear power plants. Continuing efforts will be focused on the development of advanced welding technology to help build up the welding repair service industry to serve the needs of local nuclear power plants.



▲ Fig.1 PWOLs on upper pressurizers of Maanshan Nuclear Power Plant: (a) before PWOL, and (b) after PWOL.



▲ Fig.2 PWOLs on the pressurizer surge nozzles of Maanshan Nuclear Power Plant: (a) before PWOL, and (b) after PWOL.

▲ Fig.3 WOL on the feedwater nozzle of Kuosheng Nuclear Power Plant Unit 1.

3-2 The First Training Facility for Dry Storage Operation in Taiwan: Proven Technology through Dry Runs and Well Recognized by International Communities

By Chen-Yang Liu

In order to assure the safely operations of Nuclear Power Plants (NPPs) in the designed life time and after decommissioned, more and more utilities have adopted the dry storage technology to store the nuclear spent fuels. Traditionally, the generated spent fuels are stored in the Spent Fuel Pools (SFPs), which need continuous coolants to take away the heats generated by spent fuels. This type of fuel storage is generally referred as "wet storage." In contrast to wet storage, the dry storage technology uses a sealed container (usually called a canister) filled with inert gas to provide a stable environment for fuel storage, the heats generated are then removed by naturally convection with the air flow through artificial channels between the outer wall of the canister and the inner walls of another container (generally made of concrete) surrounding the canister.

After Fukushima event in 2012, the International Atomic Energy Agency (IAEA) encouraged all utilities to adopt the dry storage technology to store spent fuels, based on the recognitions that natural convection is more reliable in contrast with the continuous needs of coolants in wet storage facilities. Figure 1 shows the operation sequences of dry storage in Chinshan NPP.

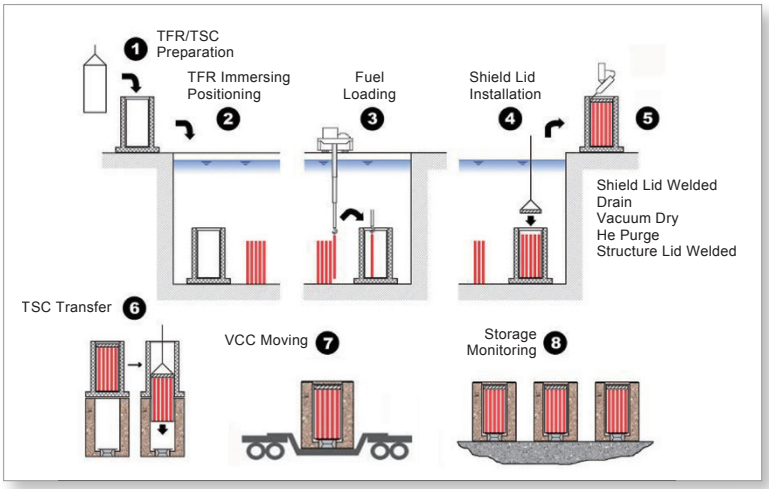
Institute of Nuclear Energy Research (INER) was entrusted by Taiwan Power Company (TPC) in 2005 to conduct the installation of the first dry storage facility in Taiwan: the Chinshan NPP dry storage project. This project adopted US NAC's UMS (Universal Multi-purpose canister System) which had been licensed by US NRC (Nuclear Regulatory Commission), in order to quickly start up the project. Some major modifications had been made to accommodate the specific layouts and features existed in Chinshan NPP. In addition to this technology transfer, INER established a training facility for dry storage operation to assure that all workers involved be familiar with the dry storage operations to be conducted in Chinshan NPP. After near five years investments on hardware and continuous efforts in improving the efficiencies and safety of dry storage operation, the satisfactory outcomes of the dry run at Chinshan NPP have proved the usefulness and robustness of the test facility. Recently, the contractor of the Kousheng NPP dry storage project contacted INER for supports in the planning, training, and supervision of the loading to be started in the year of 2015.

In order to set up a full-function training facility, INER not only collected critical documents (such as operating procedures used in other loading campaigns), it also dispatched a team of seven in 2007 to observe the loading operation in a NPP in US. After the above-mentioned processes, INER decided to focus on three core technologies to be developed within this training facility, they are: the welding technique for the sealing of a canister top cover, the retrieving processes needed when a canister can no longer maintain its designed functions, and the heavy load movement.

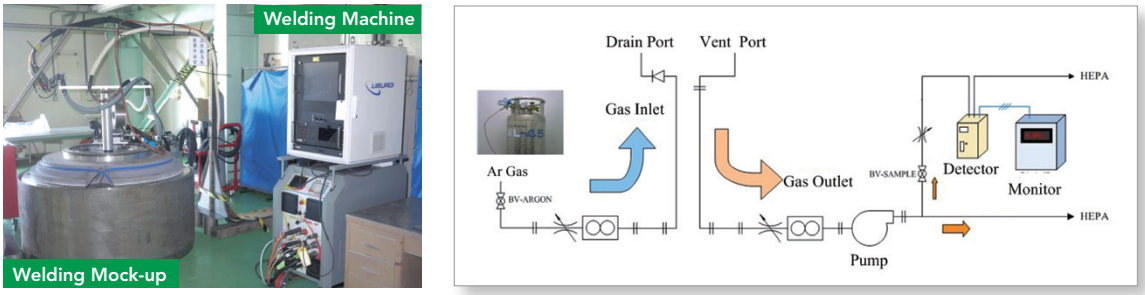
Technology Development

1. Sealing Technique

As shown in step 4 of Figure 1, after the installation of the shield lid on top of the canister (the TSC), the TSC will be welded in step 5. In addition to welding technique, other processes such as water exhausting, vacuuming, and helium backfilling are all critical techniques for TSC sealing. INER uses full scale test coupon to develop the optimum parameters for welding during the personnel training processes. A set of hydrogen control system is also developed to assure that the concentration of hydrogen inside the TSC is well controlled to be below the potential ignition threshold during the welding processes. As designed, the system will automatically start to purge argon gas into the TSC when the hydrogen concentration reaches 60% of the threshold value. The assembled hydrogen detection system is shown as Figure 2.

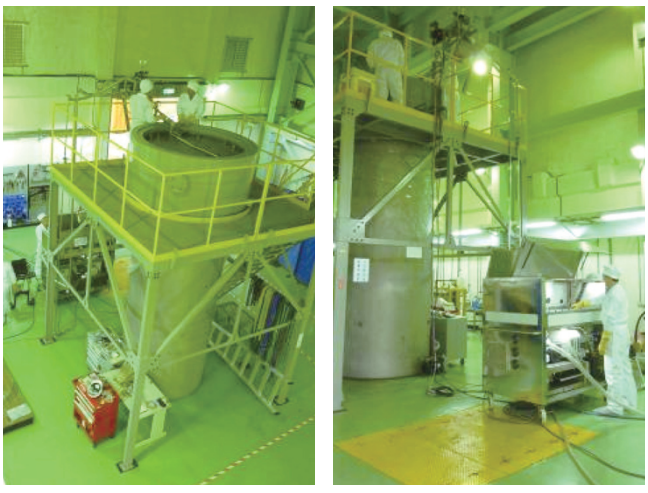


▲ Fig.1 Dry Storage Operations in Chinshan NPP.



▲ Fig.2 Remote-Control Welding Machine (left), Hydrogen Detection System (right).

The VDS (Vacuuming and Drying System) is also designed to perform the water exhausting, drying, and helium backfilling processes, which is used for personnel training. After trial-and-error processes, the system can complete the above mentioned processes within 24 hours, which is equivalent to those skilled foreign workers. Notably, this system is designed to be remotely controllable, therefore the accumulated radiation dose can be further reduced. Figure 3 shows the VDS training processes.



▲ Fig.3 Training Processes of VDS Operations.

2. Retrieving

Under a hypothetical event, the TSC might need to be replaced. In this case, the TSC will be transported back to the spent fuel pool to have the stored fuels retrieved. The removal of the welded lids on top of the TSC becomes the critical technique for retrieving. With try-and-error-and-improve processes, INER optimized the lid removal (cutting) system bought from US, with an outcome of 50% reduction on the cutting time. Figure 4 shows the V&V processes of the lid removal system.

▲ Fig.4 Dry Run for TSC Top Lid Removal.

3. Heavy load movement

Dry storage related heavy load movement can be categorized into two types, based on where the activities are taking place. The first type is the heavy load movement in or near the spent fuel pool (SFP). Since it is too sensitive to conduct dry run close to SFP, which stores many spent fuels, so INER uses a similar pool located at INER to set up an environment similar to SFP for training purposes. This approach proved to be very useful in building up the confidence of the workers, at the same time keeping the risk to SFP to a minimum.

For heavy load movement in areas other than SFP, a general approach is adopted. After the detail survey of a specific area, protection equipment and processes are developed to minimize the risk. Then dry runs (training) are conducted right in that specific area. Dry runs for these two types of heavy load movement have been accomplished by 2012. Figure 5 shows the dry runs of heavy load handling of the Transfer Cask (carrying the TSC inside) and dummy fuel loading in the SFP. The movement of the Transfer Cask (TFR) inside the reactor building and that of the concrete cask from the reactor building to the storage pad are shown in Figures 6 &7, respectively.

▲ Fig.5 Transfer Cask Movement in SFP (left), Dummy Fuel Test in SFP (right).

Fig.6 Heavy load (Transfer Cask) in the Reactor Building.

Fig.7 Concrete Cask Movement using Dolly Inside Chinshan NPP.

With investments of more than 1.6M US dollars and 20 man-year manpower, INER successfully established the first training facility specific for NPP dry storage operations, and substantial achievements have also being developed in the areas of sealing, retrieving, and heavy load movement techniques. Up to the end of 2012, this facility has been used to train for more than 25 qualified workers for dry storage operations, in which they will become the main task force for the loading campaign started by the September of 2013. With these achievements, INER becomes visible in international dry storage business and is invited to join the planning, training, and supervision of the dry storage loading in the second (Kuosheng) NPP. INER expects to have more workers trained in this facility in the near future. These qualified personnel will become the leading task force for future dry storage operations in Taiwan, in which the ultimate goal of INER, the localization of nuclear industry, can be satisfactorily accomplished.

3-3 Stress Test of Nuclear Power Plants

By Lih-Yih Liao

1. Introduction

After the accident occurred on 11 March 2011at Japanese Fukushima-Daiichi nuclear power plant, all the countries with operating nuclear power plant have conducted safety reassessment of their plants against external nature events. The member countries of the European Union have completed all the stress tests of their nuclear power plants. With an aim to guarantee the safety of our nuclear power plants, INER has assisted AEC to carry out the stress test following the ENSREG specification.

2. Major activities

Firstly, we start from studying the EU ENSREG specification and the stress test national reports of Germany, France, Belgium and Finland. Secondly, we assist AEC in reviewing the stress test reports prepared by TPC. After thorough discussions with the staff of AEC, a draft of the national report is completed with the conclusions and recommendations in the following aspects:

(1) scope and content
(2) Earthquake
(3) Flooding
(4) Extreme natural events
(5) Loss of electrical power and loss of ultimate heat sink
(6) Severe accident management

3. Conclusions of the Nuclear Power Plant Stress test National Report

Based on the review of TPC's report and the supporting documents, regulatory body(AEC) conclude that the assessments of safety margins are acceptable and the resulting action plan for improvements is adequate (Table 1 and 2), furthermore AEC identified additional requests and recommendations in order to further improve the robustness of the plant facilities.

Table 1. Power sources of Taiwan's nuclear power plants

Site	Back-up power sources	Swing DG	Air cooled G/T	Enhanced measures to increase robustness of emergency 4.16kV/480V AC power	
Chinshan	2EDGs/unit	1	2	1.Swing EDG provides emergency power to both units 2.provide power to safety-related essential buses from two black-start DGs of gas turbines	mobile diesel generators added twelve 480V 500kW one 4.16kV 1500kW
Kuosheng	2EDGs/unit 1EDG/unit for HPCS	1	2		four 480V 200kW one 4.16kV 1500kW
Maanshan	2EDGs/unit	1	2		eleven 480V 370kW two 4.16kV 1500kW
Lungmen	3EDGs/unit	1	2		five 480V 100kW two 4.16kv 500KW

Table 2. Capability to cope with Beyond DBAs

Item and Usage	CS	KS	MS
Power Vehicle - 4.16kV/1500kW (includes interfaces)	0/1	0/1	0/2
Mobile diesel generator - 480V (includes interfaces)	0/12	0/4	1/11
Diesel engine water pump – standby pump for CST, fire hydrant pressure boosting, and temporary water injection	0/6	6/15	0/7
Fire-fighting truck	2/2	2/3	1/2
Diesel engine water pump - temporary dewater pump	5/7	0/8	0/30
Spare motors of emergency service water pump	1/2	1/2	1/5
Mobile air compressor	0/5	0/5	0/3
Spare Borax and/or Boric acid (tons)	10/68	0/99	5/55

NOTE: Left side of slash is the status before improvement. Right side of slash is the status after improvement.

3-4 Early Detection Breast Cancer- INER Breastpet-The First Positron Imager Enters Clinical Trials in Asia

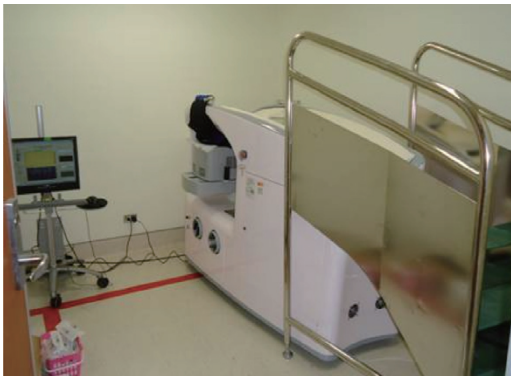
By Meei-Ling Jan

Millions of women suffer from breast cancer per year all over the world. In Taiwan, the disease tends to younger generation and the incidence rate has become the second in Asia. For these reasons, INER BreastPET was designed in the concept of breast cancer early detection, and becoming an efficient instrument for high sensitivity and painless breast cancer screening. INER BreastPET has passed the preclinical evaluations on safety and performance, and is moving to clinical trial.

INER BreastPET is an independently developed instrument for high sensitivity, high resolution and comfort breast cancer screening. The prototype was completed in 2010 and passed EMI/EMC in 2011. In collaboration with Dr. Kai-Yuan Tzen, Director of Department of Nuclear Medicine at NTUH, the clinical trial protocol was applied in May 2012. The application was approved by TFDA and IRB in August 2012. Human studies will go on in 2013.

Clinical trial of INER BreastPET is a remarkable work, that become the first case of MIT (made-in-Taiwan) large-sized high-end medical imaging device being identified in Taiwan medical. Through the clinical trial, performance of INER BreastPET on breast cancer detection can clinically be evaluated, and feedback from end-users can benefit the design improvements for the next generation. The data and results above will be important indications for clinicians, operators and patients to accept on market. Clinicians can have more confidence on the new medical devices, and manufacturers can have more assurance on medical devices development. It can be an advance for Taiwan medical and industrial promoting.

INER BreastPET is the first large-sized medical imaging device in clinical trial in Taiwan. With INER's research capability and experience on radiation filed, from fundamental knowledge to clinical trials, achievements of INER BreastPET proved that development of high-end medical imaging devices in Taiwan is no longer too far to reach. We can expect the day INER BreastPET being marketed, that can benefit Taiwan medical promoting and women's health care.



▲ INER BreastPET was moved to NTUH

3-5 The First Nanotargeted Radiopharmaceutical For Cancer Therapy Translated Into The Human Clinical Trials in The World

By Shu-Pei Chiu, Te-Wei Lee

Based on WHO report, in recent years, the world's new cancer cases increased year by year. In 2010 cancer was replace heart disease as the world's top killer diseases. Estimated in 2030, there will be 2,700 million people diagnosed cancer, 1,700 million people died of cancer. So the development of new anti cancer drugs is imperative.

The cancer treatment is usually conducted with surgery, and supported with radiotherapy and chemotherapy. ^{188}Re-Liposome owns the potential to be a radiopharmaceutical for colorectal cancer. Liposome is an artificially-prepared vesicle composed of a lipid bilayer formed by phospholipid. They are biocompatible and biodegradable. Furthermore, it can prolong the pharmacokinetics of encapsulated drugs or radionuclides. For these reasons, liposomes can be excellent drug delivery system. Rhenium-188 (^{188}Re) is a radionuclide used for imaging and therapeutic dual applications due to its short physical half-life of 16.9 hours with 155 keV gamma emissions for imaging, and its 2.12 MeV β emission with a maximum tissue penetration range of 11 mm for tumor therapeutics. The "INER Rhenium-188-liposome injection" has been proved for its ability to accumulate in the tumor tissue by Enhance Permeability and Retention (EPR) effect and to kill tumor cells by βradioactive ray.

▲ INER Rhenium-188-Liposome injection.

The preclinical data, including chemical manufacture and control (CMC), pharmacology, GLP radiotoxicology of ^{188}Re-Liposome have finished and successfully approved of eIND of ^{188}Re-Liposome by TFDA in 2012. The clinical studies are currently performed at Taipei Veteran General Hospital. It is the first nanotargeted radiopharmaceutical for cancer therapy translated into the human clinical trials in the world. We expect the "INER Rhenium-188-Liposome injection" will have contributions in enhancing the health quality of people in Taiwan.

3-6 For Smart and Energy-Saving Life, an Unprecedented New Energy- Saving and Environmental Concept of Plasma Technologies in Taiwan- Flexible and Colorful Energy- Saving Thin Film Solar Blind Modules

By Min-Chuan Wang

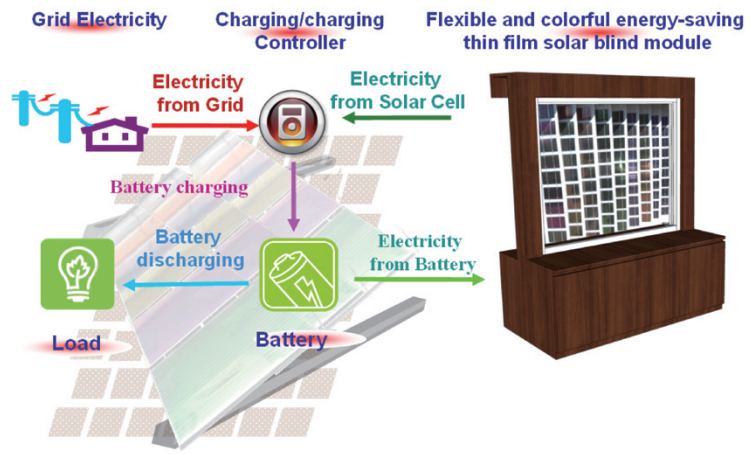
With a growing population on the earth and gradual advancement of industry and technology, energy resources required by human beings also increase. In order to avoid the exhaustion of nature energy resources in the future, programs and researches on various alternative energy resources are carried out vigorously. For energy development, most recent researches focus on discussion and study of solar energy, because solar energy is a natural resource most visible on the earth and the closest to us, and the least environment pollution and energy loss during photovoltaic conversion. It can be considered as the most feasible clean energy resource in the new generation of resources.

In the prior art, the wafer-typed solar cell applied primarily in the outdoor power generation requires high-quality packaging, which inevitably leads to a high packaging cost. And, the frangibility property of the solar cell chip requires good protection, so hard boards and glasses are still dominant materials in packaging. In addition, the wafer-typed solar cells are mainly placed in a large open area, which limits the range of combining with family life, and an urban land cost is also considerable extra expenditure. In order to achieve objectives of energy conservation in buildings and effective utilization of land, currently, in most buildings, the building structure is combined with light-weight glass curtain appearance. In the past, the technology for integrating the thin film solar cell and the building is to form components and the glass as a whole which is then sent to a construction site for installation. However, in this integration manner, the expense for integrating the glass and the solar components increases in the construction cost; besides, glass is a fragile material, so any minor deficiency during construction will break the glass, and as a result, the component is scrapped. Therefore, the future replacement of the solar cell has a higher technical requirement.

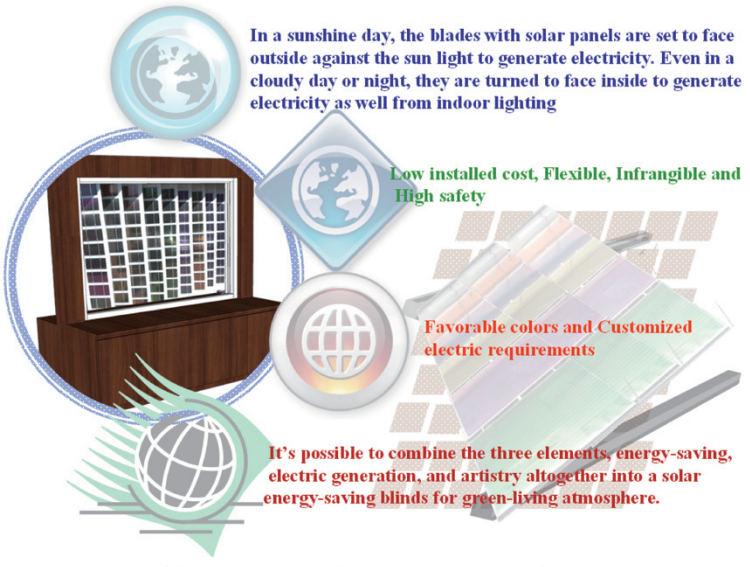
A thin film silicon solar cell has excellent advantages as followed. It is easy to manufacture by a large area, a roll-to-roll (R2R) manufacturing procedure is continuous, and an absorption coefficient for visible light thereof is greater as compared with other kinds of solar cells, thereby facilitating application in daily life. The 20-Watt energy-saving solar blind modules with an effective window area of 100cm×100cm developed by employing R2R plasma coating technologies at INER has the following characteristics. The application of flexible solar cell modules, which is a 100cm×100cm solar blind modules, is equipped with 90 pieces of 10cm×10cm lightweight, thin and flexible solar panels. Therefore, the solar energy-saving blinds can give so much more than before. With the blinds closed during the day blocking the rays of the hot sun, the PV generates the electricity and once the sun goes down, the stored electricity could be used in the night time. Furthermore, the combination of the flexible silicon thin film solar cell and the blind is cheaper and safer as compared with a conventional product combined with the glass curtain. Considering its capabilities, an area of the product exposed to sunlight can be adjusted according to the requirements of users, and thus the electric requirement is completely customized. In appearance, the adjustment of thickness of each layer in the plurality of solar cells may form different color combinations of the plurality of solar cells. Therefore, the thin film solar cell provides components of many colors according to customer requirements, and the user may select a favorable color of the solar shutter,

thereby providing an option for the appearance of the building. Moreover, a flexible thin film solar blind module formed of the hydrogenated amorphous silicon (a-Si:H) can generate power both indoors and outdoors.

Today, environmental friendliness and energy conservation have become a global consensus. Energy-saving solar blind modules have realized the concept of simple life by the integration of photovoltaic (PV) with solar blinds. Therefore, the solar energy-saving blinds can give so much more than before. With the blinds closed during the day blocking the rays of the hot sun, the PV generates the electricity and once the sun goes down, the stored electricity could be used in the night time. The light weight of flexible PV foil makes it suitable for many applications where weight is important. The very thinness of PV foil also enables the aesthetic integration with various materials. By the introduction of flexible and colorful PV modules together with the merit of indoor electric generation, it is possible to combine the three features: energy saving, electric generation, and artistry altogether into a solar energy-saving blinds. When adding one to each and every window in a home, the energy-saving life could be achieved easily with a green-living atmosphere.



▲ Illustration of flexible and colorful energy-saving thin film solar blind module.



▲ Introduction of flexible and colorful energy-saving thin film solar blind module.

4 Current Major R&D Activities

I. Nuclear Safety Technologies

By Tsu-Mu Kao

Over 44 years of devotion, 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 nuclear power plants (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, nuclear energy has proved itself as an efficient alternative and as an important "transition source of power" to the low carbon society. The INER will continue its efforts to the research and development of nuclear safety, and the operational safety of NPPs.

In response to the 2011 Fukushima Daiichi NPP accident in Japan, there will be enhanced studies on the management plan of radioactive wastes, the remediation and clearance practices after a nuclear accident and related decommissioning R&D program. The INER's nuclear safety technology research sets goals at continuously supporting the safety for operating NPPs, maintaining the quality for the constructing Lungmen NPP, 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 2012 will be described in details project by project as follows: (1) Evaluation of the new technique of structure integrity and the new issue on the seismic design of pressure vessel, and studies on the high burn-up fuel cladding properties during operation and dry storage. (2) The development and application of radwaste management technologies for nuclear power system lifecycle project including the volume reduction of decommissioning waste,to develop and apply the core technologies of radwaste treatment and disposal. 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) The project to clear up INER's nuclear facilities including completion of transferring spent fuels out of spent fuel pool of Taiwan Research Reactor (TRR), development of TRU waste container, completion of cleaning two lead cells and one TRU experimental facility building, completion of decommissioning plan for Zero Power Reactor at Lungtan (ZPRL). (4) Industrialization platform development for nuclear technology project. This includes establishing associated R&D on performing 2% Stretch Power Uprate (SPU) for Chinshan Nuclear Power Plant with a significant contribution to the reduction of annual carbon emission, developing the technology for weld overlay of hot leg nozzles and to upgrade the welding apparatuses relevant to the needs of the project, to develop the SCS-2000 Safety Control System which provides a good reference for domestic self-reliant capabilities in terms of the design, manufacturing, and application of nuclear I&C systems, and to conduct structural design of a dry storage steel cask with capacity of 61 to 69 bundles of BWR spent fuels.

1. Study on the Reactor Structure Integrity and Component Behavior

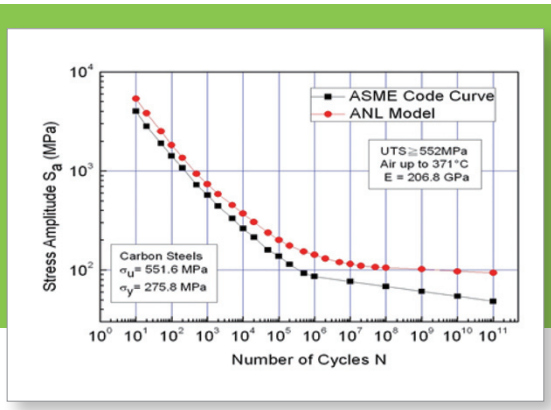
By Lih-Yih Liao

The objective of this project is to study the advanced safety evaluation techniques of the reactor pressure vessel and components. It consists of two sub-projects: (1) Evaluation of the structure integrity of pressure vessel – This work is to study the new technique on structure integrity evaluation as well as the new issue on the seismic design of pressure vessel; (2) Study on the cladding properties and operation performance – It is known that hydrogen embrittlement is one of the major degradation on high burn-up fuel cladding during operation and dry storage. The fracture mechanics is related with the concentration, morphology and orientation of zirconium hydrides. In this work, the improvement of Zircaloy fuel cladding with heat treatment is conducted. The effect of hydrogen embrittlement on Zircaloy fuel cladding related with its micro structure is studied by the fracture measurements of X-specimen.

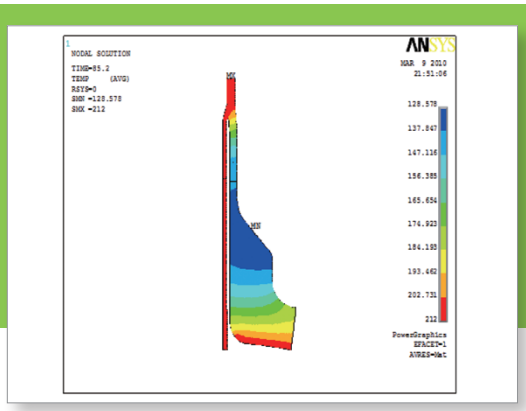
On the evaluation of the structure integrity of pressure vessel, we have completed building the procedure of response spectrum analysis and the tool for fatigue analysis. Also, we have applied the procedure and the tool to carry out case studies using the structure and component of the Lungmen nuclear power plant. On the study of the cladding properties, we focus on Zircaloy-4 cladding with 300wppm hydrogen. Before hydrogen charging, Zirclaoy-4 cladding was heat-treated with stress relief (SRA) or recrystallization (RXA) annealed conditions. The major results are as follows:

(1) The material fatigue properties are collected and the ANL model is studied and compared, as shown in Figure 1.

(2) The detail fatigue analysis (as shown in Figure 2) of a feedwater nozzle has been completed according to NUREG/CR-6909 report. We also develop a user friendly program to simplify the job.



▲ Fig.1 ASME material property and fatigue curve



▲ Fig.2 Stress contour of feed water nozzle

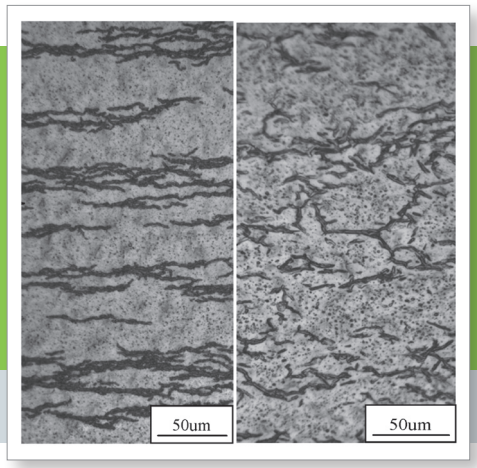
(3) Complete the seismic response analysis of the Reactor Building of Lungmen power plant using SASSI program.

(4) The different hydride morphologies were observed in SRA and RXA cladding, respectively, as shown in Figure 3.

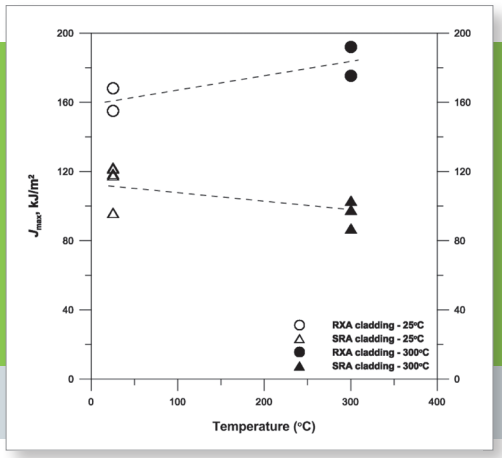
(5) The increases in the fracture toughness of Zircaloy-4 cladding after recrystallization treatment were obtained at both 25°C and 300°C, as shown in Figure 4. That could be attributed to the ductility improvement of Zircaloy materials by recrystallization anneal.

(6) At 25°C, the fracture toughness values decreased with hydrogen concentration level increasing in both of SRA and RXA Zircaloy-4 cladding, as shown in Figure 5.

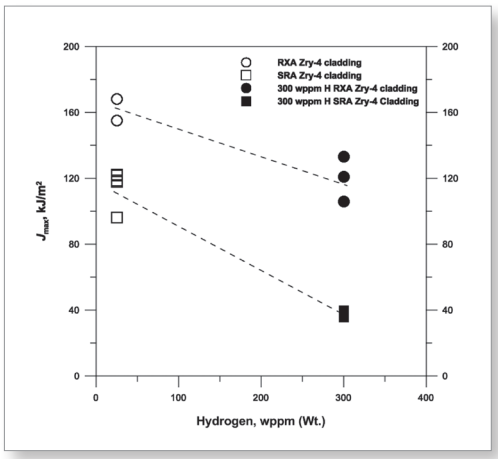
(7) At 300°C, the fracture toughness value of RXA cladding still decreased with hydrogen concentration level increasing, and much less than SRA cladding, as shown in Figure 6.



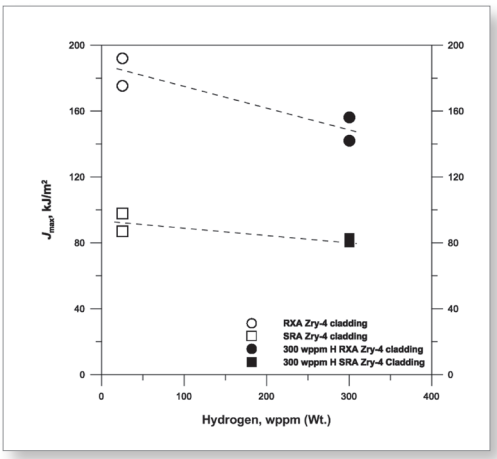
▲ Fig.3 The morphologies of SRA (left), and RXA (right) Zircaloy-4 cladding.



▲ Fig.4 The comparison of fracture toughness between SRA and RXA Zircaloy-4 cladding.



▲ Fig.5 The comparison of fracture toughness between hydrided SRA and RXA Zircaloy-4 cladding at 25°C.



▲ Fig.6 The comparison of fracture toughness between hydrided SRA and RXA Zircaloy-4 cladding at 300°C.

The fatigue evaluation technique developed in this project has been used to assist AEC in reviewing the issue of anchor bolt rupture of the pressure vessel of Kuosheng nuclear power plant. In the coming year, the study will focus on 3D FEM analysis in both the stress analysis of nuclear components and the seismic response analysis of structure. In cladding properties research, the fracture toughness of Zircaloy-4 cladding could be improved by recrystallization anneal treatment. The crack propagation in RXA cladding would be arrested due to its less continuous hydride strings than SRA cladding. RXA cladding has better resistance of hydrogen embrittlement than SRA one. The results could provide the fuel designer with the improvement of cladding materials by heat treatment.

2. The Development and Application of Radwaste Management Technologies for Nuclear Power System Lifecycle

By Tsong-Yang Wei

To make less impact on the environment as well as the public, the radwaste generated from nuclear power facility operation and maintenance must be 'safe' and 'volume-reduced'. In order to safely apply nuclear energy, both the nuclear facility decommissioning and radioactive wastes management are the major concerns.

This project is aimed to develop radwaste management related technologies required for nuclear power system lifecycle. The strategy is to perform studies on the current facilities of INER for establishing the core technologies at first. Next, the dismantling of unused nuclear facilities and the treatment of problematic radwaste that have been stored long ago in INER will be gradually carried out. The established technologies will support the operation of domestic nuclear power plants as well as the management of decommissioning radwaste in the future.

In 2012, the achievements of INER are summarized as follows. For the volume reduction of decommissioning waste, work items such as "Study on using visual feedback technique to assist control", "Adsorption of radioactive ions in TRR spent fuel poor water", "Stabilization and canning of TRR spent fuel in the hot cell", "In-situ clearance measurement using a movable gamma-ray counting system", and "Establishment of the remote taking-out equipment for high-active wastes" have been conducted. For the treatment of special radioactive liquid waste, projects including "The treatment of radioactive waste extraction solvent from Mo-99 process", "Organic wastewater treatment processes and inorganic adsorbents for radionuclide removal" have been carried out. For the final disposal of radwaste, Hydrogeology monitoring and assessment technology for nuclear facility has been investigated.

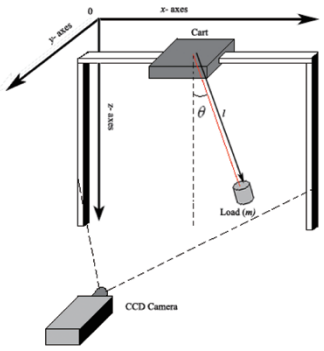
To develop and apply the core technologies of radwaste treatment and disposal are the main value of this project. Through the valuation and validation process, the developed technologies will ensure the safety and domestic possession while they are applied to the nuclear power plant decommissioning.

2-1 Study on using visual feedback technique to assist control

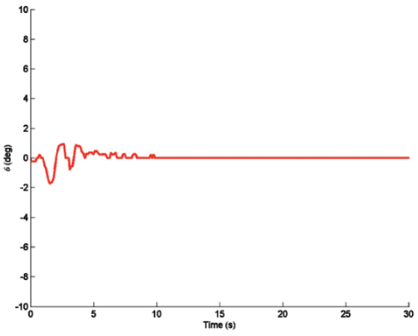
For sakes of radiation and industrial safety, it needs remote control based method to operate the crane when removing the core components of nuclear power mechanism. The implementation of visual feedback technique to assist control is in accordance with the needs of future decommissioning. Therefore, the purpose of this project is to develop a switching method to control the crane, and to utilize error-free image sensor when the crane motion is close to the destination to derive the precise control signal. The control signal can provide correct information to stop the crane at destination.

Image processing task of tracking blocks, instead of the whole image is proposed here to increase the computational speed. The tracking block is a rectangle, and covers the tracking point. The tracking point is the center of tracking patch, and must be smaller than the size of tracking block. Two tracking blocks are set to obtain the desired locations for calculation of the load swing. The distance between the first and the second tracking blocks determines the resolution of swing angle. Tracking blocks also follow the tracking point movement. Since the processing area is small, the calculation time will be faster to achieve the maximum performance of the camcorder.

The research refers various domestic and foreign visual feedback techniques; meanwhile, we compare the advantages and disadvantages of the various image sensors to develop precise control technology, in order to control technology with the TRR reactor waste dismantling of lifting planning in the future lifting operation. In the case, it can ensure to inhibit the swing and accurate positioning, and also achieve security and the exact requirements of the dismantling operations.



▲ Visual tracking and crane model.



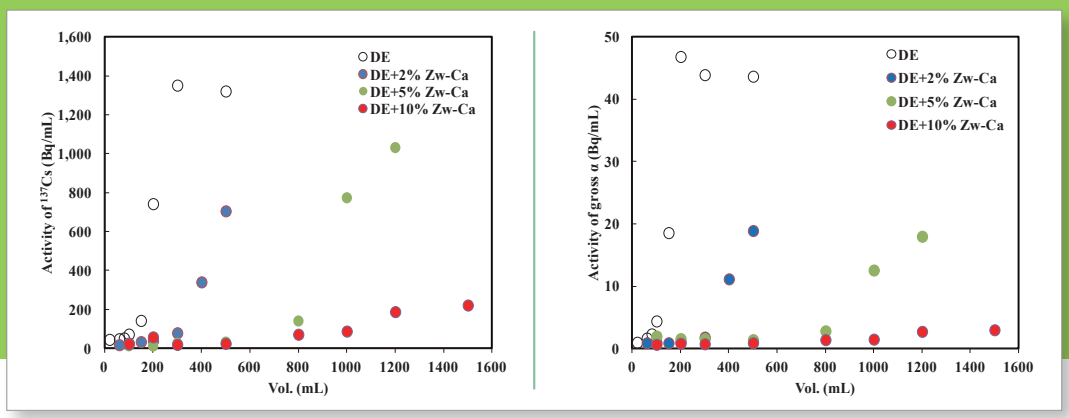
▲ The results of visual feedback control by 5kg payload.

2-2 Adsorption of radioactive ions in TRR spent fuel poor water

To maintain the purity of water in the fuel poor is significant during the operation of nuclear reactor. In the decommissioning and cleanup phase, water pond will be an alternative buffer facility for the temporary storage of activated elements and radwastes. However, the underwater tasks would be seriously disturbed in the presence of high concentrations radioactive ions and suspended solids. The previous study shows that the ionic ^{137}Cs, ^{90}Sr, and alpha-emitters could be removed by diatomite-based ceramic filter. If the higher adsorption capacity adsorbents are employed, the amounts of spent radioactive adsorbents will be obviously reduced.

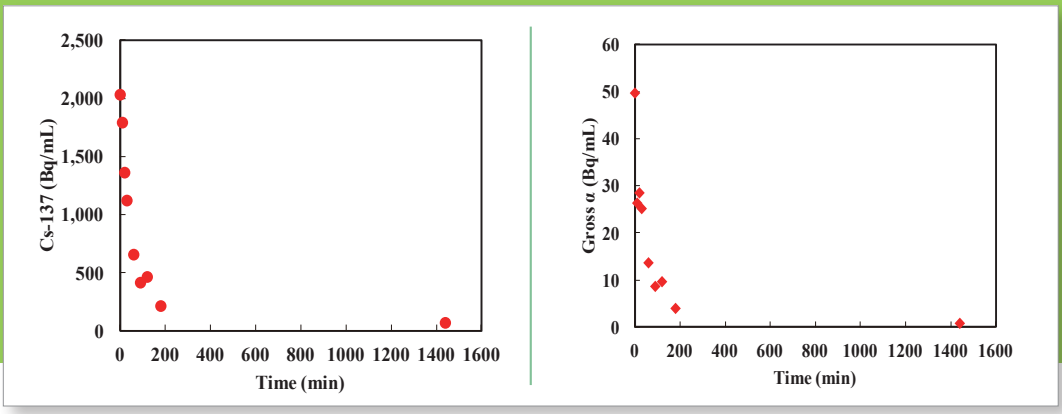
In the previous work, it was found that the radioactive ions could be adsorbed by diatomite species (represents as DE). When small amounts of Zw-Ca powder (2~10 wt.%) were mixed with diatomite powders, the adsorption capacity was dramatically increased approximately 100 times. However, packing with powder adsorbents will lead to high operation pressure and materials outflow problems. Hence, the powder species will be granulated in practical operations. The adsorption kinetics of ^{137}Cs and alpha-emitters by granular Zw-Ca were performed. The adsorption rates of ^{137}Cs and alpha-emitters using granular Zw-Ca were slower than that of the powder Zw-Ca due to the diffusion resistance.

In summary, the adsorption capacity of Zw-Ca is much higher than that of diatomite, and the secondary wastes will be obviously reduced. Furthermore, the application of granular Zw-Ca is easy to be retrieved after treatment.



▲ Breakthrough curves of ^{137}Cs (x: treated volume, y: activity concentration of effluent)

▲ Breakthrough curves of alpha-emitters (x: treated volume, y: activity concentration of effluent)



▲ Adsorption kinetic of ^{137}Cs by granular Zw-Ca (x: contact time, y-residual activity concentration)

▲ Adsorption kinetic of alpha-emitters by granular Zw-Ca (x: contact time, y-residual activity concentration)

2-3 Stabilization and canning of TRR spent fuel in the hot cell

In the progress of stabilizing and canning of spent fuels of Taiwan Research Reactor (TRR), several countermeasure processes are conducted to improve the processing quality and capacity such as changing cutting method, setting up medium size heat treatment powder collecting pan, updating the calibration of helium leak detector system, renewing the heat treatment control computer system and also revising the procedure of transferring sealed outer cans of stabilized spent fuel powder out of the hot cell.

Scheduled progresses are fulfilled as follows, to finish stabilizing 11 TRR spent fuel rods, canning and sealed welding 9 outer cans of stabilized spent fuel powder and shipping 11 spent fuel rods from the TRR spent fuel pool into the hot cell.

Totally 34 spent fuel rods, up to 87% of the project goal, have been stabilized as shown in the table1. And all of the spent fuels in TRR spent fuel pool were removed and the pool radiation activity was greatly reduced to benefit the future cleanup works.

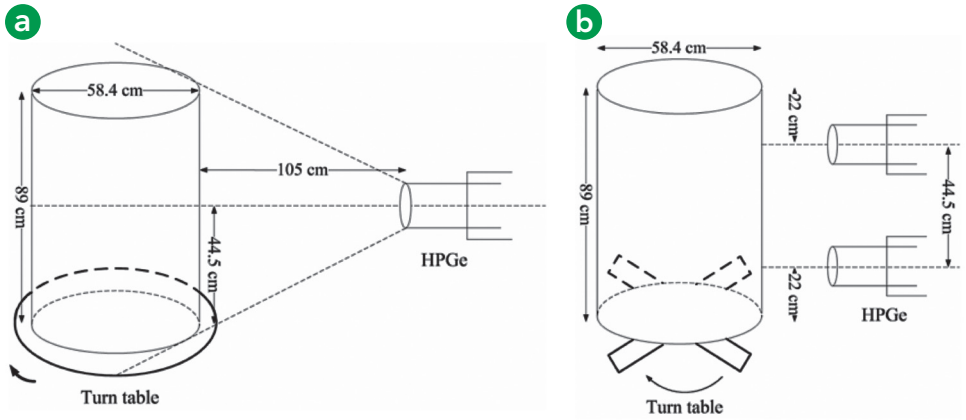
Table 1

Spent Fuel type	Number of SF rods in the pool	Number of SF rods shipped to the hotcell	Number of stabilized SF rods	Number of sealed cans of stabilized SF powder	Number of sealed cans shipped to storage cask
Spent Fuel S canister	12	12	12	16	16
Spent Fuel L canister	23	23	22		
U Test rod	2	2	0		
Th test rod	2	2	0		

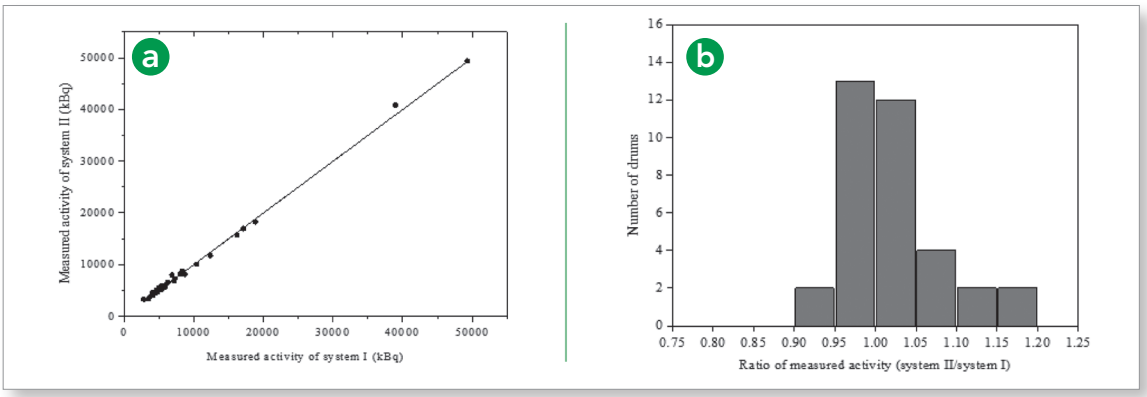
2-4 In-situ clearance measurement using a movable gamma-ray counting system

According to "Regulations on Clearance Level for Radioactive Waste Management" issued by the Atomic Energy Council, Executive Yuan in 2004, the radioactive waste is feasible to be released if its activity of specific activity is lower than the regulatory value. To fulfill the policy on waste reduction and to meet the need for clearance technique, INER has set up the Clearance Measurement Laboratory (CML) and established the techniques on instrument calibration, quality control, and whole-drum measurement, etc.

The CML introduced the movable gamma ray detection system, ISOCART, specifically for measuring large radioactive waste. First, the performance of the movable gamma ray detection system was evaluated by measuring the low level radioactive cemented barrels, and the results were compared with the ultra-low level gamma ray detection system (AQ2) and the plastic scintillator detector (SWAM2). The results showed that the deviations were within 20 % in the tests of 35 low-level radio waste barrels, where the deviations were within 10 % among the 30 tested barrels. It was demonstrated that the movable gamma ray detection system can run stably and accurately. Besides, the cemented barrels were arranged in square (with four barrels), in cube (with four and eight barrels) and in rectangular (with six and eight barrels) to simulate the geometry of large radioactive waste. The results of the measurements showed that the deviations were consistently within 20 %.



▲ (a) Illustration of the measurement geometries of (a) the movable gamma-ray counting system and (b) two-HPGe-detector counting system



▲ The linearity and ratios of the measured activities of two-HPGe-detector counting system to the movable gamma-ray counting system

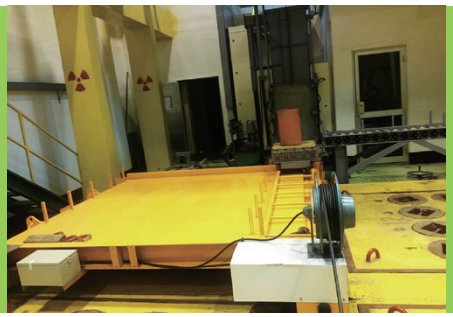
2-5 Establishment of the remote taking-out equipment for high-active wastes

For conditioning the high-active wastes stored in uderground vault 015D (hereinafter referred to as "015D vault") of INER, we are developing an underground remote taking-out and repacking technologies to raise the storage safety of those wastes.

This year (2012) we finish the cold test of the functions of the remote taking-out equipment and its peripheral units including shielding storage container and transfer way. Besides this, we also established the preliminary operation procedures for remote taking-out and repacking.

After the cold test of the remote taking-out equipment and its peripheral units in 2012, we will further execute the hot test of them to ensure their functions and try to actually taking out a small amount of the high-active wastes in vault 015D in the year of 2013.

▲ Remote taking-out equipment

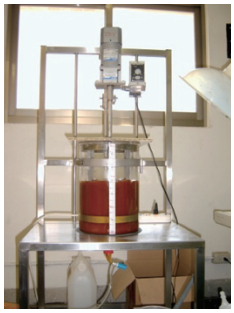


▲ Transfer platform car

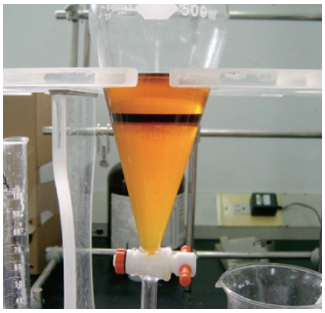
2-6 The treatment of radioactive waste extraction solvent from Mo-99 process

The Mo-99 liquid waste, which were stored in INER, included 12 tanks of high acidic inorganic solution and 6 tanks of organic waste extraction solvent. By self-developed treatment process and equipment, the radioactivity of inorganic solution was decreased to acceptable level. The remaining nitrate and mercury ion in the inorganic solution were needed to be removed. The gross alpha and beta radioactivity of waste extraction solvent were very high and needed to be removed extracting by alkaline solution. Nuclides, such as Cs-137, Sr-90, Pu-238/239 and Am-241, were extracted from organic extraction solvent to alkaline solution. The treated waste extraction solvent could be incinerated for safe disposal, and the alkaline solution would be then neutralized and treated by bone char and/or zeolite via adsorption to remove nuclides to meet the wastewater discharge limitation. After the treatment of Mo-99 waste solution, the risk of radioactive material leakage is decreased.

▲ Storage tank of waste extraction solvent



▲ Treatment of waste extraction solvent



▲ Settling: Three phase formed

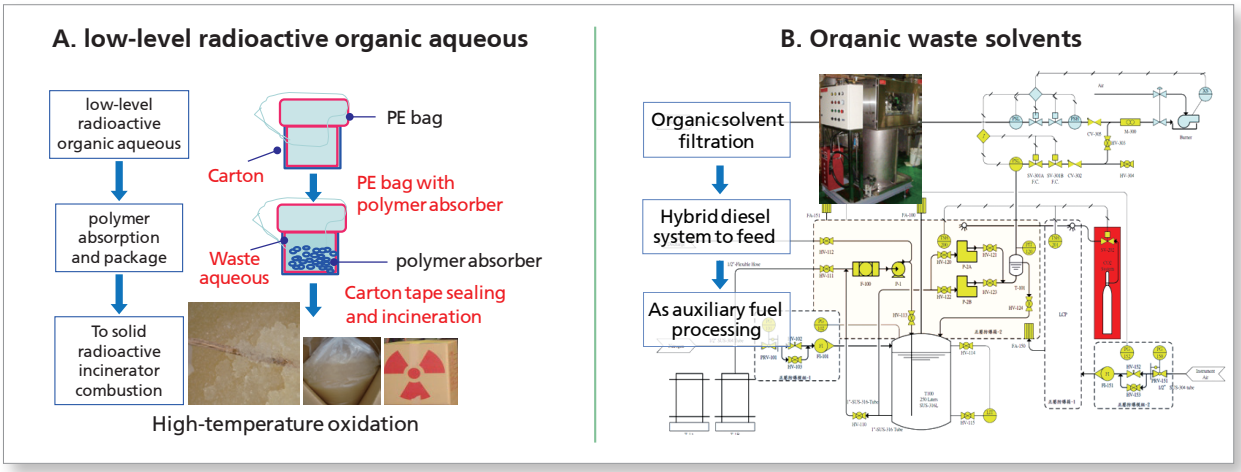
▲ Storage of treated solution

2-7 The study of radioactive organic wastewater treatment

The treatment strategy of radioactive organic wastewater was to separate it at first then to treat it step by step with the characteristics of liquid layer.The radioactive organic wastewater was separated into three layers, the organic layer, aqueous layer and the bottom gel mastic. The organic layer was 23% of the total ingredients (no chlorine), the intermediate layer occupied 75% of the total (containing 0.7% sodium chloride) aqueous solution, the bottom of mastic was about 2% of the total (containing 0.94% chlorine ion). The aqueous layer of organic waste was with total carbon content about 20,000 ppm. The combustion test shows good treatment performance and all samples in high temperature incineration can be decomposed completely.

The radioactive waste incinerator has been operated for 200 batches in which 3,000L of low-level radioactive organic aqueous solution has been treated. The process was operated smoothly and the emission values were far below the regulatory limit. Furthermore each kilogram of polymer absorber can absorb 45 kg aqueous solution to form a solid combustible material and can be decomposed by high-temperature oxidation.

Organic waste solvents were diesel miscible and had similar calorific value of diesel. Therefore, they are to be used as solid radioactive waste incinerator auxiliary fuel, test run will begin in next year (2013). It is expected to save fuel diesel consumption, and can properly treat such waste liquid.



▲ Polymer absorbed and high-temperature oxidation decomposition

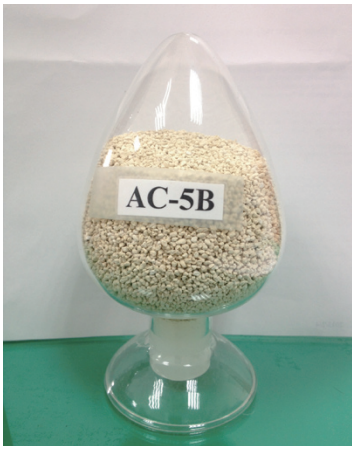
▲ Used as incinerator auxiliary fuel

2-8 Development of inorganic adsorbent for the removal of actinides and lanthanides in wastewater

The treatment of spent fuels generated from nuclear power plant will accompany various kind of radioactive waste. To ensure environmental sustainability and the continuous development of nuclear industry, safe and efficient approaches of radioactive waste treatment, disposal and storage are essential. Among the radioactive waste generated, great attention must be paid particularly to the treatment of wastewater containing actinides and lanthanides, such as U, Pu, Am, Np and Cm, because these radionuclides have long half life and will emit alpha radiation during their decay process.

In responding to the treatment of the problematic actinide and lanthanide-containing wastewater, INER has developed inorganic adsorbent called AC-5B specialized for the removal of actinides and lanthanides. The approach developed is simple and cost effective comparing with the traditional methods

of wastewater treatment, including chemical precipitation (usually require large equipment and space, with high cost), evaporation (energy consuming, more complicated equipment), and membrane filtration (high maintenance and installation cost). INER's AC-5B inorganic adsorbent exhibits excellent radiation resistance, hydraulic performance, mechanical strength and good adsorption capacity. Its particle (granule) size can be controlled within 0.5~2 mm which is suitable for column operation. Moreover, the adsorbent is low cost comparing with other commercially available products in the world. Since AC-5B adsorbent is 100% inorganic, it is stable in the final waste form. The technology for the production of AC-5B is developed locally with procedures been tested and verified to give high quality products. Besides treating wastewater containing actinide and lanthanide, AC-5B also shows good removal efficiency for other common radionuclides such as Cs-137, Sr-90 and Co-60. Currently, the adsorbent has been produced and implemented in INER's liquid waste treatment plant. Patent application for the adsorbent is undergoing. It is hoped that in the future, this technology can be applied to the treatment of wastewater in domestic/foreign nuclear facilities.



▲ INER's AC-5B inorganic adsorbentdecomposition

▲ INER's AC5-MX inorganic adsorbent (modification of AC-5B)

2-9 Hydrogeology monitoring and assessment technology for nuclear facility

In order to provide control factors for protecting natural environments of site, technology for hydrogeology monitoring and assessment has been developed. System build up has been completed from view point of practical and feasible skills. This project completed the simulation and assessment of radioactive migration and potential of groundwater flow system for the target site. A pioneered system for the purpose of pump-treat-injection has been designed and manufactured, resultant performance was tested and improved. In the future, it will provide an alternative facility to enhance environmental protection.

▲ Tracer test for groundwater flow system

▲ Monitoring of infiltraction for shallow land

3. Clearing Legacy Nuclear Facilities

By Ling-Huan Chiao

In order to fulfill the government assignments, INER has constructed 41 nuclear facilities such as research reactor, nuclear fuel cycle laboratories, radioactive waste processing and storage facilities, and ionizing radiation application facilities etc. in the past 40 more years. When the missions were completed, facilities stop operating. To meet the radiation and environmental safety requirement and internal needs for facility site recovery and reuse, INER sets up a project to proceed with nuclear facilities clearing step by step. This project complies with the nuclear safety policy and aims to achieve a frame work that would release the public from worries in uncertainty to the radioactive waste and would lead to a sustainable environment.

To implement nuclear decommissioning and radioactive waste management technologies that INER has developed, the major accomplishments of this project for year 2012 are as follows,

- Development of greater than class C waste container,
- Installation of monitoring system on TRR biological shielding block waste,
- Completion of cleaning lead cell 115 and 116,
- Revision of working permit for radioactive contaminated metal melting facility,
- Completion of cleaning TRU experimental facility building 016,
- Completion of decommissioning plan for Zero Power Reactor at Lungtan (ZPRL),
- Completion of a study of the air-gap membrane distillation performance,
- Incineration of 42 MT combustible radioactive wastes.

The achievement made in this year are definitely positive beneficial to the follow-up.

3-1 Development of greater than class C waste container in Institute of Nuclear Energy Research

According to Regulations on Final Disposal of Low Level Radioactive Waste and Safety Management of the Facilities, it is forbidden to dispose of greater than class C wastes without permission from the authority. However, the selection of low level radioactive waste disposal site was still on going; the disposal of greater than class C wastes cannot be expected in the near future. During the operation phase and decommission phase, some amounts of greater than class C wastes were generated, and the spaces of waste storage warehouse can be expected to be insufficient nowadays at INER.

To increase the storage capacity, a safe and compact container will play a significant role. Conclusively, the container should provide multi-functions including transportable, safely storable, stackable, radiation shielded, vapor ventilated, particle filtrated and so on. This kind of container has been certificated and employed for storage of radioactive wastes by several nationals' decommissioning projects.

After auxiliary systems of the storage facility are upgraded at INER, the certified container will be applied to contain greater than class C wastes. The main advantages of using the container are better storage capacity and improvement on waste management safety.

▲ TRU-Shield containers

▲ Stacking storage

▲ 55 gallon stainless steel drum

行政院原子能委員會核能研究所 函

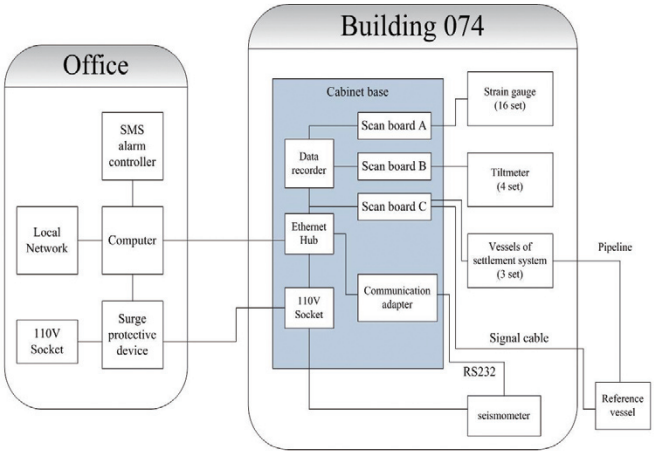
所長 馬殷邦

▲ Application for authority.

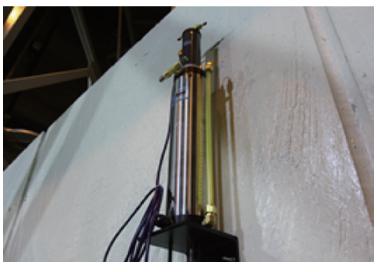
3-2 Monitoring system for TRR biological shielding waste

Decommissioning project of TRR (Taiwan Research Reactor) is progressing. The reactor biological shielding block was moved to the dismantling building 074 for SAFSTOR in 2002. A monitoring system, equipped with tiltmeters, settlement systems, 3-axi strain gauges, data collector and seismometer, was installed to enhance the SAFSTOR of reactor assembly waste in 2012.

The safe monitoring system monitors the settlement of foundation, strain of steel frame, earthquake and inclination of structure. Four sets of tiltmeter and additional vessels of the settlement system were installed at the four aspects of TRR reactor assembly waste. A reference vessel was placed on the chimney in the west of dismantling building 074 for the measurement of relative settlement referred by the difference of liquid level. Sixteen sets of 3-axis strain gauge were installed on the octagonal steel frame, which located on the base of TRR reactor assembly waste. The seismometer was installed on the ground nearby the northeast of TRR reactor assembly waste. All data will be transmitted automatically to data computer. Data and charts will be recorded and analyzed by the program of data computer, then the real-time monitoring of structure and long-term monitoring database will be available. The stabilities of structure and geology and the influence of natural disasters on TRR reactor assembly waste could be derived from collected data to ensure the SAFSTOR.



▲ Monitoring system structure

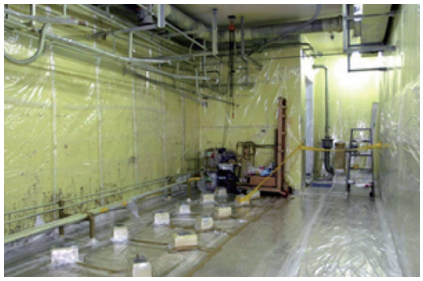


▲ Additional vessels of the settlement system

3-3 Clearing of the trans-uranium contaminated facilities

The goal of the project for the clearing of trans-uranium contaminated facilities in Building 016 of INER has been accomplished, i.e. the building has met the criteria of low radiation and low contamination. Two large-scale glove boxes of highly -contaminated (Unit 20 and Unit 21), five large-scale liquid waste tanks, all the analytical lead-cell line, waste liquid pipelines, treatment of liquid waste stabilization, and high vacuum system contamination duct have been successfully dismantled.

Based on the approved working plan, the systematic functional test for three isolating working areas were executed, including dismantling area in room A56, cutting area in room A55, and packaging area in room A43. The equipments for radiation system monitoring and recording were also examined. Some other preparation task including personnel training was also finalized. Annual goal is achieved with both industry and radiation safety requirement. After several times of radiation detections for each demolition work area, the building has reached the criteria of low radiation and less contaminated. "Building No.16 dismantling of the Trans-Uranium Contaminated Facilities Technology and Development Plant" has been successfully implemented.



▲ The Basement A56 in Building 016

▲ Post dismantling of the Basement A56

3-4 Decommissioning planning of ZPRL

ZPRL (Zero Power Reactor at Lungtan) was designed and established by INER. This type of reactor used water as moderator and graphite as reflector. The original power was 10 KW and was increased to 30 KW later. The design purposes are to provide nuclear experiments and people training.

ZPRL was built in 1970 and reached critical operation condition on February 2, 1971. No accident occurred during the operation period and maintained an excellent operation record. After missions were completed, the spent fuels were removed from the reactor and shipped back to the US. The status of ZPRL is permanent shutdown.

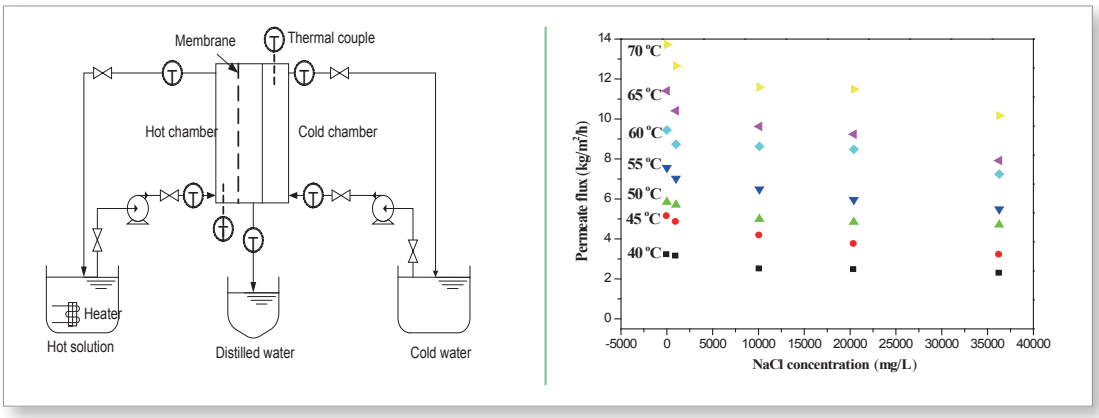
Radioactive wastes survey and dismantling methods research were performed in 2012 to apply the decommissioning permit. The Decommissioning Proposal of ZPRL was submitted to the authority, AEC for decommissioning permit based on Nuclear Reactor Facilities Regulation Act and its enforcement rules for the implementation. It is under review process now. The decommissioning project will be divided into 3 phases. The first phase is planning of facilities dismantling. The second phase is facilities dismantling. The third phase is building cleaning and recovery. The utilities include electric power, fire fighting, communication, crane and radiation monitoring will be preserved, and the others will be dismantled. The purpose of the decommissioning is to achieve the criteria of restricted usage, so the building can be reused.

▲ Sampling of the internal parts of the ZPRL reactor in the pool.

▲ Site survey by officers of Fuel Cycle and Materials Administration and review committee for "The Decommissioning Proposal of ZPRL".

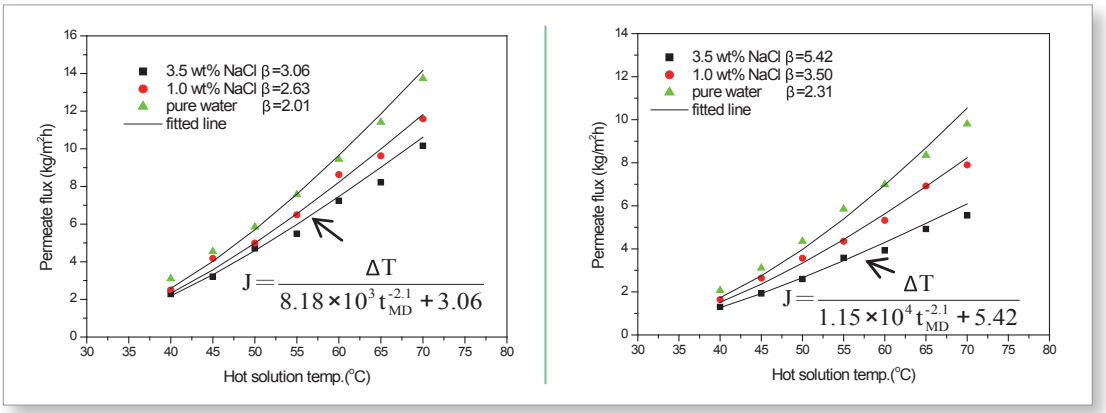
3-5 A study of the performance of the air-gap membrane distillation

Membrane distillation is a promising green technology applied to desalination and wastewater treatment, for it could be driven by the solar and waste thermal energy. Simulation solution, sodium chloride solution with the concentration up to 3.5 wt%, was treated by the flat air-gap membrane distillation (AGMD) equipped with PTFE (polytetrafluoroethylene) membrane area of 0.1 m^2 at cold side inlet temperature of 25°C in this study. The experimental results show that the permeate flux increased from 3.2 to 13.8 kg/m^2h when the hot side inlet temperature increased from 40 to 70°C. The permeate flux was not significantly affected by the two flow modes, co-current and counter-current. The permeate flux increased approximately 30% and salt rejection was not significantly affected, when the nominal pore size of PTFE membrane increased from 0.25 to 0.45 μm. The permeate flux decreased approximately 25% when the sodium chloride solution concentration increased from 0 to to 3.5 wt %. The rejection rate ranged from 98.3 to 99.9%. Moreover, direct comparison of the experimental results with the proposed modeling prediction shows a fairly good match.



▲ Schematic diagram of AGMD system

▲ Effect of different solution concentrations and temperatures on the permeate flux for PTFE membrane with the nominal pore size of 0.45 μm.



▲ Comparison of the experimental results with the proposed modeling prediction for PTFE membrane with the nominal pore size of 0.45 μm.

▲ Comparison of the experimental results with the proposed modeling prediction for PTFE membrane with the nominal pore size of 0.25 μm.

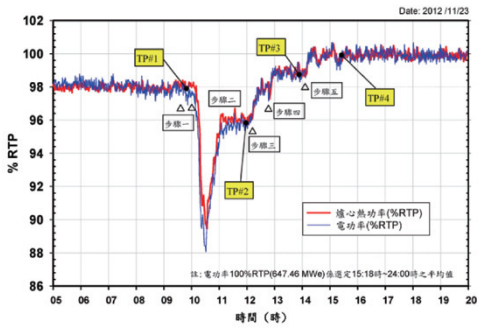
INER steadily proceeds with nuclear facilities clearing and volume reduction of radioactive waste on the basis of nuclear decommissioning and radioactive waste management capabilities that INER has developed. The project "Clearing nuclear Legacy Facilities" aims to solve the physical problems at home. On the other hand, practice makes perfect. Those experiences, such as categorization, decontamination, disassembling, and radioactive waste management, accumulated in the process of on-site exercises would be of good references for the probable decommissioning project of domestic nuclear power plants in the near future.

4. Industrialization Platform Development for Nuclear Technology

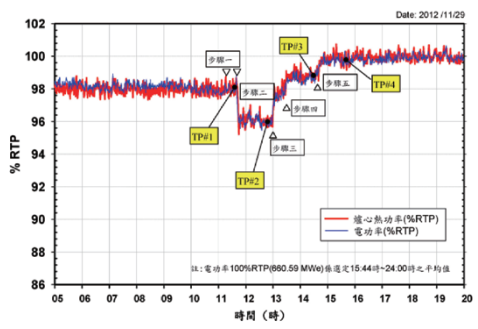
By Lain-su Kao

It is expected that the domestic electricity demand will be continuously increasing. Also, it is required internationally that the carbon dioxide emission be reduced every year. It turns out, in this country, the nuclear industry and its electricity production are becoming more and more important in the aspects of stabilizing energy supplies, reducing carbon emission, and maintaining stable economic development. In view of this, it is essential to actively proceed the nuclear industrialization work at current stage, such as establishing independent safety analysis technology, improving safety and performance of the plant operation, establishing maintenance/repairs technology and capability for plant equipments and components, technical specification development for plant instrument &control and related components, licensing technology development for nuclear industrialization, and establishing dry storage system and test center for spent fuels. In all, the goal of nuclear industrialization is to improve further the technologies in the aspects of safety analysis and maintenance/repairs of nuclear power plants in operation. The achievement of the goal will not only enhance the safety and performance of the plant operation but also be helpful to let the nuclear technology be rid of the commercial monopoly from foreign vendors.

(1) The subprogram is to establish associated R&D on perform 2% Stretch Power Uprate (SPU) for Chinshan Nuclear Power Plant Units 1 and 2. Through the implementation of the SPU program, the electrical energy output is expected to be increased KW-hr per year with corresponding reduction of carbon dioxide emission by 126,000 tones through replacing equivalent fossil fuel. It ends that the subprogram has a significant contribution to the reduction of annual carbon emission.



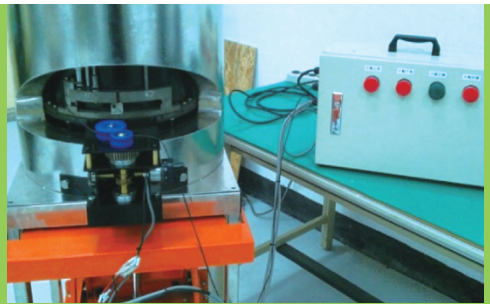
▲ Fig.1 Chinshan Unit 1 SPU Power Ascension Test



▲ Fig.2 Chinshan Unit 2 SPU Power Ascension Test

(2) In 2012, efforts were made to develop the technology for weld overlay of hot leg nozzles and to upgrade the welding apparatuses relevant to the needs of the project. Three sets of welding equipments in total were retrofitted. A full-scale mockup of reactor-hot leg nozzle was also built for welder training. The two welding procedures, one for high-deposition welding and the other for duplex stainless steel, were established. In addition, an automatic annulus scanner for Phased Array UT inspection was developed. It makes possible the UT inspection of Reactor Internal Pump casing welds to be conducted in a narrow space of 18 mm high.

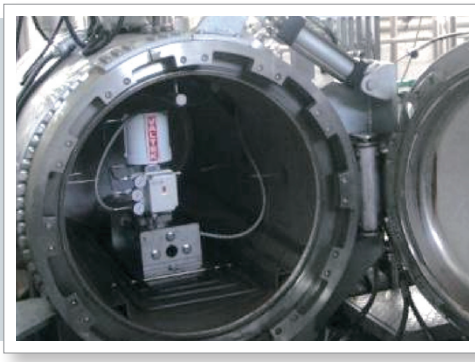
▲ Fig.3 Welding machines for overlaying the reactor-hot leg nozzles



▲ Fig.4 Automatic Phased Array Inspection of the RIP Mock-up

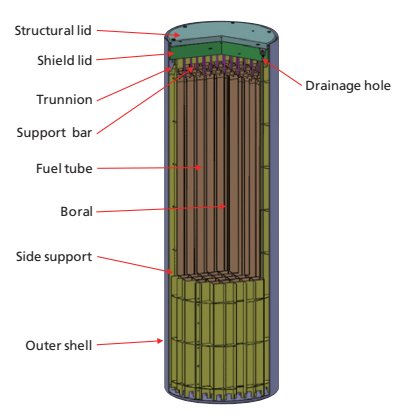
(3) The SCS-2000 Safety Control System which provides a good reference for domestic self-reliant capabilities in terms of the design, manufacturing, and application of nuclear I&C systems is developed in this project. We also establish the test and verification capability to assure that control valve's positioner perform its safety functions under design basis event environment qualification. It can be used not only in the nuclear grade I&C system, but also in the I&C system of other industry which requires high reliability. The program can be applied further to promote domestic industry's capability of manufacturing nuclear grade control valves.

▲ Fig.5 SCS-2000 Safety Control System

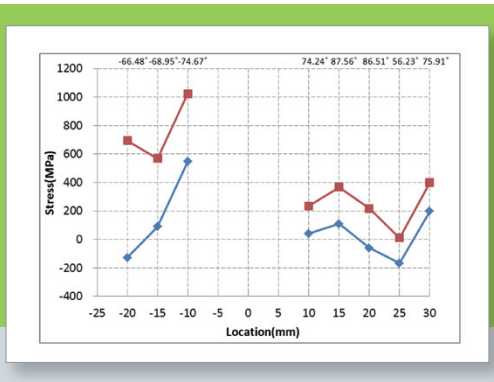


▲ Fig.6 Positioner perform its safety functions under design basis event environment qualification

(4) This project conducts structural design of a dry storage steel cask with capacity of 61 to 69 bundles of BWR spent fuel. Through the project, the technologies on structural design, analysis verification and measure technique for dry storage system are established. It also helps to resolve the technical problems of interim storage of spent fuel in Taiwan.



▲ Fig.7 High capacity dry storage cask



▲ Fig.8 Weld residual stress of dry storage cask

The program is conducted in line with the demand of domestic industry. Through the integration of regulation, review, analysis, assessment, and design, the program is intended to cover short-term technology establishment, mid-term technology verification, and long-term technology transfer &service. Emphasis is put on the integration of the central technologies, which are unique, leading, and demanded. These central technologies are subsequently applied for industrialization of related nuclear service to assure the safety of the public and promote the performance of nuclear power plant operation. In the program, a convincible and competitive research and development team is formed and the fields involved will cover all related nuclear technologies. Also, through the active deployment of the possessed independent and specific nuclear technology, a safer and more efficient nuclear power generation is expected. In the meantime, moving forward in line with the target of international carbon dioxide emission, the development of domestic nuclear industrialization can be extended further to the world level such that nuclear energy becomes a necessary choice for sustaining the stable domestic energy supply. In all, the prospect of the program is to promote the nuclear technology and embed its root into the domestic industry platform, and meanwhile, to establish an objective and judicial image for domestic nuclear industry.

II. Environment and Energy Technologies

By Ying-Sheng Lee

INER, recognizing the importance of global warming problems, has conducted research and development program on new and renewable energy to meet the challenges of environmental and energy sustainability as well as to create more green jobs and strategic emerging industries. The research topics in the program are: environmental plasma, photovoltaic systems, solid oxide fuel cell (SOFC) power system, clean carbon, microgrid, wind power, cellulosic ethanol production and energy industry technologies.

In environmental plasma technologies, efforts have been made on perfecting the thermal plasma torch, and treating the waste gases and biomass gasification, as well as applying low-temperature plasma coating on thin-film solar cells and other energy-saving devices. The project of photovoltaic systems development is focused on R&D of high concentration photovoltaic (HCPV) system, polymer solar cell, upgraded metallurgical grade (UMG) silicon solar cell and copper-zinc-tin-sulfide (selenium) (CZTS) thin film solar cell. SOFC power system is one of the unique technologies in INER. A long-term test of 5047 hours (V=0.837 V, I=300 mA/cm2, P=251 mW/cm2) for an INER's MEA showed a low degradation rate of 0.38%/khr, comparable to that of international levels. Collaboration and technical transfers of kW SOFC systems with local industry partners are now pursued. The program of clean carbon consists of two projects: (1) Commissioning of an integrated test facility, which includes gasification, system design and optimization, warm/hot gas separation and clean-up; and (2) Carbon capture technology development, which focuses on pre-combustion capture with solid sorbent. A pioneered "Microgrid Test Field" of 100 kW scale was constructed in INER. Power electronics technology was developed to connect microgrid to utility power. A real time monitoring platform with intelligent control and energy management system for a smart house was also established to display load behaviors and forecast renewable power generation. For wind power technology development, blade design of a 150 kW wind turbine was modified and upgraded to fulfill the requirements of IEC 61400-1 Class-IA. The cellulosic ethanol pilot plant is currently acting as a platform for promotion of biomass-to-ethanol conversion technology. Both of biomass pretreatment and recombinant xylose-fermenting yeast technologies are recognized as having potential for commercial application. MARKAL Elastic Demand (MED) energy model is established. The MED model is an extension of standard MARKAL model with more completed parameters to adjust the price elasticity setting, which can be used to evaluate the effects of energy prices on energy service demand for each sector. Our study also indicated that, in addition to renewable energy, CCS technology is essential for Taiwan to meet long-term CO_2 reduction target.

1. Developments and Applications of Environmental Plasma Technologies

By Chi-Fong Ai

According to the national energy and environment policy as well as the technical advantage of plasma technology over decades of accumulated experience at INER, the mission has devoted to the development of environment- protection energy technology as well as the green environment energy-saving technology. In the year of 2012, the "environmental plasma" project thus was carried out with two subprojects, i.e., "plasma technology research and development of plasma technologies on the environmental protection and energy production and "Development and promotion plasma technologies on the green surface engineering." The first subproject focused on perfecting the thermal plasma torch, treating the waste gases and biomass gasification with plasma-assisted means. The latter subproject applied low-temperature plasma coating technology on thin-film solar cells and energy-saving applications. Six selected outcomes of this project are highlighted as follows.

1-1 Research and developments of plasma technologies on environmental protection and energy production

Development of a novel low-current three-sectional plasma torch and its application to waste gas treatment

The unique high-temperature plasma technology at INER has been effectively developed and applied to the environmental and energy area. In this year the core technique of high-temperature plasma technology, i.e. direct current plasma torch, had been further advanced, and a new three-sectional plasma torch had been developed. In comparison with the previous two-section plasma torch, the key feature of the new torch was its capability of operation at a much lower current. Since the erosion rate of the torch electrode is proportional to the square of its operating current, the lifetime of this new torch is expected to be enhanced at least by a factor of 2~4 (i.e. maintenance period > 2000 hours for operation at 12 kW). This new torch had been technologically transferred to a domestic semiconductor equipment company, which had applied it on the destructive abatement for the green-house gases (GHGs), such as perfluorinated compounds (PFCs), exhausted gases from the manufacturing processes commonly used in the semiconductor industry. The developed technology can reduce the emission of GHGs and improve the air quality. It can also assist domestic company to use local technology and equipment, to reduce the threat of monopoly from foreign equipment company such as Korea, and to promote the technology localization and international competitiveness for our important domestic semiconductor industry.

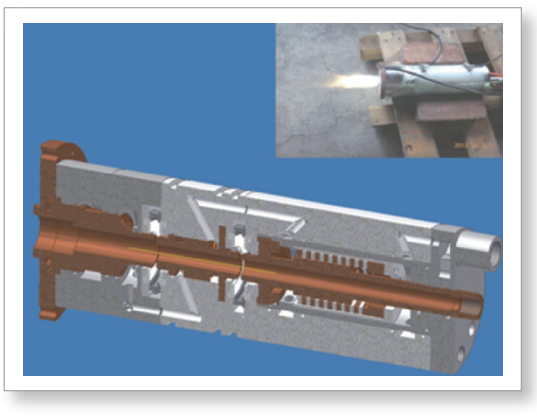
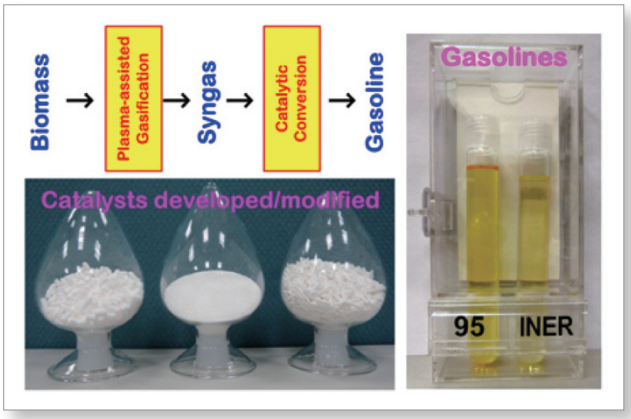


Fig.1 A three sectional plasma torch with low operating current and long lifetime features.

Plasma-assisted gasification for bioenergy development

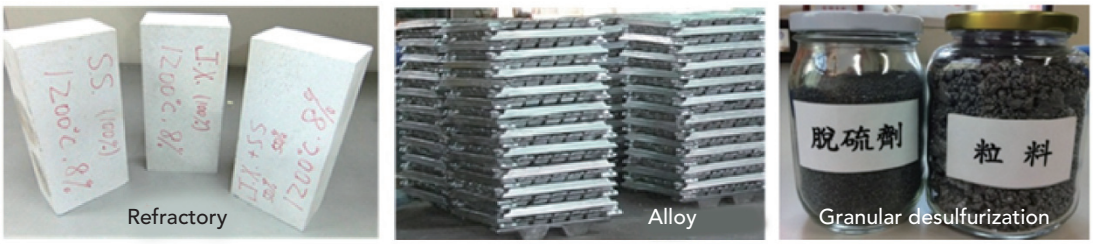
In terms of biomass renewable energy development, plasma torches provide high enthalpy gases (i.e., high temperatures), which are beneficial to the biomass gasification, a 500 kWth pilot-scale plasma-assisted gasification plant for the electricity generation has been set up. To improve the economy of plasma torch technology, this year we focused on R&D of lowering the energy consumption of plasma torches. Experimental results showed that the heating value of syngas generated and the gasification rate achieved were 520 kWth and 104 kg/h, respectively, when wood chips were gasified at the oxygen plasma power of 10 kWe and the gasification pressure of 5 kg/cm^2. In other words, the plasma-assisted gasification system could successfully be operated at low plasma powers (ca. 2% of energy of the syngas produced), and accordingly the thermal conversion efficiency was greatly enhanced. On the other hand, for widening the applications of syngas and improving the overall economy of the plasma-assisted gasification technology, we have also paid attention to the R&Ds on conversion technologies from syngas to liquid fuels and chemicals. We have successfully developed or modified a variety of catalysts, which could be used to produce biofuels like methanol, dimethyl ether (DME) and gasoline. This year a kilogram-scale production demo system, with exhaust gas recycling function had been set up. The system could convert either methanol or DME into gasoline-like oils, being a fuel of high antiknock rating (the octane number greater than 98). The success of this project is beneficial to the localization of bioenergy technologies as well as the energy independence of our country.



▲ Fig.2 Illustration of plasma-assisted gasification technology for gasoline production at INER.

Promotion of plasma melting and reclamation technique

The plasma melting and reclamation technique is able to increase the life cycle of secondary resources, to decline the demand of importing primary resources, to avoid nature resources exploitation, to reduce carbon dioxide emissions and the inappropriate treatment of industrial wastes that impact on environment. Through the development of critical materials and components, the technique could also enhance domestic business (e.g., electric ceramic and energy saving industry) innovation and sustainable development. The accumulated abundant know-how and experience on treating industrial wastes to produce end-products as green materials and the established test platform for physical, chemical, mechanical strength, thermal and electrical properties of materials can be applied to solve the waste disposal problems for the industries. INER has been commissioned with the Jia Jie Co., Ltd. since 2010 to extract aluminum dross to substitute for alumina oxide and realized to produce refractory from aluminum dross. The Ministry of Economic Affairs has licensed for recycling aluminum dross to manufacture and sell four kinds of products. The Jia Jie Co., Ltd. has become the first legal company to recycle aluminum dross in Taiwan. Additionally, we have also commissioned with the Ci Ji Co., Ltd. to develop a pilot scale system (12.5 kg/h) to extract silicon carbide from grinding and polishing suspended material of optoelectronic and semiconductor industry. The purity of silicon carbide is higher than 99.6% and suitable for the fabrication of the ceramic carrier and/or heat sink of LED.



▲ Fig.3 Commercial products from waste aluminum dross by using plasma melting and reclamation technique, developed at INER in cooperation with the Jia Jie Co., Ltd.

1-2 Research and promotion of plasma technologies on the green surface engineering

■ Roll-to-roll plasma coating platform successfully demonstrates manufacturing of silicon thin-film photovoltaic devices

Roll-to-roll (R2R) plasma coating platform, featured by its compatibility with flexible substrates such as stainless steel, plastics and glass, is an important industrial manufacturing technology for continuous production of flexible devices consisting of multilayer thin films. It can be applied to the manufacturing processes of varieties of flexible electronic devices, e.g. thin-film solar cells, smart windows, flat panel displays and touch panels. Nevertheless, it is still difficult for relevant domestics companies to make major breakthroughs in this field due to its technological difficulties. At present, the key knowledge for customized design of R2R plasma deposition platform is still completely possessed by major foreign companies. In order to make advances in this issue, we have successfully integrated three different kinds of R2R systems, including a substrate pre-treatment system, a PEPVD (plasma enhanced physical vapor deposition) and a PECVD (plasma enhanced chemical vapor deposition), into a R2R coating platform, which aims to the development of silicon thin-film solar cells and electrochromic devices. In this program, our main goal is to develop independently a R2R plasma coating platform so that there is no need to rely on the imported technologies.

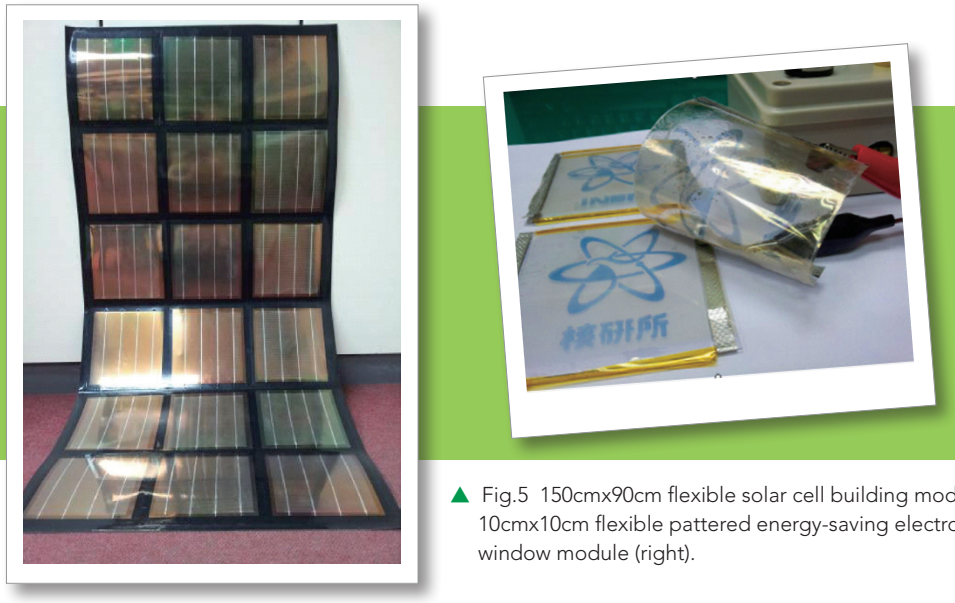
The R2R substrate pre-treatment system employs atmospheric-pressure DBD (dielectric barrier discharge) reactors to enhance the cleaning performance. With a power of 3.0 kW and a moving speed of substrate at 1.0 m/min, the obtained contact angle is lower than 20°, which can fulfill the requirement of cleanness for silicon thin-film solar cells. Furthermore, the gas gates installed in the R2R PECVDs used to deposit different thin films can effectively prevent contaminations from adjacent chambers, making it applicable to the continuous deposition of p, i and n layers. An in-line PEPVD is subsequently used to deposit TCO (transparent conductive oxide) on top of nip layer. With such a typical coating platform, the conversion efficiency of the a-Si thin film solar cells by only the single junction achieves at 5.8%, which meets our expectations. It also demonstrates that the developed pilot R2R plasma coating platform has the potential for the commercialization of flexible electronic devices.

▲ Fig.4 Roll to roll PECVD system.

In the future, we are going to further improve the performance of the platform. It is expected that we are able to transfer the technology to domestic companies and consequently build up complete self-supported techniques for flexible solar cell and energy-saving industries.

Plasma-coated energy-saving thin-film devices for life applications

Green energy and material are two major aspects in the promotion of domestic green culture. Due to the gradually serious effect on global warming and the upsurge of global environmental protection and energy-saving intention, energy-saving on buildings through the application of energy-saving materials begins to rise and develop a wave of unrest. In accordance with these applications, it is necessary to apply adequately the core plasma technologies and to further develop the lightweight, flexible, energy-saving devices. Also, it is possible to produce thin film energy-saving devices with high added value, to look for combined applications and to provide real life experiences. Furthermore, it is also effective to make energy-saving technologies and life experiences merge together. The key technologies, which have been developed, include the flexible thin film solar cells with creative applications and the flexible electro chromic devices with energy-saving functions. By roll-to-roll plasma coating technology, the 150cmx90cm flexible solar cell building modules has been already developed. Furthermore, the solar cell module also provides lightweight and flexible characteristics and combines life applications of building materials. Therefore, it is possible to combine the three elements, energy saving, electric generation, and artistry altogether into energy-saving building materials with the green-living atmosphere. Besides, the electro chromic device with the characteristics of light transmission controlled up to 40% and IR cut-off more than 95% within the solar radiation has been set up by flexible plasma coating process. In the future, the flexible pattered energy- saving electro chromic window module with the area of 10cmx10cm will be delivered and also provide more energy-saving life applications .



▲ Fig.5 150cmx90cm flexible solar cell building module (left) and 10cmx10cm flexible pattered energy-saving electro chromic window module (right).

Promotion of plasma-coated energy-saving flexible thin films in industry applications

In the rudimentary stage, energy-generation and energy-saving thin film devices developed by roll-to-roll plasma-coating technology are planned to be promoted exclusively in the market of energy-saving application, and will gradually be integrated into the market of low-carbon, smart and energy-saving.

Now, the early evaluation of mass production in industry, cooperated with some companies, has been implemented and some embryo products have been developed with proved performances.

For instance, the high-end product of low-E and energy-saving film, which has the structure of alternate multilayer on PET substrate, processed by roll-to-roll plasma coating system, has excellent thermal blocking performance because the coating layer can transmit visible light up to 70% and reflect more than 80% IR within the solar radiation, which turns out to be a highly transparent for heat rejection products. In the next step, it will be tested and verified by the industry for the evaluation of its applicability in hollow-typed energy-saving window.

In order to promote the application market of the flexible thin film solar cell modules, the solar blind modules with the area of 100cmx100cm have therefore been developed by the integration with ninety-pieces of 10cmx10cm solar cells into solar blinds. In a sunshine day, the blinds with solar panels are set to face outside against the sun light to generate electricity. Even in a cloudy day or night, they are turned to face inside to generate electricity as well from indoor lighting, which means a substantially energy-saving capability.

This new energy-saving concept is unprecedented in Taiwan. The embryo modules have been exhibited in 2012 Taipei International Invention Show & Techno art, followed by TV news report and industry attention. In the other hand, cooperation with some domestic optoelectronic firms to evaluate the energy-saving efficiency and market acceptance of integration, such as thin flexible solar cell into energy-saving notebook, touch panel, E-paper and smart window is also in progress.

▲ Fig.6 The solar blind module exhibited in 2012 Taipei International Invention Show & Technomart (left) and energy-saving embryo cooperated with some domestic optoelectronic firms, such as thin flexible solar cell integrated into touch panel, E-paper and smart window (right).

In line with the government restructuring together with the transition of INER to the Institute of Energy Research, applications of the low-temperature plasma technology is hence gradually shifted from the traditional surface engineering to the technology-intensive value-added thin-film electronic components, especially in the fields of energy-saving application. Preliminary results are promising. Now and in the future, we are focusing on system integrations of key energy-saving electronic components, including the light, thin, and flexible all-solid-state thin-film photovoltaic, thin-film light-controlled devices, thin-film energy-storage devices, and thin-film solar energy concentrators for photo-to-electricity and photo-to-heat. These are important products to create the next new generation of green energy and energy-saving industry.

Much experience on thermal plasma technology has been accumulated at INER for decades. Parts of its outcomes have been promoted commercially and applied to the industries. In the future, we will try to expand the application fields of thermal plasma technology in terms of the unique advantage of high-enthalpy feature, for giving assistance with the domestic environment protection and energy industries to their innovation and sustainable development.

2. Development of Photovoltaic System Technologies

By Cherng-Tsong Kuo

This project is engaged in the R&D of photovoltaic (PV) technologies, including those of high concentration photovoltaic (HCPV) system, polymer solar cell, upgraded metallurgical grade (UMG) silicon solar cell and copper-zinc-tin-sulfide (selenium) (CZTS) thin film solar cell. High concentration photovoltaic system, adopting concentrating lenses to reduce solar cell material usage, is well known for its feature of III-V multi-junction solar cell with high energy conversion efficiency and low temperature coefficient. Owing to HCPV taking advantage of direct normal irradiance (DNI) to generate electricity, it fully exerts its performance in regions of high direct normal irradiance. According to the report of GTM (Greentech Media) Research, as DNI is greater than 6 $kWh/m^2 \cdot day$ HCPV has the lowest levelized cost of electricity (LCOE), which overmatches the crystalline silicon and thin film PV. It is easy to apply roll-to-roll printing method for fabricating the polymer solar cell by solution process. The polymer solar cell has the commercial potential due to the advantages of large-area processing, mechanic flexibility and low fabrication cost. The R&D of upgraded metallurgical grade silicon solar cells aims to exploit thin film epitaxial silicon solar cell technologies that have the competitive edge of low cost and can be compatible with the conventional processes of crystalline silicon solar cells in the photovoltaic industry. CZTS thin film solar cell shares many advantages with CIGS one but replacing rare metals with abundant elements to lower the cost. In future, when the conversion efficiency is raised, this can be the main choice of thin film solar cells. The goal of this project is to develop high efficiency, low cost photovoltaic system technologies, and assist domestic PV related industries in building up their capabilities with international competitiveness.

2-1 R&D achievement of HCPV system technology

INER have developed HCPV systems technologies since 2003, including epitaxial and fabricating processes of III-V solar cell, manufacturing process of concentration solar module, manufacturing of solar tracker, establishment of system monitoring and integration, and qualification of solar module, etc. The accomplishments are: 76 patents acquired, 14 items of technology transferred, and 47 items of technical services provided till the end of 2012. INER has effectively integrated the upstream, middle-stream, and down-stream of domestic industry to reduce the system cost, and to promote the industrialization of HCPV. The R&D achievements of INER HCPV technologies are listed as follows:

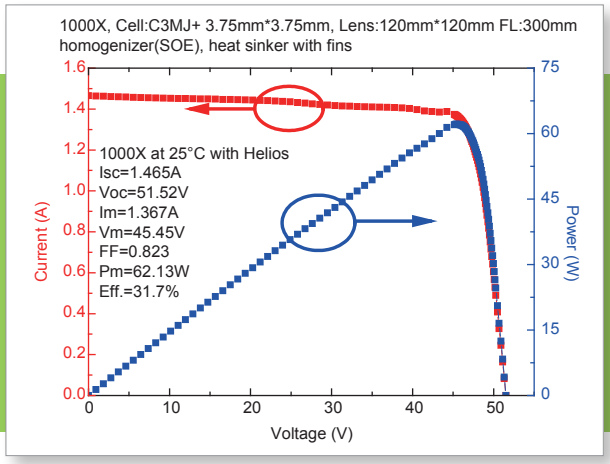
a. Accomplished the design and manufacturing of CPV module, with the geometric concentration ratio of 1,000, the highest outdoor conversion efficiency is 30.78% and the result measured by simulator under DNI of 850 W/m^2 is 31.7%. Besides, the CPV module developed by INER acquires Certificate of Compliance (Certificate Number: 20121011-E332984) issued by UL, making INER become the first one in Asia to pass the qualification conforming to the standard of IEC 62108, which surely helps domestic vendors take another step forward in the global solar market.

b. Fulfilled the development of image-based sun position sensor, prototype of sun tracking controller, and relevant experimental platform. By use of the platform to test the tracking accuracy, the value of ±0.04 degrees can be obtained.

c. Via the net and incorporated with the existing central control and monitoring system, INER has accomplished the on-line diagnosis prototype by acquiring data from the generated power, meteorological information, controller status, etc., to speed the maintenance and management personnel to become aware of and control the abnormal and save time from routine checks.

d. Photovoltaic module qualification Laboratory of INER has passed the extendable auditing of TAF, and acquires the certificate (Certificate Number: L2060-120514). Moreover, INER has completed the auditing process of China General Certification Center (CGC) for the qualification of technical procedures and documents, and acquired the certificate (Certificate Number: CGC/SYS-95-SQS).

e. Acquired awards of "2012 Taipei International Invention Show & Technomart" are as follows:
   a. Gold Medal Award of "Concentrator Photovoltaic Module": This technology has acquired patents of the U.S., Japan, and Republic of China;
   b. Bronze Medal Award of "Lift-Off Structure for Substrate of a Photovoltaic Device and Method Thereof": This technology has applied patents for the U.S., Japan, and Republic of China.



▲ Highest Outdoor Module Efficiency with the Geometric Concentration Ratio of 1,000 is 30.78%.

▲ INER's CPV Module Acquires Certificate of Compliance.

2-2 R&D achievement of polymer solar cell technology

Achievement of this project mainly divides into two parts: research and development of (1) the polymer solar cell with high performance, and (2) commercial large- area processing of polymer solar cell.

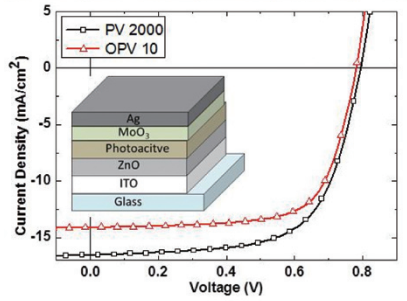
In the first part, we have established the process technology for polymer solar cells consisting of low band-gap polymer, PBDTTT-C, and PC71BM. The PCE of PBDTTT-C/PC71BM is achieved at 6.42% by using DIO as additive. This result is comparable with the highest PCE of PBDTTT-C/PC71BM reported in previous literature (~ 6%). Additionally, commercial solutions, OPV 10 and PV 2000, are used as the photoactive layer. The PCE of 7.73% and 8.51% are achieved for OPV 10 and PV 2000 respectively.

In the second part, there are three subdivisions including spray process, ink-jet printing process and roll-to-roll printing process. Firstly, we continually develop the spray process to fabricate polymer solar cells based on blends of P3HT and PC61BM. Spray technique uses an ultrasonic nozzle to atomize the active layer solution into small droplets at micro-scale, and then these droplets are uniformly deposited on the substrate. It is a feasible way to fabricate the device area up to 100cm^2, and our device fabricated by spray process shows a conspicuous PCE of 3.73% as compare to the PCE reported in literature (~ 3%).

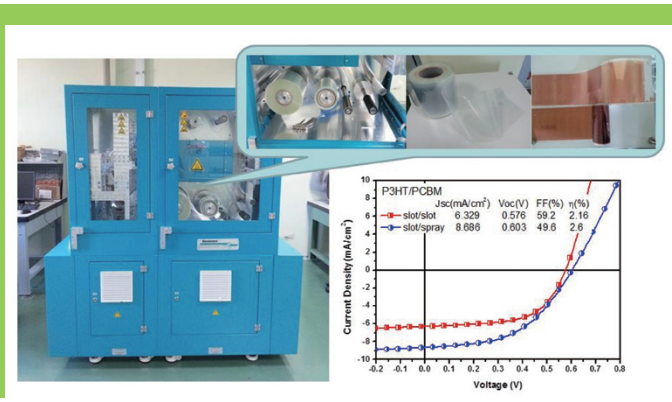
The second subdivision is the development of ITO-free solar cell by using ink-jet printing process. To lower the cost of solar cells, we used a hybrid electrode which is combined silver grids deposited by ink-jet print with a highly conductive PEDOT: PSS as an alternative to ITO electrode. The PCE is achieved at 2.8% by incorporating large-area spray process.

Finally, we develop the roll-to-roll printing technology and flexible polymer solar cells. The slot die coating at present is our emphasis among the numerous roll-to-roll printing technology. The PCE of slot die coated hole transport layer (PEDOT: PSS) incorporating sprayed active layer (P3HT/PC61BM) is achieved at 2.6%; however, the PCE of both layers coated by slot die is achieved at 2.16%.

Sample	J_{sc} (mA/cm^2)	V_{oc} (V)	FF (%)	η (%)
PV 2000	16.539	0.794	65.1	8.51
OPV 10	14.098	0.781	69.5	7.7



▲ I-V curve of OPV10 and PV2000 polymer solar cell.

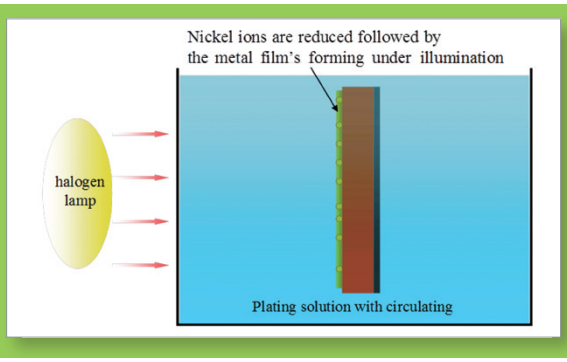


▲ Roll to roll (slot die) coated P3HT/PCBM solar cell.

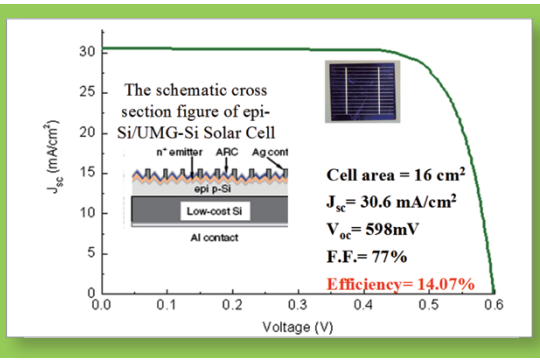
2-3 R&D achievement of UMG-Si solar cell technology

Because of replacing sliver contacts with nickel/copper is a promising route to the lower-cost silicon solar cell mass production, we have developed a progressive process for nickel plating by using the Light-Induced Nickel Plating (LINP) technique. Nickel films have been plated using a fast and simple process without the need for a reducing agent, surface pre-treatment, additional voltage or special heating requirements. We propose that the interfacial potential which is induced between the aluminum metal and the plating solution leads to the nickel deposition. The plated nickel films are shown to display uniform surfaces. Furthermore, nickel silicide can be formed by annealing and further thickened by copper electroplating. The research results have been patented by INER and published in the International Journal of Electrochemical Science.

In terms of epitaxial thin film solar cells, we utilize vacuum-free Atmospheric Pressure Chemical Vapor Deposition (APCVD) system to grow a ~20μm thick high quality epitaxial layer on top of the in-situ HCl gas gettered UMG-Si substrate at 1150°C. The resultant sample, referred to as Epitaxial Wafer Equivalent (EpiWE), is subjected to in-situ H_2 gas pretreatment and plasma texturing in the plasma etching equipment. Finally, the sample is further processed utilizing the traditional bulk silicon solar cell process and forms the so-called thin film epitaxial silicon solar cell. The maximum conversion efficiency of about 14.07% is achieved at present.



▲ The experimental setup for the plating process.

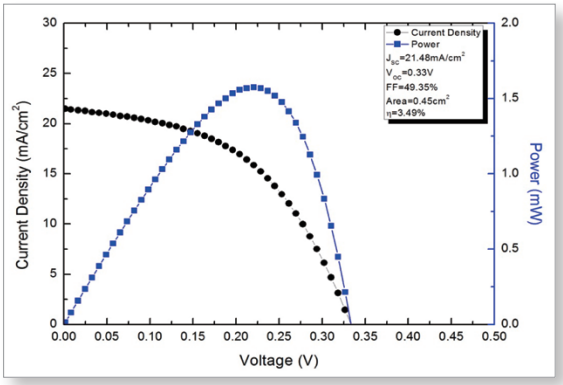


▲ The I-V curve of the thin film epitaxial silicon/ UMG-Si solar cell.

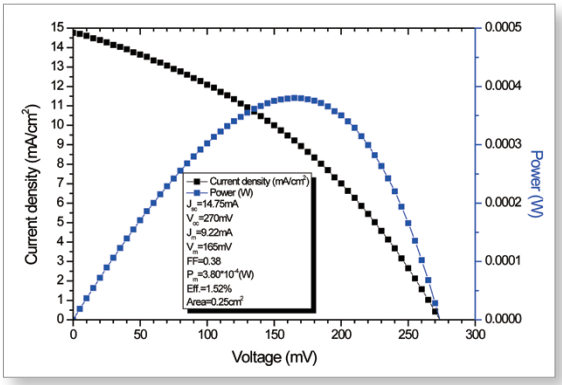
2-4 R&D achievement of CZTS solar cell technology

A project on CZTS solar cell was kicked off in 2011. In the first half year, we focused on clean room and equipment establishment. In the last half year, we started to develop the vacuum and non-vacuum absorber processes. Vacuum processes were evaporation and sputtering. Non-vacuum process was sol-gel method. The achievements are listed as follows:

a. In vacuum processes, devices made by selenization of e-beam evaporated precursors had the highest conversion efficiency of 3.49% and those made by sputtered precursors had the highest conversion efficiency of 2.63%.
b. In non-vacuum process, devices made by selenization of sol-gel precursors had the highest conversion efficiency of 1.52%.
c. In patent portfolio, we applied for a patent about the MOCVD absorber process.
d. In industrial promotion, the Refining & Manufacturing Research Institute, CPC entrusted us to develop non-vacuum CZTS processes and the target was reached meet the deadline.



▲ I-V curve of the device made by selenization of e-beam evaporated precursors.



▲ I-V curve of the device made by selenization of sol-gel precursors.

According to the report of CPV Technology and Market Forecast (2009~2020), despite of the global economic recession, the CPV market has continued to grow steadily. In 2012, installed capacity of CPV is about 505 MW, and predicted to reach 3.9 GW in 2020. The conversion efficiency of concentration modules made by INER under the geometric concentration ratio of 476 and 1,000 is 32.5% and 31.7%, respectively. In the future, to reduce the cost but maintaining the quality, INER will enhance the CPV module performance, and assist domestic vendors to establish the automated manufacturing process in production of photovoltaic cells and modules to empower local products to compete globally.

Our performance of polymer solar cells has reached the world-class in both small-area and large-area ones. From now on we would continually develop different structures, such as inverted and tandem, or ITO-free polymer solar cells. Our goal is to commercialize the large-area polymer solar cells processing with low cost, low pollution and low energy consumption, and to establish our specific patent portfolio.

Besides innovative research, we will make efforts to apply the results of research to the PV industry in the coming years. Because cost is still the priority in the future PV industry, our strategy is to strengthen our patent portfolio in the field of simplifying the processes and optimizing the performance in the conventional silicon solar cell production, including the integration between passivation process and contact process, and in-situ processes, etc.

In CZTS solar cell project, we already had a preliminary result on conversion efficiency within half year. More works will be done to raise the conversion efficiency. In 2013, our target is 5%~6%. Our final goal is 17%~20%.In addition, we will put efforts on Cd-free buffer layer. In the end, a non-toxic and low cost thin film fabrication process is our final target.

3. Technology Development and Application of Solid Oxide Fuel Cell Power System

By Ruey-Yi Lee

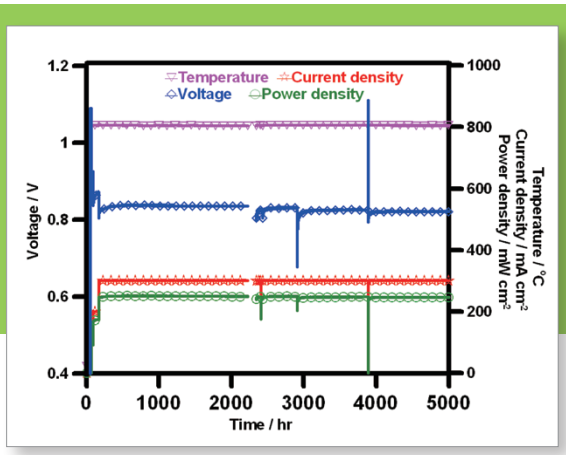
The Institute of Nuclear Energy Research (INER) has committed to developing the SOFC technology since 2003. In compliance with the national energy policy, the SOFC project at INER focuses on establishing capability of design, analysis, fabrication and validation for SOFC components and integration technology of SOFC power system. It is aimed to build up efficient, reliable and cost-effective SOFC systems. The short-term target of the project is set to establish the capability for 1~5 kW SOFC distributed power generation systems and then to extend its long-term prospect to integration with the Integrated Gasification Combined Cycle (IGCC) technology for biomass and coal based central power generation and large demonstration systems.

To accelerate the progress on SOFC development, sub-projects, including MEA, stack, reformer and power system, are formed so as to break down main tasks and to identify the key technical issues and then to find out proper resolutions. Intensive cooperation among sub-projects is well coordinated to clarify interfaces and avoid erroneous discrepancy. After elaborate works for years, substantial progresses have been made on cell, stack, BOP components as well as system integration.

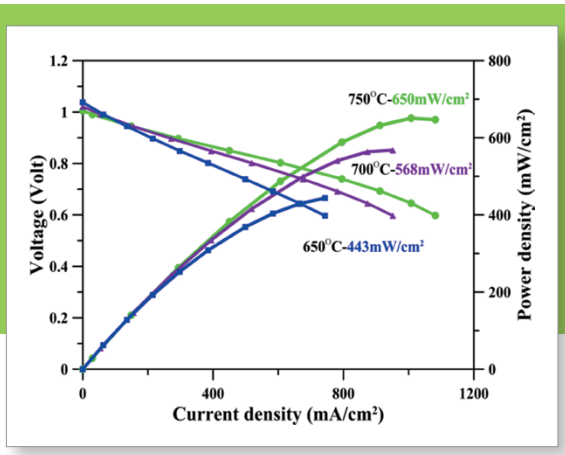
Major Achievements

Achievements of the SOFC project in the fiscal year of 2012 are briefly outlined as follows.

- MEA development: Fabrication processes for planar anode-supported cell (ASC) by conventional methods and metal-supported cell (MSC) by atmospheric plasma spraying are well established. ASC cells with various compositions of electrodes and electrolytes are investigated for different applications. At this stage, the maximum power densities of INER's ASCs are 652 mW/cm^2 at 800°C for IT-SOFC (600~800°C) and 608 mW/cm^2 at 650°C for LT-SOFC (400~650°C). A long-term performance test for an INER's MEA is indicated in Fig.1. A low degradation rate of 0.38% per thousand hours is achieved. The power densities of INER's MSCs are 540 mW/cm^2 and 473 mW/cm^2 at 0.7 V and 700°C for a cell and a stack tests, respectively. Fig.2 shows the current-voltage-power curves of an INER's MSC cell. Durability tests for MSCs at constant current densities of 300 mA/cm^2 and 400 mA/cm^2 indicates the degradation rate is less than 1%/khr.

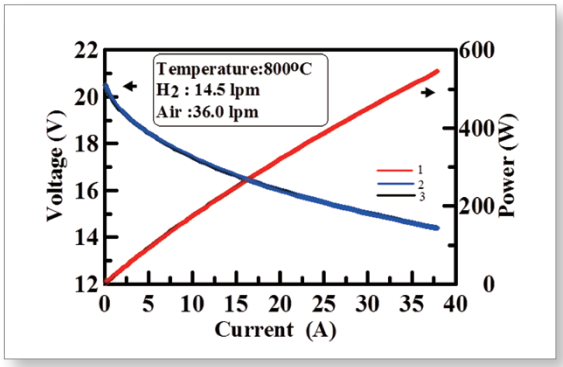


▲ Fig.1 Long-term performance test for an INER's MEA.



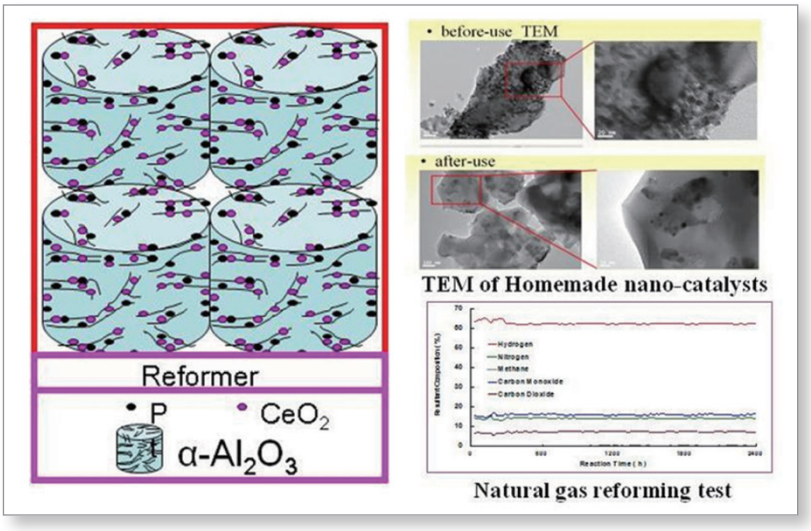
▲ Fig.2 Current-voltage-power curves for an INER's MSC cell.

- Stack development: Procedures and techniques for stacking and cell/stack performance tests are continuously improved to enhance the quality and reliability. Comparable or higher power performance is now achieved with respect to the specs of commercial cells at similar operating conditions. Consistent performance within a variation of 2% is achieved for 3 modules of 18-cell stacks at a nominal power output of 500 W as shown in Fig.3. Meanwhile, INER's MSC 18-cell stack has brought a power output higher than 500 W as well.



▲ Fig.3 Comparisons of power performance for 3 modules of 18-cell stacks.

- Reforming catalyst development: Innovative nano-structured catalysts, where reduced Pt and CeO_2 particles dispersed onto the Al_2O_3 carriers to prevent the migration and coalescence of the metal crystallites, are thermal stable and possess a conversion ratio higher than 95% for reforming of natural gas. The reforming catalyst has been test continuously for 2400 hours with insignificant degradation. Please refer to Fig. 4.



▲ Fig.4 Nano-catalysts and the result of TEM and reforming test.

- System development: Major system components, including: stack, reformer, afterburner, heat exchanger, fuel/oxidant gas supply system, power conditioning system, data acquisition system, instrumentation and control logics, water treatment system, piping and other balance of plant (BOP) units, are developed. After separate tests and successive system validation tests, a self-sustaining power system with fuel utilization 54.9 %, electric efficiency 35.1% (LHV) and power output of 760 watts is achieved.

- With creative innovations and remarkable progresses of the SOFC Project, five special awards, including 1 Platinum, 2 Gold Medal, 1 Silver Medal and 1 Bronze Medal Awards, were granted in the 2012 Taipei International Invention Show and Techomart.

The SOFC technology, with advantages of environmental friendly, high fuel flexibility, and high energy conversion efficiency, will be one of the key technologies for achieving the nation's goal on energy-saving and reduction of CO_2 emissions. It is highly expected that a viable and thriving growth of the SOFC global market will become reality in a few years.

Currently, the INER has possessed the critical core technologies from powder to power for the SOFC technology. On the basis of these technical foundations, continuous improvement will be made to move forwards their applications. Intensive collaboration and technical transfers with local industry partners are now comprehensively pursued. Moreover, to take advantage of Taiwan's strength on the "system integration" and "cost down" capabilities, this institute is willing to foster and/or to cooperate with domestic and international industry partners to launch a new energy industry on the SOFC technology.

4. Development of Clean Carbon Technologies

By Yau-Pin Chyou, Po-Chuang Chen, Ming-Hong Chen, Yi-Shun Chen, Liang-Wei Huang, Ching-Tsung Yu, Wei-Chin Chen

Introduction

The subjects of the present project are to develop the clean-coal technology, conform to the conditions of sustainable society, and gradually construct the prospective engineering techniques and advanced processes for clean-coal systems.

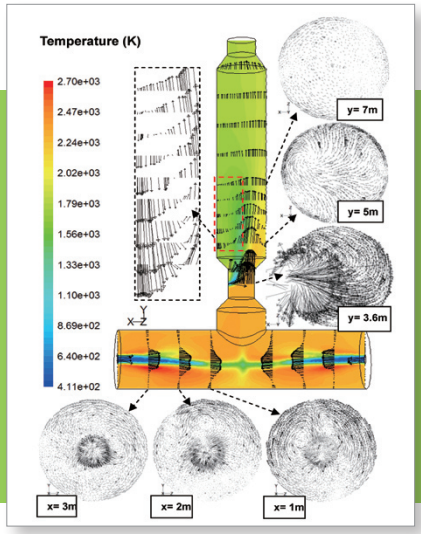
This work focuses on the viewpoints of both practical development and advanced research, which covers clean coal, carbon capture and reutilization, advanced processes for gas separation/hydrogen production, etc. The aim is to develop carbon capture-ready processes for the need of sequestration, and advanced hydrogen generation technologies for the era of hydrogen economy in the future. At present, the program consists of two projects: (1) Commissioning of an integrated test facility for clean carbon system, which includes gasification, system design and optimization, warm/hot gas separation and clean-up; and (2) Carbon capture technology development, which focuses on pre-combustion capture with solid sorbent.

R&D Achievements

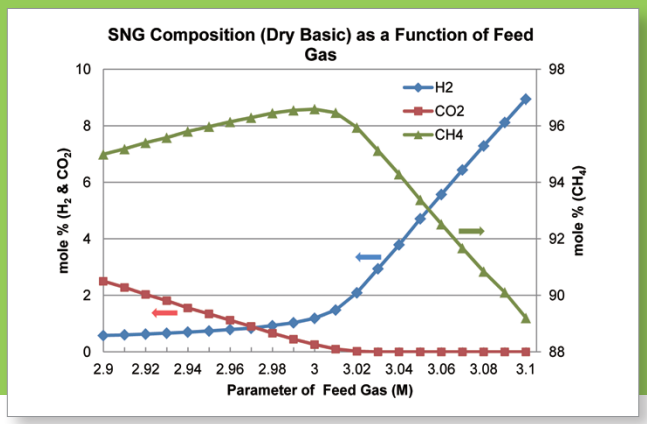
4-1 Work Group (WG) 1

The gasification process of a pressurized, oxygen-blown, entrained-flow E-Gas like gasifier through numerical modeling is investigated by solving the 3-D, steady-state Navier–Stokes equations with the Eulerian–Lagrangian method. Eight chemical reactions are solved via the Finite-Rate/Eddy-Dissipation Model. The preliminary gasification process is successfully modeled and the global chemical reactions are proved to be strongly affected by the finite rates. Fig. 1 shows the profile of temperature and velocity in the gasifier. The results of parametric study show that the increasing O_2/Coal ratio results in a decrease of CO, but an increase of CO_2 and exit temperature. With a modified water-gas-shift reaction rate, a more reasonable trend is obtained that as the coal slurry concentration decreases, the mass flow rate of H_2, CO_2, and H_2O increase while that of CO decreases. As the amount of coal slurry mass flow in the first stage increases, the exit temperature and the mole fractions of H_2 and CO_2 increase, while that of CO decreases. However, different fuel distributions do not provide notable influence on gasification performance due to the large space inside the E-Gas gasifier allowing complete reaction. The overall results show that the present CFD model can adequately capture the gasification behavior and analyze gasification performance inside the gasifier.

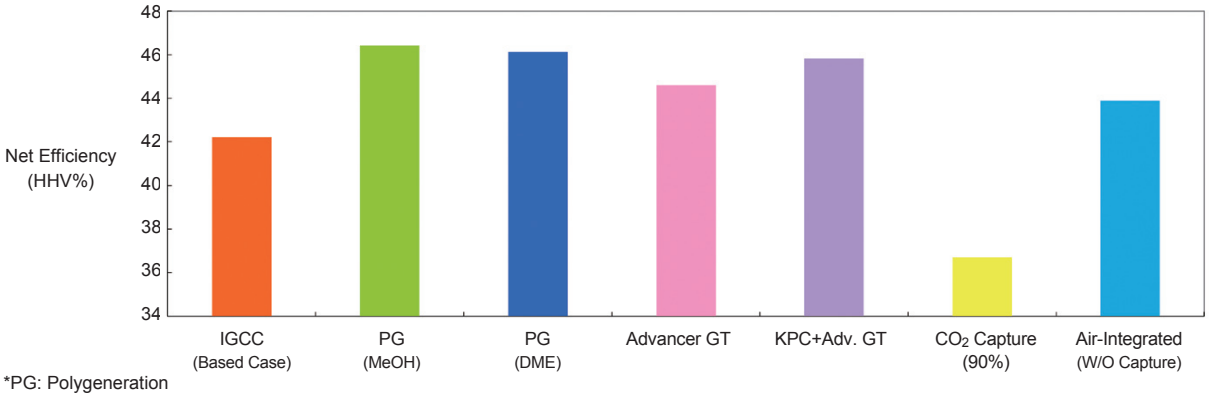
In the application of gasification technology, the synthetic natural gas (SNG) production with syngas feed from gasification was simulated via commercial chemical process simulator. Fig. 2 shows SNG composition as a function of feed gas. The results show that the conversion rate of CO is higher than 99.99% and the deviation is within 5% compared with public literature. The project team cooperated with Gibsin Engineers, Ltd. to perform the cost analysis of SNG produced in Taiwan, and the results show that the cost of SNG is around NT 13/Nm^3. Furthermore, the system performance was estimated and compared with various gasification applications. The results show that the poly-generation is still the better choice due to higher system performance in Fig. 3.



▲ Fig.1 The profile of Temperature and Velocity in the Gasifier



▲ Fig.2 SNG Composition as a Function of Feed Gas



▲ Fig.3 System Performance

4-2 Work Group (WG) 2

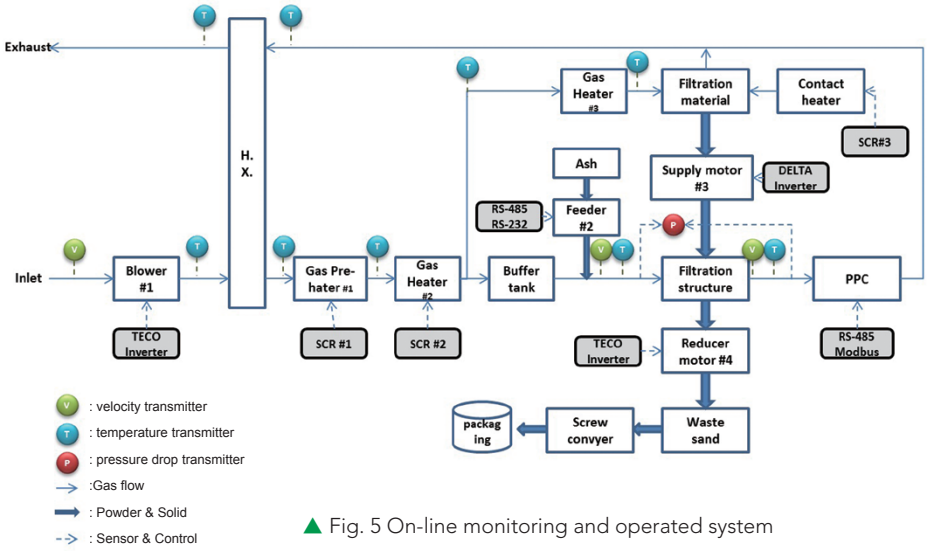
This work represents the follow-up efforts for mitigating greenhouse gas emissions from sustainable development viewpoints. It is expected that this strategic planning will establish the essential foundation for technologies needed to fulfill the policy of energy saving and carbon abatement. This work focuses on the strategic planning of clean carbon-based energy technologies, from the viewpoints of both practical development and advanced research. The exhibited technology consists of two categories. The first one is advanced gas filtration technology in granular moving bed filter (GMBF). Development of the GMBF system was operated under the high-temperature of 500°C. In 2012, commissioning the hot model of three-dimensional granular bed filter (GBF) with the sub-systems is finished to supply the high-temperature environment for experimental study under 400°C, as shown in Fig. 4 and Fig. 5.

Secondly, warm/hot gas desulfurization (WHGD) is one of the pioneer technologies to control gas contaminant emission. Taking cost into account, the research work focuses on developing iron-based sorbents, which is used to capture H_2S and COS from syngas. Sorbents are prepared by incipient wetness impregnation procedure. Iron-nitrate solution was poured on porous carrier supports, and sorbents were formulated after high-temperature calcinations. To comply with warm/hot gas clean-up projects, the facilities of WHGD, as shown in Fig. 6, were operated between 300-700°C. The study showed that iron-based sorbents could suppress outlet sulfide concentration to near 0 ppm for a long time, and this result

assures the quality of syngas to be applied to gas turbine, chemical synthesis or fuel-cell. In addition, after investigating the effects of many kinds of reaction parameters, such as temperature, space velocity and syngas composition, the sulfur capacity of our sorbents could reach a value above 7 g-S/100g sorbent. After multi-cycle tests, sorbents still keep good chemical activity, and sulfur capacity could be maintained above 90% of the initial value. The breakthrough curve of multi-cycle tests is shown in Fig. 7.

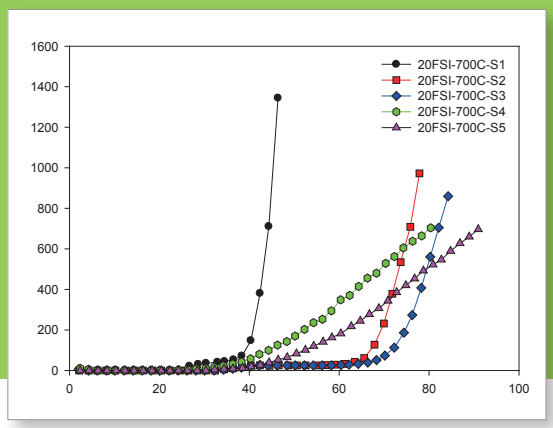
In the future, the integrated tests will be executed in warm/hot gas clean-up processes. By developing two-stage granular filter system, which includes particulates removal in first stage and sulfide removal in second stage. When raw syngas passes through this system, particulates and sulfide will be captured accordingly to obtain clean syngas. The domestic R&D ability on gas clean-up technologies will be improved by developing two-stage filter system, which can evolve into multi-contaminant control system. The related technologies could be applied to catalysis, fluidized-bed combustion, oil-refining, semiconductor industry, etc.

▲ Fig. 4 Hot-model of GMBF system



▲ Fig. 5 On-line monitoring and operated system

▲ Fig.6 Warm-hot gas desulfurization system

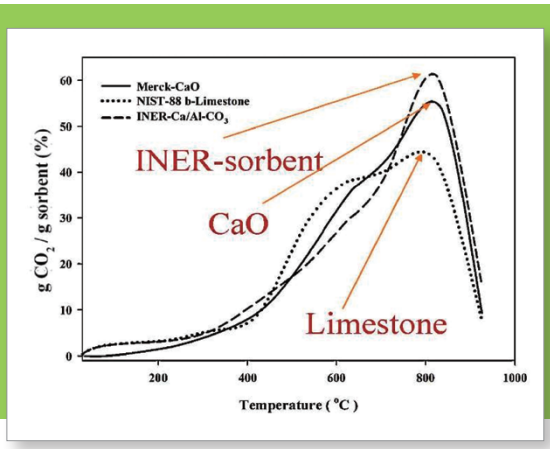


▲ Fig.7 Breakthrough curve of multi-cycle desulfurization reaction

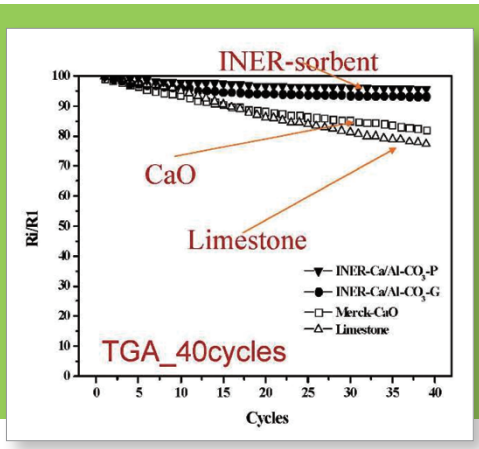
4-3 Work Group (WG) 3

To find out a suitable temperature for the best sorbent performance, the results of CO_2 adsorption test of different sorbents as a function of adsorption temperature were shown in Fig. 8. The activated CaO, limestone and INER-Ca/Al-CO_3 were carbonated from room temperature to 900°C at a rate of 20°C /min and 50 ml/min pure CO_2 stream. As seen from Fig. 8, the profiles showed two stages of adsorption temperature. All sorbents started to adsorb CO_2 above 400°C, and reached another quick kinetic adsorption rate of CO_2 around 700-800°C. From TGA study, a significant weight change happened at 750°C that was chosen for the following CO_2 adsorption experiments

To understand the contribution of Ca/Al-CO_3 LDH structure, pure CaO and limestone were used in the CO_2 adsorption analysis. The stability of multi-cycles of CO_2 sorption performance is shown in Fig. 9. After 40 cycles, the CO_2 recovery of INER-Ca/Al-CO_3, limestone, and CaO were 94-97%, 77% and 82%, respectively. CaO and limestone demonstrated poor recovery of long-term capturing performance. This indicated that during carbonation-calcination process, CaO particles were aggregated by sintering. According to the aforementioned results, the incorporation of Al prevented the sorbent from sintering during long-term stability test.; thus, the LDH sorbent could provide excellent adsorption capacity of CO_2 at higher temperature without deactivation. For further investigation, larger scale production of LDH sorbents needs to be pursued towards commercial application.



▲ Fig. 8 CO_2 adsorption test of different sorbents as a function of adsorption temperature



▲ Fig. 9 CO_2 adsorption recovery of different sorbents after 40 cycles

Besides the continuous development of techniques, the international trend will also be closely monitors, including the implementation of clean-coal technology and the progress of shale gas/oil. Knowing the developing trend will enable us to scrutinize the pros and cons of the present study and verify the direction of future work. Introducing the developed techniques into industry will enhance their competitiveness and output value.

5. MicroGrid Technology Development

By Yih-Der Lee, Hsiang-I Feng, Jung-Mao Li, Wei-Nian Su, Yung-Ruei Chang

As compared to traditional and centralized control of power system, the next generation of power system will be small-scale and decentralized control of dispersed generation by renewable energy. However, due to intermittent and uncertain characteristics, the high penetration of renewable power generation will cause dramatic impact to the operation of regional power system, and result in voltage and frequency fluctuation phenomenon. Dispersed Generation (DG) and MicroGrid (MG) technology provide possible solutions to stabilize regional power system and control penetration rate of renewable power generation up to 20%. This technology can not only ensure national energy security but also bring development of national industry.

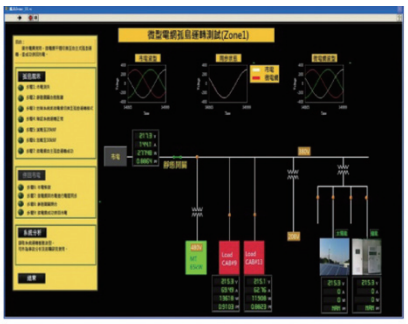
■ **INER is currently developing the low voltage microgrid technology as follows:**

5-1 Power system engineering and integration technology

A hundred kW scale of "Microgrid Test Field", including wind power, high concentration photovoltaic (HCPV) generations, micro turbine generators and energy storage system, was firstly constructed in Taiwan as shown in Fig.1 and Fig.2. Fig. 3 shows a real-time measurement and control system that were established in the SCADA platform, which can be used to perform various operation scenarios for microgrid. To obtain more accuracy of microgrid model for simulation, the transient waveforms of microgrid between grids connect and stand alone transition operations were recorded. By using microgrid model, the fault detection algorithm, harmonic analysis, and load shedding scheme then can be developed and implemented in this platform in the future.

▲ Fig.1 Microgrid Test Field

▲ Fig.2 Microturbine

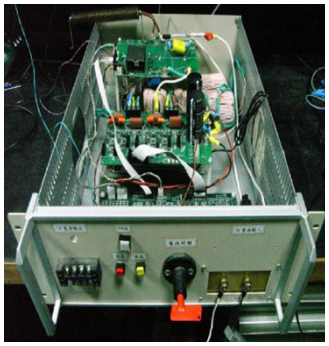


▲ Fig.3 Display and test of grid connect and standalone operation for Microgrid

5-2 Power electronics technology

In order to control renewable energy power generation and correct power factor for microgrid, a 15 kW three phase power converter with bidirectional real and reactive power control was designed as shown in Fig.4. The anti-islanding technique shown in Fig.5 is implemented with static switch (SS) to detect interruption or serious fault condition on utility. A 5 kW smart inverter with very high efficiency was designed to achieve seamless transfer between current control and voltage control so that can prevent renewable generation from outage.

▲ Fig.4 Three phase 15 kW AC/DC bidirectional real and reactive power converter

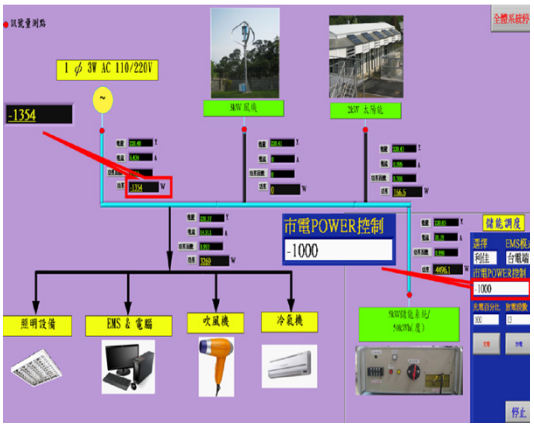


▲ Fig.5 Static switch with anti-islanding technology

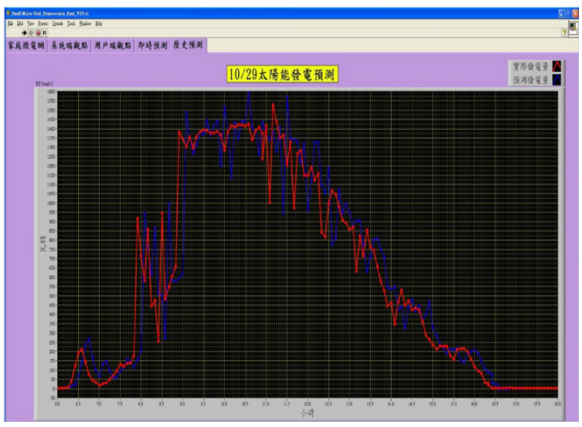
▲ Fig.6 5 kW bidirectional power converter with high efficiency and seamless control

5-3 Intelligent control and energy management system

In order to apply microgrid technology to our life, we also established a real time monitoring platform with intelligent control and energy management system for a smart house as shown in Fig.7. This platform can display load behaviors and forecast renewable power generation. By considering dynamic electricity pricing, the bidirectional energy storage is controlled to achieve peak shaving and economic dispatch. In the future, the Power-Line Communication, PLC, Zigbee and Wi-Fi would be incorporated in this platform to increase renewable energy usage and efficiency for the smart house.



▲ Fig.7 Real time monitoring and control platform for a smart house



▲ Fig.8 Generation forecast for renewable energy

The introduction of Microgrid technology can increase the renewable energy penetration at the regional distribution network. In the Mid and long term, electric vehicles and energy storage industries will be emerged and widely applied in the communities to increase energy usage efficiency. We hope that the industry, government, academic, and research can join this project to obtain more benefits including promote renewable energy usage, increase power supply quality and reliability. With these, we can develop environmental friendly clean energy to provide stable energy supply.

5-4 The development and manufacture of the 2nd-generation 150 kW wind turbine blade

The wind power is extracted and utilized by conversion of mechanical power, which is induced by the wind flow, into the electrical power. For the purpose of promoting the small-and-medium-sized wind power system in Taiwan, a demonstration project was initiated to design and fabricate the 25 kW and 150 kW wind turbines by the Institute of Nuclear Energy Research (INER) in 2005. However, due to the considerations of performance and durability enhancement of the 1st-generation 150 kW wind turbine, the blade has to be modified and upgraded to fulfill the requirements of IEC 61400-1 Class-IA.

In order to improve the structural strength and reduce the total weight of blade, fiberglass mixed with carbon fiber is adopted for the lamination of skin and box beam. The blade is designed to withstand the design load derived from various Design Load Cases (DLC) as required in IEC 61400-1 standard (Fig. 9). The prototype of the 2nd-generation turbine blade shown in Fig. 10 is manufactured by *Atech Composites*. The new generation blade is composed of four parts: upper skin, lower skin, upper box beam and lower box beam. The prototype is fabricated by implementing the Vacuum Assisted Resin Transfer Molding (VARTM) method. Furthermore, in order to ensure sufficient structural strength and safety of the blade, a static blade test has been performed with application of 135% design load.

It is expected that the established high efficiency wind power demonstration system could further facilitate the formation of associated industrial chain and the development of large-scale wind turbine, *i.e.* MW wind power system, in Taiwan as well.

▲ Fig.9 Design and analysis of the 2nd-generation wind turbine blade.

▲ Fig.10 Manufacture and test of the 2nd-generation wind turbine blade.

6. The Development and Research of Scale-up Technology for Cellulosic Ethanol Production

By Chiung-Fang Huang

The objective of this project was to develop cellulosic ethanol production technology, support under the government policy for promoting bioethanol, and to foster the development of domestic cellulosic ethanol technology and biorefinery-related research. Owing to the cellulosic ethanol is an emerging biomass energy conversion technology, it is necessary to establish a pilot-scale plant as a research platform for technology scale-up and process validation to reduce the risk associated with technology transfer and commercialization. In 2009, the Institute of Nuclear Energy Research (INER) has completed the construction of a cellulosic ethanol pilot plant with daily feed capacity of one ton dry biomass; testing operation was commenced in 2010 to produce ethanol. The pilot plant is used to develop and improve production processes, test production feasibility from various bio-resources, provide staff training and education promotion, seek cooperation with industry or international organization. Implementation of the project is expected to foster the growth of domestic, commercial scale bioethanol industry to produce ethanol as transportation fuel from agricultural or forestry residues. Further perspectives will also be to promote the development of low-carbon industries, energy diversification and reduction of carbon dioxide emission.

▲ Fig. 1 Ton-scale cellulosic ethanol pilot plant facilities in INER

■ **Substantial efforts have been and continue to be made to develop core technologies needed for cellulosic ethanol, major accomplishments of this year are as follow:**

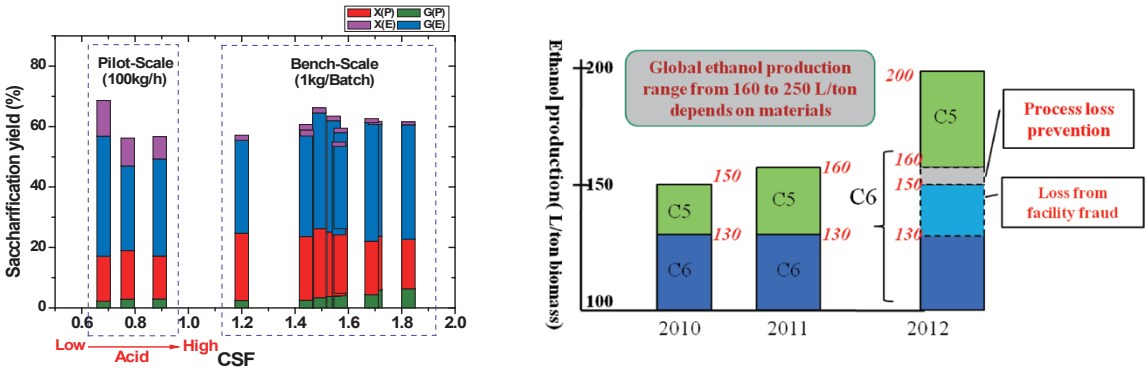
6-1 Test operations of ton-scale cellulosic ethanol pilot plant

Pilot plant operations of this year were focused on the simultaneous saccharification and fermentation (SSF) process, and evaluation of various feedstock materials for ethanol production. The yearly goals were to establish a stable operation of SSF process, continue to improve facility functions, develop new process based on the operational obstacles and requirement needed for future scaling up. Meanwhile, developed designing skills for commercial-scale plant based on the information acquired from optimizing the configurations of existing operations and the whole plant energy efficiency and cost assessment.

The pretreatment system of the pilot plant was constructed based on the principle of acid-catalyzed steam explosion process. In addition to the continual improvement of facility performance, the pretreatment system was aimed to develop potential capacity on processing various biomass feedstocks which would be suitable for global market demand. Progress has shown that this developed technology can be applied to various lignocellulosic materials, including bagasse, soft and hard wood chip.

Furthermore, the yield of enzymatic hydrolysis of pretreated materials can be stably maintained above 80%, this demonstrated that the pretreatment technology has reached the maturity level of scaling up technology required for commercial application.

Eight batches of whole plant test-run operations and several independent runs of pretreatment system have been carried out this year. The whole plant test-run was operated in feeding 10 consecutive days with daily input capacity of one ton dry rice straw, approximately 15 days for completion of an operation run. The operation was mainly focused on the simultaneous saccharification and fermentation (SSF) process. From the fourth quarter of the year, the simultaneous saccharification and co-fermentation (SSCF) process was began to test in pilot plant. Over 70 tons of rice straw and 10 tons of bagasse have been in use for ethanol production, estimation of maximal 200L of dehydrated ethanol was obtained from conversion of one ton rice straw.

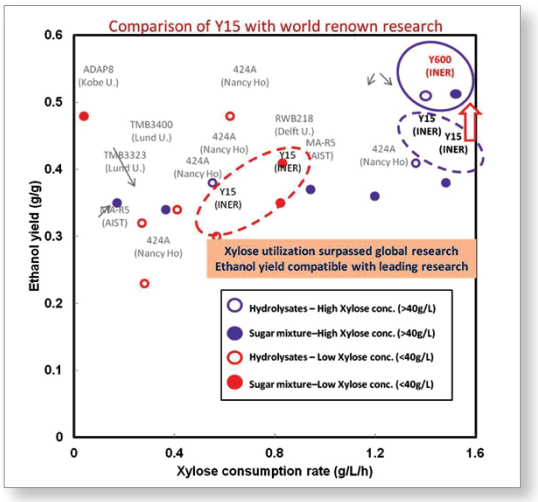


▲ Fig 2 (left) 70% of total sugar yield can be obtained from sugarcane bagasse pretreated by ton-scale pretreatment system. (right) ethanol production in INER's pilot plant is gradually increased to 200 L/ton biomass by year.

6-2 Development of core technologies for cellulosic ethanol production

Application of cost-effective hydrolytic enzymes is critical to the success of a commercial cellulosic ethanol process. By using the project-developed acid-catalyzed pretreatment process and specific operation parameters, the project has successful prepared rice straw solid substrate used for on-site cellulase production as well as established technology of ton-scale cellulase production, with combination of real-time feeding technique and operational optimization. The in-house produced cellulase could replace commercial enzyme for used in the enzymatic hydrolysis process in pilot plant. The enzymatic activity of the crude cellulase extract produced by the method can now be reached to 15 FPU/ml, which has yet to achieve the level of 10 FPU/ml requirement for commercial application. Future effort will focus on the production cost reduction.

The other hand, with the help of the improvement of genetic engineering and optimal screening strategy, a glucose and xylose co-fermenting yeast, *Saccharomyces cerevisiae* Y15, with improved performance was obtained, derived from the previous construct of YY5A. Compared to the YY5A, Y15 showed much faster in xylose utilization. The xylose consumption rate of 1.5 g/L/h has surpassed the level of the published literatures. And the highest ethanol yield of Y15 can be enhanced from 0.38g/g to 0.41g/g from the fermentation of low inhibitor content of lignocellulosic hydrolysate; the result has reached the leading level of global research. It is expected to apply Y15 in the simultaneous saccharification and co-fermentation (SSCF) process as the basis for the future operation in ton-scale pilot plant.



▶ Fig. 3 Comparison of INER co-fermenting yeast with world renowned yeasts.

6-3 Integrated assessment of energy for cellulosic ethanol process

Energy integration is one of the critical factors affecting production cost of cellulosic ethanol; energy efficiency of the production process is required for valuable industrial applications. Many literatures have demonstrated the energy efficiency of cellulosic ethanol despite of the technology has not yet been to the commercial scale The information was investigated mainly based on the assumptions instead of realistic operation condition, therefore, the references value is limited for industrial participation. The energy integration assessment conducted in this project was based on the data obtained from the past two years of pilot plant operation experience; it is intend to provide consolidate information for future commercialization of cellulosic ethanol.

The study was investigated based on the result of pilot plant operations, in addition to basic process, two of the energy integrations were considered, one was heat integration (including the pre-heating process from acid and the distillation process), the other was CHP (reference from NREL configuration, including solid residue, waste broth from fermentation and hydrolysis). Calculation of the material and energy balance of the overall model was based on processing of one ton dry rice straw. The net energy ratio (NER) of the ton-scale pilot plant is less than 0.5 without energy integration; however, the NER could be enhanced to above 1 or even greater than 4 while incorporating methods of energy integrations. Reduction of steam and electricity demand through energy integrations, improvement of enzymatic hydrolysis efficiency, process losses prevention during production or the use of plant waste as material could promote economic competitive for cellulosic ethanol.

Table 1: NER for SSF process by different energy integration measures

Feedstock	Energy integration	Process consumption		CHP generation		Net input (MJ)	Output (alcohol) (MJ)	NER
		Power (kWh)	Steam (kg)	Power (kWh)	Steam (kg)			
Rice straw	non	902.0	2350.8	0	0	9288.9	3986.1	0.43
	heat integration	902.0	1524	0	0	7164.0	3986.1	0.56
	CHP by lignin	902.0	1524	-127	-1358	3216.8	3986.1	1.24
	CHP by lignin and waster water	902.0	1524	-662	-1524	864.2	3986.1	4.61
Bagasse	non	902.0	2350.8	0	0	9288.9	4453.3	0.48
	heat integration	902.0	1524	0	0	7164.0	4453.3	0.62
	CHP by lignin	902.0	1524	-127	-1358	3216.8	4453.3	1.38
	CHP by lignin and waster water	902.0	1524	-662	-1524	864.2	4453.3	5.15

6-4 Promotion of cellulosic ethanol research for industrial application

The project has begun the promotion of biomass-to-ethanol conversion technology as well as the INER pilot plant facilities since 2009 and recent breakthroughs on the process technology have made solid progress. Being of assistance simultaneously on government policy for promoting high-value petrochemical industry for biomaterial development in Taiwan, the future is perspective although the progress is still in its early stage. Recent progresses on promotion of industrial application are as follow:

a. Since 2011, INER has provided the ton-scale pilot plant platform and the 16 related technical services to domestic industry for testing operation. Future plan will focus on establishing strategic alliance with international industry on promotion of INER's cellulosic ethanol process and demonstration of INER achievement on cellulosic ethanol development.
b. Production of two kiloliters (KL) of CNS15109-regulated dehydrated rice straw fuel ethanol for use in the demo project of "Tainan Rende of bioethanol demonstration towns". The use of rice straw ethanol in demonstration E3 gasohol indicated a major step in Taiwan toward the utilization of bioethanol as a transportation fuel produced from non-food material.
c. Cooperation on commercialization of cellulosic ethanol with CPC, TSC and Far Eastern group of Taiwan, the state-owned enterprise or industry, through MoU consignment.
d. The global leading biotech has recognized both of biomass pretreatment and recombinant xylose-fermenting yeast technologies developed by INER as having potential for commercial promotion, and intended to cooperate with INER for market promotion. This could open up the path for INER in marketing technologies in Asia area.

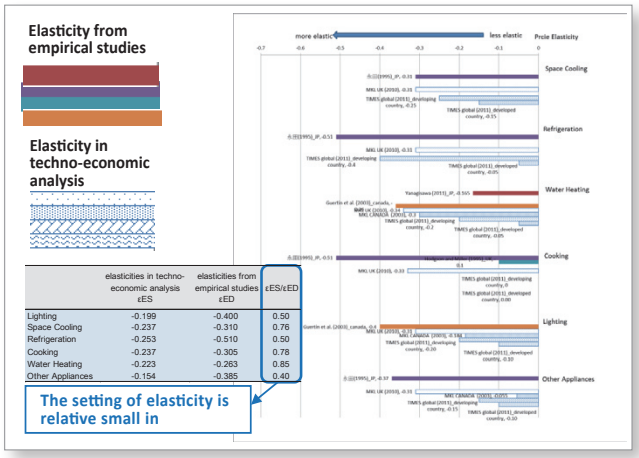
7. MARKAL-ED Energy Model - Estimation of Price Elasticity and Trend Analysis of CCS Development in Taiwan

By Chia-Hao Liu

Institute of Nuclear Energy Research (INER) had established the standard MARKAL energy model since 2005, and held the expert symposiums for the verification of the settings in BAU (Business As Usual), electricity sector, industry sector, transport sector and residential & commercial sector. Due to the price elasticity of energy service demand has huge relationship with social economic environment variation and the promotion of national energy policy, the appropriate energy service demand is not only crucial for optimizing each sector's carbon emissions but also important for analyzing the cost-benefit of policy enforcement. We introduce the MARKAL Elastic Demand (MED) energy model since 2011. The MED model is an extension of standard MARKAL model with more completed parameters to adjust the price elasticity setting, which can be used to evaluate the effects of energy prices on energy service demand for each sector. However, the original price elasticity in MED model is referenced from UK, and could not express Taiwan circumstances correctly. According to the calculation from econometrics method with domestic energy consumption data, we estimate the localized price elasticity of energy service demand. Results show that there are significant differences between UK's default value and our estimation.

In addition, the trend and cost estimation of the carbon capture and storage (CCS) technology development in Taiwan are evaluated by using MED energy model in 2012. Under the assumption of meeting Taiwan's CO_2 reduction target, three scenarios are created to represent the possibility of technology development. Moreover, we assume that the first large scale CCS coal-fired power plant and gas-fired power plant will be available to operate commercially since 2025 and 2030. Results show that the CCS cost will decrease to 53.9-88.2 USD/tonCO_2 in 2035 and the price of CO_2 trade will be up to 120 USD/tonCO_2 at the same time. Comparing to CO_2 trade, CCS technology in Taiwan has the competitive advantage on CO_2 reduction cost since 2030-2035.

Under the new national energy policy, the government promotes an energy development vision of "ensuring nuclear safety, gradually reducing reliance on nuclear power, and creating a low-carbon economy in order to gradually become a nuclear-free country". In order to complete Taiwan's long-term CO2 reduction gap, not only promoting renewable energy and demand side management, but also the development of CCS technology is essential for Taiwan to meet long-term CO_2 reduction target.

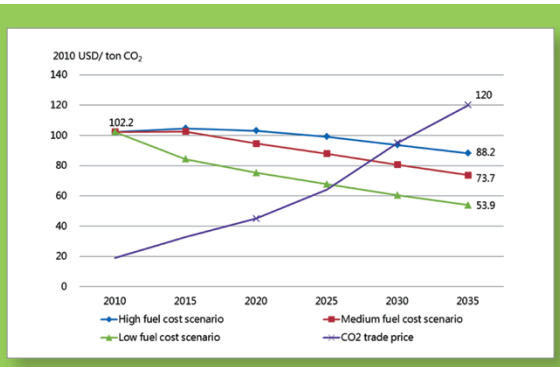


▲ Fig.1 Elasticity in techno-economic analysis and empirical studies.

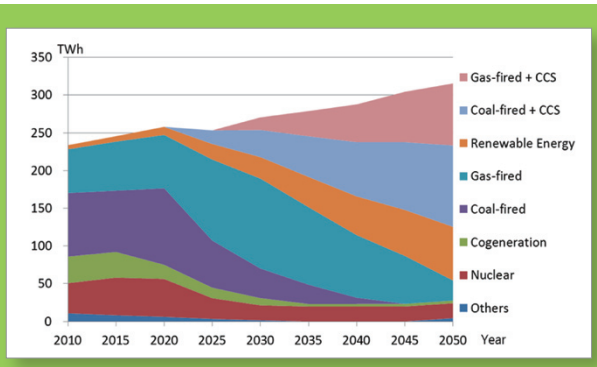
Residential Sector	UK MKL	Lower bounds of elasticity (short-run elasticity)
Lighting	- 0.31	- 0.33
Space Cooling	- 0.31	- 0.39
Refrigeration	- 0.31	- 0.30
Cooking	- 0.33	- 0.28
Water heating	- 0.34	- 0.39
Other Appliances	- 0.31	- 0.12
Average	- 0.32	- 0.29

Service Sector	UK MKL	Lower bounds of elasticity (short-run elasticity)
Space Cooling	- 0.32	- 0.38
Lighting	- 0.32	- 0.42
Other Appliances	- 0.32	- 0.42
Average	- 0.32	- 0.41

▲ Fig.2 Setting of price elasticity in MARKAL-ED model



▲ Fig.3 Trend of CCS cost and CO_2 trade price.



▲ Fig.4 Electricity generations in Taiwan during 2010-2050 (The moderate CCS development scenario).

III. Radioactive Pharmaceutical Science Development and Application

By Wuu-Jyh Lin

2012 Radiation application group of INER focus on:

- Diagnostic Nuclear Medicine: (1) Cancer diagnostic drug F-18 FLT has been developed for automatic synthesis process. The average production yield is about 30-40%. (2) Neuroblastoma diagnostic drug I-123 MIBG was successfully cooperated with NTUH for clinical trial. The clinical results showed that MIBG's specificity is 100% better than F-18 DOPA which is 88%. (3) Novel glucose-regulated protein GRP 78 is under developing. It is considered as a biomarker for gastric cancer. (4) Neurological drug I-123 ADAM, a serotonin transporter, has been used for the diagnosis of depression is under NDA phase II clinical trial.
- Therapeutic Nuclear Medicine: phase 0 clinical trial of Re-188 liposome has been performed at Veteran General Hospital-Taipei. 8 subjects were completed this year. Physiological and biochemical results showed that it is safe in patients.
- Service of Molecular Imaging platform: this platform offers radioisotopes, liver and tumor targeted molecules, neurological drugs to help local institutes and universities for the development of the novel drugs. With the assistance of this platform, the developing speed towards clinical trial could be accelerrated.
- Radiation Diagnosis Instrument: Light, thin, low energy cost, and anti-interfere imaging device would be developing to assist local companies with world-wide competitive ability.

2012 research achievements including 71 patents, 37 journal papers, 9 international conferences, 137 internal reports are very fruitful. The purpose of this research is to establish the business ability of nuclear medicine of Taiwan, to maintain the health welfare of our countrymen.

1. Radiation Biomedical Research, Development and the Application

By Jenn-Tzong Chen, Tsai-Yueh Luo, Chun-Chia Cheng, Hsin-Chin Liang, Shiou-Shiow Farn

The development Goals of this project are major to the development of radiation biological radioisotope research and related technology for the application of nuclear medicine and development of hardware and software technology for positron emission tomography (PET), in order to achieve the purpose of radiation application used in biomedical field.

Recently, polymeric nanoparticles (NPs) such as liposomes, nanogold particles, dendrimers, and micelles, are used as drug carriers in diagnostics and therapeutics of cancers due to the high permeability and retention effect (EPR), leading to increased drug accumulation and spreading into the tumor parenchyma. It has been reported that synthetic biocompatible polymer NPs can also prolong the half-life of drugs in circulation coupled with reduction in rapid renal clearance of soluble proteins by reticuloendothelial system (RES). Therefore, imaging reagents or anti-cancer drugs equipped with NPs carriers can gain more accessibility to target into tumors.

The advantages of compact, low-power consumption, and magnetic-immune make the semiconductor-photonics-based imaging detector technology an essential key for developing the new-generation nuclear imaging devices. In this project, the semiconductor-photonics-based imaging detector technologies were planned to be established began with basic researches, to build our own tech-ability for developing new imaging scanners practical to be used.

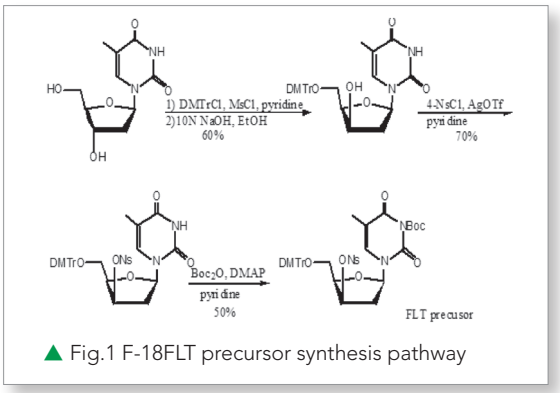
1-1 Establishment of precursor synthesis capacity of fluorine -18 FLT

The development of F-18 FLT precursor synthesis method: This project also integrates the application of F-18 targetry development and radiofluorination process. The whole study includes organic synthesis, radiofluorination process and separation method development. It is the first integration study from targetry development, precursor synthesis, radiofluorination process and brain animal study in Taiwan. The precursor is successfully applied to the radiofluorination process to produce F-18 FLT and prove the image availability in animal brain tumor model.

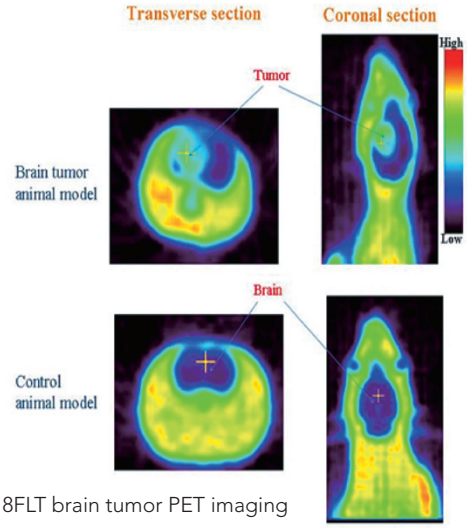
F-18 FLT as the follower of the molecular of the century, F-18 FDG, is treated to be the next most potential PET tumor imaging agent and radiopharmaceutical for commercialized purpose. F-18 FLT PET is complementary to F-18 FDG PET in tumor imaging with better specificity. Both of them are not patent protected radiopharmaceuticals; therefore meet the spirit of Nobel Prize laureate. The goal of this project to develop the PET imaging precursor is promoting the contribution of radiochemistry worldwide. In the same time, due to the highly sensitive technology need to be established to reach the goal, the level of science could be increased. Besides, the contribution of predecessor can be well known and confirmed in the future.

The starting material of this project to synthesis the precursor of F-18 FLT is thymidine. After three synthesis steps and purification, the yield is about 20%, and the purity is larger than 95% as in Fig.1. The DMTr protecting group protects the hydroxy group at No. 5 carbon of the pentose of the starting material, than the nosyl leaving group replace No.3 hydroxy group, the final synthesis is using Boc to protect the amine of the base ring. The product is lyophilized. After radiofluorination, F-18 will replace the nosyl leaving group to produce the product with functional group protected. The final step is the

deprotection reaction. In this reaction, F-18 FLT is produced. After the purification process, fluoride-18 ion and phase transfer catalyst can be removed to reach a limited concentration. The whole process takes 30 minutes in the synthesizer, radiochemical yield higher than 90% and the yield is about 30-40 percent, 60 percent is the maximum yield. Tumor to normal ratio of animal mouse model is higher than 2, which represents the synthesis method and quality of the F-18 FLT precursor developed in this project is valuable.



▲ Fig.1 F-18FLT precursor synthesis pathway



▶ Fig.2 F-18FLT brain tumor PET imaging

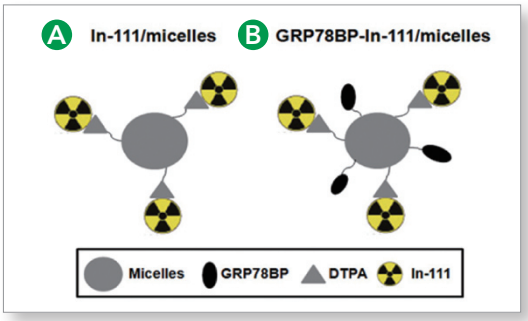
1-2 I-123 MIBG clincal trial with National Taiwan University Hospital (NTUH)

INER has started to cooperate with NTUH for the clinical trial of I-123 MIBG since 2008. According to the contract between INER and NTUH, INER will supply 80 doses of the high-quality I-123 MIBG radiopharmaceutical and NTHU will be in charge of the clinical trial. In mid-term of 2012, the clinical trial was successfully finished. The clinical result demonstrated that I-123 MIBG has higher specificity than F-18 FDOPA (100% vs. 88%) in the diagnosis of neuroblastoma. These results were also published in the Journal of Nuclear Medicine which is the top Journal in the field of Radiology and Nuclear Medicine (2013; 54:42-49).

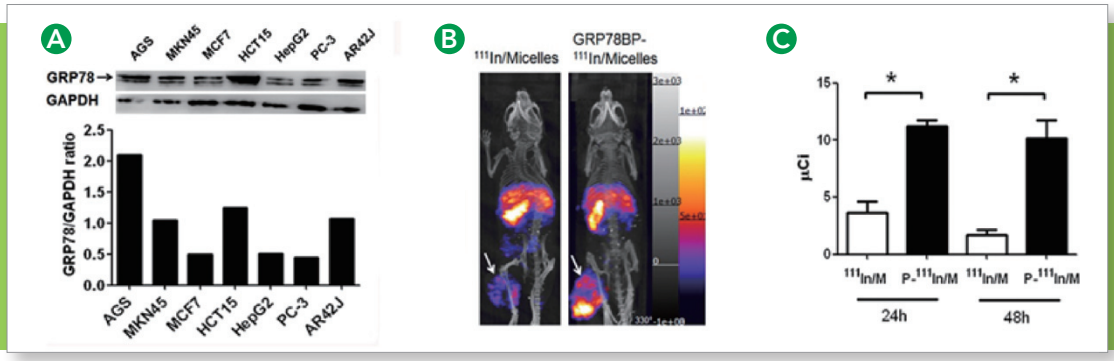
1-3 Novel targeted nuclear imaging agent for gastric cancer diagnosis: glucose-regulated protein 78 binding peptide guided polymeric micelles-In-111.

Increased expression of cellular membrane bound glucose regulated protein 78 (GRP78) is considered as one of biomarkers for gastric cancers (GC). Therefore, peptides or molecules with specific recognition to GRP78 can act as a guiding probe to direct conjugated imaging agents to specifically localize cancers. Based on this rationale, we designed and manufactured the GRP78 guided polymeric micelles for nuclear imaging detection of tumors. To our knowledge, GRP78 is an endoplasmic reticulum (ER) protein, and functions as a refolding protein, which would be translocated to the plasma membrane in tumor cells as a tumor target. Therefore, enhanced drugs targeting to GRP78 of tumor cells may be useful in nuclear imaging during diagnosis, leading to improve the diagnostic accuracy. In summary, we rationally designed and constructed the polymeric micelles carrying with tumor-directing peptide and the isotope chelator DTPA for generating a novel nuclear imaging agent during tumor diagnosis. The GRP78 binding peptide and DTPA were individually labeled onto micelle polymers, and the conjugating efficacy was more than

90%. In nuclear imaging for detecting gastric tumors inoculated on the thigh of nude mice, we found that a higher radioactive intensity in the xenograft murine administrated with the micelles decorated by GRP78 binding peptide were observed, compared to that in the murine treated only with micelles. The result indicated that this GRP78 binding peptide can enhance the targeting efficiency and concentrate imaging reagent onto tumors, and provide a better resolution and diagnostic accuracy in nuclear imaging for diagnosis of tumor.



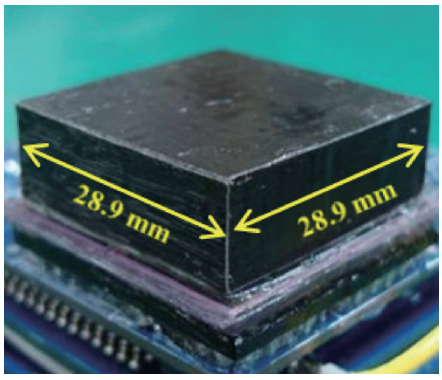
▶ Fig.3 Schematic design of nuclear imaging agent for detecting gastric cancer. (A) Polymeric micelles was labeled with radioactive isotope, Indium (In)-111, through diethylenetriamine penta-acetate (DTPA) molecule, and (B) further conjugated with glucose regulated protein 78 binding peptide (GRP78BP, RGDKGGWIFPWIQL).



▲ Fig.4 GRP78 specifically expressed in gastric cacner cells and GRP78 binding peptide improved the tumor-accumulated efficacy of micelle polymers. (A) GRP78 expressions in the variety of cancer cell lines were detected using Western blotting. The results demonstrated that higher expression of GRP78 in gastric cancer cells (AGS and MKN45), colorectal cancer cells (HCT-15), and pancreatic cancer cells (AR42J), but lower expression in breast cancer cells (MCF-7), liver cancer cells (HepG2), and prostate cancer cells (PC-3). Therefore, we found that GRP78 specifically expressed in gastric cancer. (B) The radioactive compounds including In-111-micelles, GRP78 binding peptide conjugated In-111-micelles, and In-111 alone were injected into gastric cancer xenografts via tail vein, while In-111 was used as reference for radioactive quantification. From the nuclear imaging captured by nanoSPECT/CT, we found that radioactive intensity of GRP78 binding peptide conjugated In-111-micelles was higher than that of In-111-micelles in tumor (indicated by arrows), demonstrating that GRP78 binding peptide can guide the micelles into tumor cells and increase the radioactive signal. (C) Radio-quantification in 24h and 48h showed that GRP78 binding peptide (P) improved the accumulated efficacy of micelles in tumor tissue compared to In-111-micelles compound. *p<0.05.

1-4 Semiconductor photonic imaging detector

In this project, there were two key technologies established this year. One is PCB-based semiconductor-photonic array building method, and the other is derive-readout-integrated electronics technology. With the two technologies applying, a semiconductor-photonics-based imaging detector with an effective area larger than 1-square inch was successfully developed. Through this output, a world-wide tech level was exhibited [H-S Yoon et. Al., 2012]. The two tech results this year were contributed to the photonics array developing and its optimal operating, which are essential basic techs for developing imaging scanner of a new-generation medical imaging device.



▲ The preliminary semiconductor- photonics-based imaging detector, with an effective area of 1.3 square inches and pixel size of 1.9 mm.

For the medical equipment R&D team, through the above-mentioned results, establishment of fundamental techniques for the semiconductor-photonics-based imaging detector technology was presented. To achieve the tech-necessaries for developing practical and valuable scanners, i.e. high-resolution, large detecting area, and dead-space-less packages, further improvements on the readout electronics and optical assembling techs are required. It is expected that the complete semiconductor-photonics-based imaging detector technology makes our team capable of developing the world-wide competitive, new-generation molecular imaging device.

The strategies of the new drug development for radiation application research are from establishment of precursor synthesis technology to the clinical trial application to hold the key techniques in the various stages and the integration of the professional resources from bench-top to bedside in the field to jointly develop potential diagnostic radiopharmaceuticals and valuable new drugs. This year focused on the development of diagnostic drug for tumor, neuroblastoma cell tumors and neurological disease, in the future, the direction of research and development actively promote not only the clinical application of the drug, but also to reach out toward the liver and lung drug development.

Both the new drugs and medical equipment development of this project are not only to upgrade the establishment of the nuclear medicine industry in Taiwan, but also to safeguard the health of citizens. More importantly, to achieve the unique radiopharmaceuticals and leap to international competition platform.

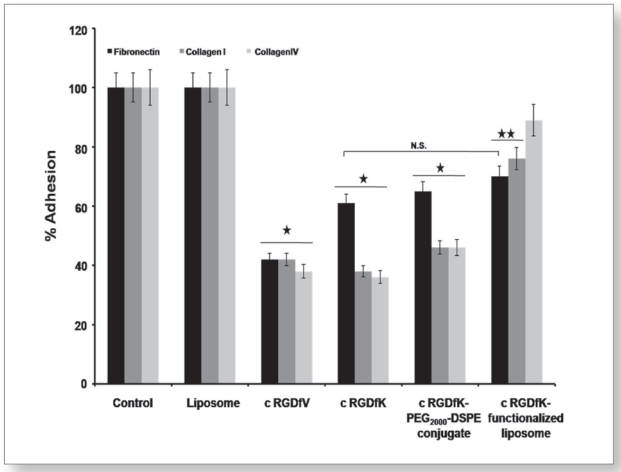
2. Development of Nano Diagnostic and Therapeutic Radiopharmaceutical Technology and Their

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

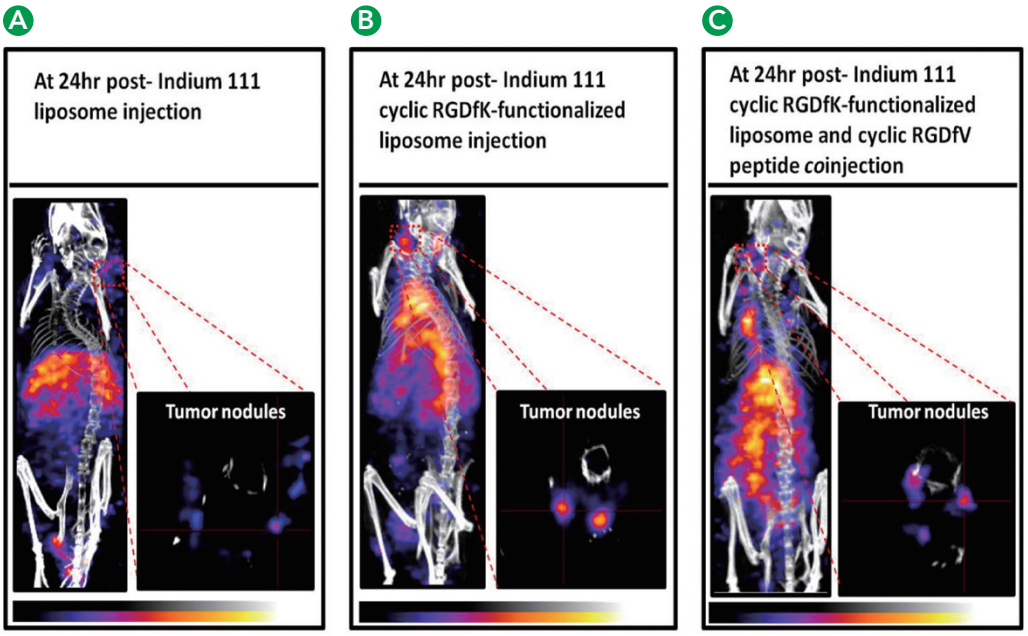
The Project, entitled "Development of nano diagnostic and therapeutic radiopharmaceutical technology and their applications", covers three main topics, including (1) nano diagnostic radiopharmaceuticals (2) nano therapeutic radiopharmaceutical (3) carbon nano tubes as early phase NPC diagnostics. The main purpose of this project is to integrate radiopharmaceutical and nanotechnology for medical diagnostics and therapy.

2-1 The indium 111-labeled cyclic RGDfK-functionalized liposome represents human melanoma in a nude mouse xenotransplantation model

The aim of this study was to develop an alphaVbeta3 ($\alpha V\beta 3$) integrin-targeting nano-particle as imaging modality for the detection of human melanoma. An indium111 labeled cyclic RGDfK-conjugated liposome was prepared and also cell-based assays and a nude mouse xenotransplant model were conducted to test the targeting efficacy of the indium111 labeled cyclic RGDfK-conjugated liposome in the detection of melanoma. We found that this formulation inhibited the $\alpha V\beta 3$ integrin-mediated cell adhesion of human melanoma cell to extracellular matrix proteins, that this formulation had no considerable inhibition effect on the function of phagocyte including the engulfment of bacteria and the generation of reactive oxygen species, and that by SPECT/CT imaging, this formulation was clearly accumulated at tumor nodules in human melanoma-bearing nude mice. The indium111 labeled cyclic RGDfK-conjugated liposome could be as an imaging modality for the detection of human melanoma.



◀ Fig.5 The cRGDfK-functionalized liposome inhibited the adhesion of A375.S2 cell to extracellular matrix proteins A375.S2 cell was pretreated with 100 nM cRGDfV, cRGDfK, cRGDfK-PEG_{2000}-DSPE or cRGDfK-functionalized liposome and allow to adhere to immobized fibronectin, collagenI or collagenIV for 1 hour at 37°C before washing and detection of cell adhesion. ★, $p<0.01$, compared with control; ★★, $p<0.05$, compared with liposome; N.S., non significant.

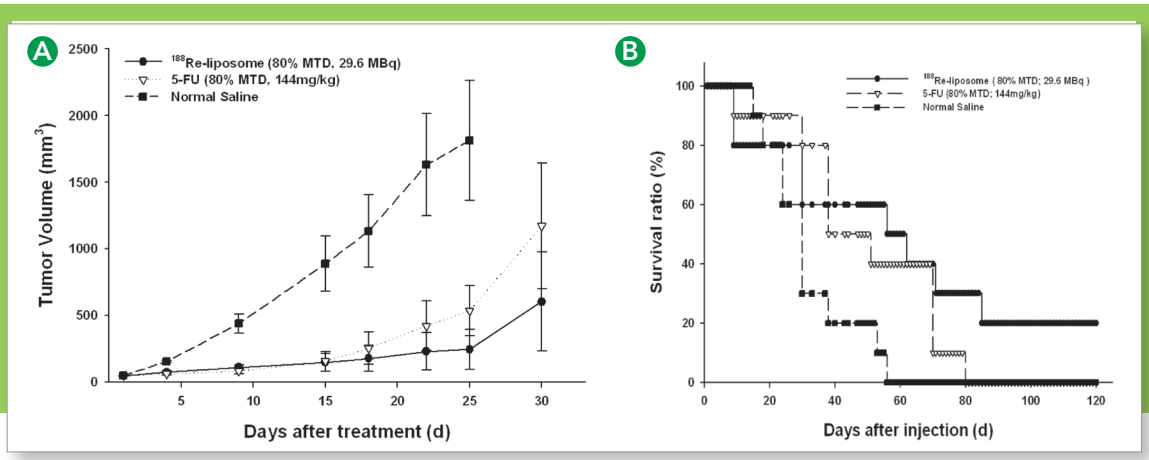


▲ Fig.6 Representative single photon emission computed tomography(SPECT)/CT imaging of tumor-bearing mice after an injection of ^{111}In-liposome or ^{111}In-cyclic RGDfK-functionalized liposome. Scale bar for indium 111 is 0 – 100% for maximum intensity projection and tumor slices(minimum –maximum: 0-7.66×10e^{-5} injection dose).

2-2 Therapeutic efficacy of ^{188}Re-Liposome in a c26 murine colon carcinoma solid tumor model

Nanoliposomes are good drug delivery systems that allow the encapsulation of drugs into vesicles for their delivery. Radiolabeled nanoliposomes have potential applications in radiotherapy and diagnostic imaging. The objective of this study is to investigate the therapeutic efficacy of a new radio-therapeutics of ^{188}Re-labeled pegylated liposome in a C26 murine colon carcinoma solid tumor model. The safety of 188Re-Liposome was evaluated before radiotherapy treatment. The anti-tumor effect of ^{188}Re-Liposome was assessed by tumor growth inhibition, survival ratio and ultrasound imaging. Apoptotic marker in tumor was also evaluated by the TUNEL (terminal deoxynucleotidyl transferase biotin-dUTP nick-end labeling) method after injection of ^{188}Re-Liposome. The group treated with ^{188}Re-Liposome displayed slight loss in body weight and decrease in white blood cell (WBC) count 7 to 14 days post-injection. With

respect to therapeutic efficacy, the tumor-bearing mice treated with ^{188}Re-Liposome showed better mean tumor growth inhibition rate (MGI) and longer median survival time (MGI = 0.140; 80 d) than those treated with anti-cancer drug 5-FU (MGI = 0.195; 69 d) and untreated control mice (MGI = 0.413; 48 d). The ultrasound imaging showed a decrease in both tumor volume and number of blood vessels. There were significantly more apoptotic nuclei (TUNEL-positive) in ^{188}Re-Liposome-treated mice at 8 h after treatment than in control mice. These results evidenced the potential benefits achieved by oncological application of the radio-therapeutics ^{188}Re-Liposome for adjuvant cancer treatment.



▲ Fig.7 Tumor growth and survival curves. (A) Tumor growth volume (mm3) versus time (days), and (B) survival curve for BALB/c mice implanted with C26 murine colon tumors after administering ^{188}Re-Liposome (29.6 MBq; 80% MTD) or 5-FU (144 mg/kg; 80% MTD) by single i.v. injection. The therapeutic studies demonstrated better survival time and tumor growth inhibitory efficacy for mice treated with ^{188}Re-Liposome (80% MTD; 29.6 MBq).

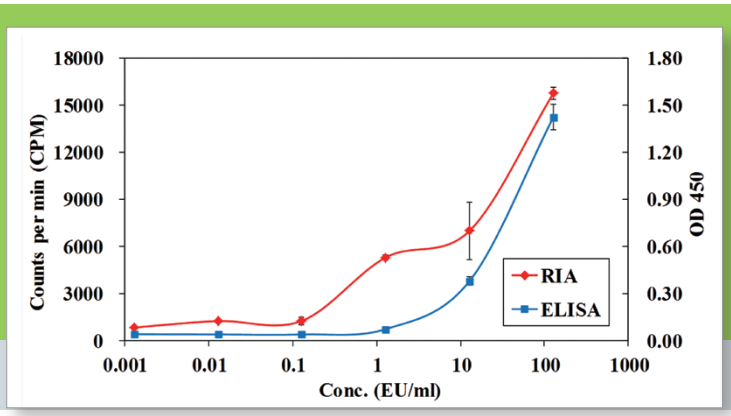
2-3 Phase 0 clinical study proved the safety of ^{188}Re-Liposome in metastatic cancer patients

Phase 0 clinical study of ^{188}Re-liposome was performed in Veteran General Hospital-Taipei, the study aims to investigate the safety of microdose ^{188}Re-liposome in patients with metastatic cancers and who are refractory to current standard/available therapies. Each subject will receive a microdose of less than 3 mCi ^{188}Re-liposome by intravenous drip at day 1. The SPECT/CT scan, which provides information for biodistribution and dosimetry, will be conducted one hour after drug administration, as well as at 4h, 8h, 24h, 48h and 72 h a post-injection. Similarly, blood and urine sample will be taken at the mentioned time points right before SPECT/CT scan for radioactivity analysis. The planar and SPECT imaging were performed at 1, 4, 8, 24, 48, and 72 h after injection of single-dose ^{188}Re-Liposome. One of the patients had bone metastases from esophagus cancer can observed accumulation of ^{188}Re-liposome in suspected tumor location from imaging. There were 8 subjects were completed in 2012. Physiological condition and results of blood biochemical tests were normal. Is shows no adverse reactions in the clinical trials. Clinical studies also proved the safety of ^{188}Re-Liposome in patients.

2-4 Nano RIA Kit for EBV IgA Detection

Epstein-Barr virus (EBV) is a human herpesvirus and strongly associated with development of nasopharyngeal carcinoma (NPC). Nasopharyngeal carcinoma (NPC) is the common tumor in Taiwan, Hong Kong, Singapore and Southern China, and EBV immunoglobulin A (IgA) titer is higher in NPC patients serum. Nowadays, Co-60 irradiated carbon nanotubes (CNTs) can be easily controlled by external magnetic fields, and be used as a biosensor substrate for protein biomarker screening.

In this study, a radio immunoassay (RIA) kit was developed to detect EBV IgA in human serum. EBV antigens were coated on carbon nanotubes (CNTs) combined with ^{125}I-anti-human antibody to detect EBV IgA in human serum. Therefore, this kit can also detect less EBV antibody (0.128 EU/ml) than traditional 96-well plate kit (1.28 EU/ml). The RIA clinical trial had the approval of Mackay Memorial Hospital Institutional Review Board (IRB). We believe our product, in vitro diagnostic devices of RIA, can detect NPC (Nasopharyngeal Cancer) at early stage and monitor treated NPC patients.



▲ Fig.8 Detection Limits of ELISA and EBV IgA RIA Kit. Sample serial dilution: 10X, 100X, 1,000X, 10,000X and 100,000X of 128 EU/ ml. The detection Limit of RIA is lower than the ELISA (1.28 EU/ml).

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" and "EBV IgA detection kit" are proceeding. ^{188}Re-Liposome is the first nanotargeted radiotherapeutic drug for cancer translated into the human clinical trials in the world. ^{188}Re-Liposome can be applied to internal radiotherapy in patients with metastatic cancer. We expect the nano-radiopharmaceutical will have contributions in enhancing the health quality of people in Taiwan.

3. Radiation Applications and Molecular Imaging Technical Platforms for Domestic Highly

By Mei-Hui Wang

The aims of the project are to establish and supply technology platform of radiation applications and molecular imaging, and in coordination with National Research Program for Biopharmaceuticals (NRPB) to develop pharmaceuticals for early diagnosis/therapy of common diseases occurred in Taiwan. This technology platform includes radioisotope production, radiation irradiation, drug production, liver and tumor targeted molecules, molecular image platform, assessment platform for nervous system functions, cGMP/GLP drug quality control, small molecule and chelating agent platform.

The purchase of nanoPET/CT was finished in this year, this imaging instrument can produce 3D images of F-18 labeled drugs instead of 2D planar images. There are 70 service cases in this year, including isotope production and supply 5 cases, radiation sterilization or radiation for electronic homogenization 53 cases, cancer target molecular image 8 cases, neurological medicine biodistribution 2 cases, drug or precursor supply 2 cases. Some of the cancer target molecule and neuromedicine have been proved to be effective. Nucleotide derivatives as cell proliferative probe were developed, which contains nucleotide derivative synthesis, I-123 isotope labeling and in vitro serum stability test have been accomplished. Its isotope labeling yield is more than 85%, and radiochemical purity is more than 95%. The in vitro stability study showed that the purity of the radiochemistry is still more than 90% after 24 hours. The animal image study indicates the developed nucleotide derivative can obviously exhibit the location of tumor in LL2 and A549 lung cancer cell model through molecular imaging. This agent maybe benefit the investigation progress of lung cancer research. This year we earn 1 ROC invention patent, 1 USA invention patent and 2 SCI papers (impact factor 3.046 and 8.362 respectively).

This project belongs to one of resource centers of NRPB. We will continuously cooperated with research group of NRPB, actively played the translational role in the whole pahrmaceutical development chain, in particular, to fulfill the pharmacokinetic and biodistribution study, and to help the pharmaceuticals fastly get the approval of clinical trials, and more to consolidate the energy of molecular image to keep up the competition power in the international arena. We hope to be the leader of global molecular image and pharmaceutical development, especially in the field of Asian domestic highly epidemic disease.

5 Appendices

- *Honors Reported*
- *Patents*

Honors Reported

In order to avoid the limitation caused by complacency and conservativeness, INER encouraged the various units to accept outside evaluations in the organizational development to establish the organizational culture for the pursuit of progress.

During the past year, the award-winning deeds and the participations in facility evaluation of the superior organization or an external organization are summarized as follows:

- INER signed technology transfer contracts and awarded Invention Award in 2012 Taipei International Invention Show & Technomart.

Award-winning schedule in
2012 Taipei International Invention Show & Technomart

Award-winning Category	Patent Name
Platinum Award	■ Solid oxide fuel cell and its production method
Gold Award	■ The innovative composite synergistic making procedures and formulations for highly integrated solid oxide fuel cell membrane electrode assembly components
	■ Separation device of Radioisotope thallium-201
	■ The seat structure of condenser
	■ Burning reformer applied to the fuel cell power generation system
Silver Award	■ Anode handling procedures to enhance the output power density of the solid oxide fuel cell membrane electrode assembly
	■ High temperature capture carbon agent of nano-layered carbonate
Bronze Award	■ Structure derivative of the Hypoxia contrast agent HL91-NI
	■ Promoting algae growth device with ionizing radiation irradiation
	■ A thin film photovoltaic device and its manufacturing method
	■ Sealing materials for glass - ceramic composition
	■ Peeling structure of the substrate of photovoltaic elements

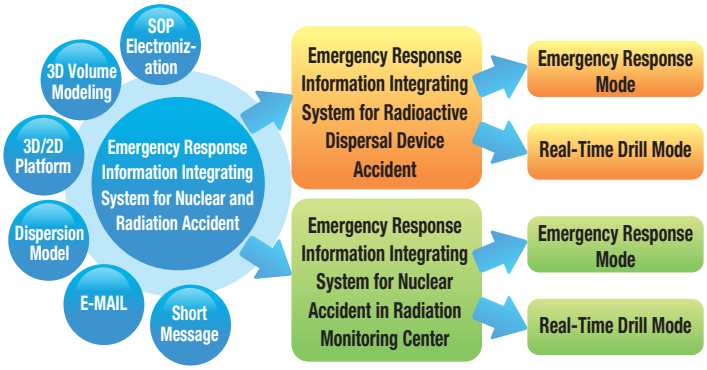
Award-winning schedule in 2012 Taipei International Invention Show & Technomart

Platinum Award

- The Ninth National Innovation Award: Innovative applications of drugs: Rhenium-188 liposome (Body radiation therapy) and "the development of serotonin transporter imaging agent iodine-123-ADAM and it's application in the clinical of depression" participated in "The ninth National Innovation Award - Gakken group" organized by the Institute for National Biotechnology Industry in the ECCC (Health Planning Council) , and won National Innovation Award.

- Obtained the Best Pushing Hands Award of technology development program of Ministry of Economic: Performed technology development program "Radiation pharmacological technologies applied to the development of new drugs for the four-year plan (1/4)" of the Ministry of Economic Affairs, and was awarded the Best Pushing Hands Award of corporate technology development program by the Technology Department of the Ministry of Economic Affairs.

- Obtained "Best in Promoting Service Award" of Gold Figure Award by TGIS in 2012: "Nuclear and Radiation Emergency Response Information Integration Management System", including the integration of mobile devices such as the information technologies of disaster relief emergency response process, 3D modeling, GIS Figure station, instant space radiation diffusion mode, mobile smart phones and virtual reality, was awarded "Best in Promoting Service Award " of Gold Figure Award by TGIS in 2012.



- The verified institution of nuclear energy at the same level product components: Completed periodic replacement of licenses through the audit. Performed verification /validation technical service for a total of 13 cases. Verified components include: Machinery-stainless steel pipe fittings, locator, disc valve, cable prop network ...; Electronic-e-cards, medium voltage power cable, K2 magnetic contactor. Offered opportunities for local manufacturers to legally participate in replacement of safety related equipment components of nuclear power plant.

- Certification of Consortium Accreditation Foundation: The Earthquake Platform Lab, The Radiation Chemical Analysis Laboratory and Solar Cell Module Verification Laboratory obtained certifications of Consortium Accreditation Foundation.

- Obtained CGC Golden Sun Laboratory Accreditation Certificate: Solar Cell Module Verification Laboratory obtained CGC Golden Sun Laboratory Accreditation Certificate that would help the domestic industry to overcome threshold conditions for entering the mainland market.

- Reaffirmed organizational performance: The Institute is the only award-winning public office of "Blue chip" employer for nine consecutive years for the Defense Industrial Reserve Duty System and Military Training. Dr. Chun Chuang was awarded "The Second Conscription Professional Medal" by Minister of the Interior for outstanding performance in the implementation of the administrative matters of military service. Mr. Chun-Liang Chang a R & D substitute military employee, had been selected as one of the 25 annual merit draftees of the year from nearly 10,000 active-duty draftees. Mr. Chang obtained the Blue Chip Draftee Award for 2 consecutive years.

- Obtained Award for Radioactive Materials Security Operations and Award for Outstanding Contribution in the Radioactive Research Development:

  Obtained Award for Outstanding Contribution in Radioactive Material Research and Development (Group Award)- Intractable Radioactive Waste R&D Team of Chemical Engineering Division. Obtained Award for Radioactive Materials Security Operations (Group Award)- Taiwan Research Reactor (TRR) Furnace Waste Safe Storage Management Team. Obtained Award for Radioactive Materials Security Operations (Individual Award)- Dr. Yaw-Hwa Shiu of Nuclear Fuels and Materials Division.

- Obtained Excellence Awards of Involved in the Proposed System Competition: Obtained Excellence Award for "Convergence" to Standard and "Eating " with Confidence. Obtained Honors Award for Application of Private Cloud Storage System in Collaboration.

- Dr. Hou-Chin Chu a member of Nuclear Fuels and Materials Division was chosen as the Exemplary Civil Servant of 2012 years by Executive Yuan.

Patents

1. Yang, Cha-Si, Ho, Yen-Shen, Lu, Li-Huei, Chen, Shu-Lin, Lee, Te-Wei, "Method For Manufacturing Diethylene Triamine Pentaacetic Acid Derivative", Japan, Patent5004438, 2005.06.09-2015.06.08.
2. Tang, Sun-Yun, Lin, Wuu-Jyh, "Method For Recycling Thallium-203 Isotope In Remnant Solution of Thallium-201 Radioisotope", Japan, Patent4936304, 2005.11.28-2015.11.27.
3. Chung, Jen-Chren, "Preparation Method for Oil-Based Magnetic Fluid", EU, EP1821323B1, 2006.02.15-2016.02.14.
4. Chung, Jen-Chren, Chen, Ming-Nan, Huang, Chin-Tsun, "Lipiodol-Ferrofluid, and A Process For Preparation Thereof", EU, EP1855295B1, 2006.05.08-2016.05.07.
5. Wu, Chih-Hung, Cheng, Kai-Sheng, Shin, Hwa-Yuh, "Optical Switch Structure", Japan, Patent4947572, 2006.05.22-2016.05.21.
6. Kuo, Weng-Sheng, Lain, Cheng-Hong, Hu, Chung-Hsing, Fun, Chi-Ho, Tung, Wu-Hsiung, "Method For Analyzing Fuel Displacement Accident of Boiling Water Reactor", Japan, Patent5057426, 2006.07.24-2016.07.23.
7. Cheng, Mao-Hsong, Cheng, Dao-Chi, Chu, Kao-Yuan, Hwang, Bin-Yuan, Chen, Jenn-Tzong, Duh, Ting-Shien, Lin, Wuu-Jyh, "Circulated Cooled Target", EU, EP1892314B1, 2006.08.24-2016.08.23.
8. Hwang, Chang-Sing, "Nanostructured Composite Anode With Nano Gas Channels and Atmosphere Plasma Spray Manufacturing Method Thereof " , Japan, Patent5028063, 2006.10.16-2016.10.15.
9. Lee, Te-Wei, Chiu, Shu-Pei, Yu, Chia-Yu, Chang, Tsui-Jung, Chang, Chih-Hsien, " Preparation of Lipid - Spacer - Reactive Functional Groups - Peptides", R.O.C, Patent I362270, 2012.04.21-2016.10.30.
10. Chang, Hwei-Liang, Tsao, Cheng-Si, Chang, Hen-Rong, Shieh, Kuo-Lon, Cheng, Bee-Shin, "Method For Fabricating A Proton Exchange Membrane Having A Relational Selective Coefficient", R.O.C, Patent I357914, 2012.02.11-2017.01.03.
11. Chang, Hwei-Liang, Tsao, Cheng-Si, Chang, Hen-Rong, Shieh, Kuo-Lon, Cheng, Bee-Shin, "Method For Fabricating A Proton Exchange Membrane Having A Relational Selective Coefficient", Japan, Patent5057364, 2007.03.09-2017.03.08.
12. Chang, Hwei-Liang, Chang, Hen-Rong, Shieh, Kuo-Lon, Cheng, Bee-Shin, "Method For Fabricating Membrane Electrode Assembly", Japan, Patent4919166, 2007.06.28-2017.06.27.
13. Chen, Jun-Chin, Hsu, Ning-Yih, Chiou, Shean-Du, Lin, Su-Hsine, "Apparatus and Method For Controlling The Oxidation State of Catalyst", R.O.C, Patent I375593, 2012.11.01-2017.07.18.
14. Tang, I-Chung, Luo, Tsai-Yueh, Wu, Yu-Lung, Cheng, Shan-Yun, Yeh, Yuen-Han, Shen, Tsan-Maou, Liu, Shiu-Wen, Lin, Wuu-Jyh, "Radioactive Material For Inhibiting Cancer and Preparation Method Thereof", R.O.C, Patent I378801, 2012.12.11-2018.07.25.
15. Hong, Hwen-Fen, Lin, Kou-Shin, Shih, Zun-Hao, Shin, Hwa-Yuh, Kuo, Cherng-Tsong, "Solar Cell Dissipation Package", R.O.C, Utility Patentm428501, 2012.05.01-106.07.26.
16. Hong, Hwen-Fen, Shih, Zun-Hao, Chen, Ying-Ru, Shin, Hwa-Yuh, Kuo, Cherng-Tsong, "Radiating Apparatus For Solar Cell", R.O.C, Utility Patentm428502, 2012.05.01-106.07.26.
17. Hsieh, Cheng-Chang, Wu, Ming-Wen, Ai, Chi-Fong, "Atmospheric Pressure Plasma Reactor", R.O.C, Patent I355866, 2012.01.01-2017.08.15.
18. Wang, To-Mei, Yang, Sheng-Fu, Chiu, Wen-Tung, Lee, Wen-Cheng, Chen, Ching-Liang, Tzeng, Chin-Ching," Light Lava Sheet Manufacturing Method", R.O.C, Patent I368631, 2012.07.21-2017.08.15.
19. Chang, Hwei-Liang, Cheng, Hen-Rong, Shieh, Kuo-Lon, Cheng, Bee-Shin, "Apparatus For Making Tubular Film Transistors", R.O.C, Patent I3556523, 2012.01.11-2017.08.15.
20. Lian, Chun-Shen, Chao, Yu, Chen, Chin-Que, Chiu, Chin-Lee, Li, Shuo-Wei, " Hydrogen-Rich Gas Fuel Production Systems and Hydrogen-Rich Gas Fuel Production Program", R.O.C, Patent I359107, 2012.03.01-2017.08.20.
21. Chen, Tsao-Yu, Liao, Chi-Hung, Huang, Chin-Tsun, Chang, Ching-Tu, "Vermiculite Supported Catalyst For CO Preferential Oxidation and The Process of Preparing The Same", R.O.C, Patent I357355, 2012.02.01-2017.08.22.

22. Lin, Deng-Lain, Tzeng, Chin-Ching, "Direct Current Steam Plasma Torch and Method For Reducing The Erosion of Electrodes Thereof ", R.O.C, Patent I357781, 2012.02.01-2017.08.30.
23. Wu, Szu-Han, Lin, Kin-Fu, Lee, Ruey-Yi, Liu, Chien-Kuo, Yung, Tun-Yuan, Lee, Tzang-Sheng, Chen, Li-Ging, "Sealing Material For Solid Oxide Fuel Cells", R.O.C, Patent I378592, 2012.12.01-2017.09.03.
24. Chen, Charn-Ying, Chang, Chun-Lung, Liu, De-Sin, Shu, Ji-Uen, Cha, Hou-Chin, "Method For Supplying Fuel To Fuel Cell", Japan, Patent4938600, 2007.09.10-2017.09.10.
25. Hsieh, Cheng-Chang, Wu, Ming-Wen, Ai, Chi-Fong, "Atmospheric Pressure Plasma Reactor", US, US8,142,608B2, 2007.09.11-2017.09.10.
26. Lee, Wen-Cheng, Yeh, Fu-Jen, Chen, Ching-Liang, Li, Chin-Hua, Chen, Hue-I, Chen, Yun-Hua, "Method For Recycling Precious Metal From Used Printed Circuit Boards", R.O.C, Patent I365225, 2012.06.01-2017.09.12.
27. Wu, Szu-Han, Lin, Kin-Fu, Lee, Ruey-Yi, Liu, Chien-Kuo, Yung, Tun-Yuan, Lee, Tzang-Sheng, Chen, Li-Ging, "Sealing Material For Solid Oxide Fuel Cells", Japan, Patent5069989, 2012.08.24-2017.09.24.
28. Huang, Chin-Tsun, Chang, Ching-Tu, "Method For Solidifying and Stabilizing Waste Acid", EU, EP2043109B1, 2007.09.26-2017.09.25.
29. Wang, To-Mei, Yang, Sheng-Fu, Chiu, Wen-Tung, Lee, Wen-Cheng, Chen, Ching-Liang, Tzeng, Chin-Ching, " Light Lava Sheet Manufacturing Method", Japan, Patent4901671, 2007.09.28-2017.09.27.
30. Hong, Hwen-Fen, Lin, Kou-Shin, Shih, Zun-Hao, Shin, Hwa-Yuh, Kuo, Cherng-Tsong, "Solar Cell Dissipation Package", Japan, Patent5057379, 2007.09.28-2017.09.27.
31. Lee, Maw-Chwain, Kao, Wei-Xin, Lin, Tai-Nan, Cheng, Yan-Jung, Wang, Jun-Shou, "A Novel Synergistic Process and Recipe For Fabrication of A High Integrity Membrance Electrode Assembly of Solid Oxide Fuel Cell", Japan, Patent5099892, 2007.10.01-2017.09.30.
32. Liu, Chien-Kuo, Yung, Tun-Yuan, Lin, Kin-Fu, Wu, Szu-Han, "Method For Bonding Two Plates", R.O.C, Patent I356046, 2012.01.11-2017.10.03.
33. Chu, Hou-Chin," Abrasive Thinning Specimen Method", R.O.C, Patent I361888, 2012.04.11-2017.10.04.
34. Li, Ming-Hsin, Zen, Tain-Shi, Lin, Wuu-Jyh, "Automated Dispenser For Radiopharmaceuticals", US, US8,181,677B2, 2007.10.08-2017.10.07.
35. Liu, Chien-Kuo, Yung, Tun-Yuan, Lin, Kin-Fu, Lee, Ruey-Yi, Lee, Tzang-Sheng, "Glass-Ceramic Sealant For Planar Solid Oxide Fuel Cells", R.O.C, Patent I365860, 2012.06.11-2017.10.10.
36. Chen, Shiaw-Huei, Chen, Yun-Ji, Yan, Jyh-Ming, Huang, Men-Han, Yanh, Ming-Song, "One Atmospheric Pressure Non-Thermal Plasma Reactor With Dual Discharging-Electrode Structure ", R.O.C, Patent I357090, 2012.01.21-2017.10.10.
37. Cheng, Chia-Rong, Chen, Chia-Chieh, " Chinese Herbal Medicine Devices of Nuclear Medicine Molecular Imaging Detection", R.O.C, Patent I374729, 2012.10.21-2017.10.17.
38. Chung, Jen-Chren, Zeng, Yu-Zhen, Liu, Yu-Chang, "Multi-Layer Film Electrode Structure and Its Preparation", R.O.C, Patent I370549, 2012.08.11-2017.10.18.
39. Lin, Dong-Wei, Shyu, Hung-Fa, Who, Hung-Tsan, "Nondestructive Testing Auxiliary Apparatus", R.O.C, Patent I357606, 2012.02.01-2017.10.18.
40. Chen, Tsao-Yu, Liao, Chi-Hung, Huang, Chin-Tsun, Chang, Ching-Tu, "Vermiculite Supported Catalyst For CO Preferential Oxidation and The Process of Preparing The Same", Japan, Patent5154887, 2007.10.19-2012.11.14.
41. Yo, Shi-Fan, Wu, Tzong-Da, Jan, Meei-Ling, "Photomultiplier Tube Interface Device", R.O.C, Patent I365475, 2012.06.01-2017.10.24.
42. Wu, Ming-Wen, Hsueh, Tien-Hsiang, Hsieh, Cheng-Chang, Ai, Chi-Fong, "Apparatus and Method For Double-Plasma Graft Polymerization At Atmospheric Pressure", R.O.C, Patent I358414, 2012.02.21-2017.10.25.
43. Wang, Mei-Hui, Lin, Wuu-Jyh, Lee, Re-Chen, Shen, Lie-Hang, Chen, How-Rang,"Glyco-Molecular Imaging Method For Remaining Liver Function Measurement and Its Glyco-Molecular Imaging Agent Thereof", US, US8,142,759B2, 2007.12.12-2017.12.11.

44. Kao, Wei-Xin, Lee, Maw-Chwain, Lin, Tai-Nan,Wang, Jun-Shou, Cheng, Yan-Jung, Lin, Li-Fu, "A Process For Fabrication of A Fully Dense Electrolyte Layer Embedded In Membrane Electrolyte Assembly of Solid Oxide Fuel Cell", EU, EP2083465A1, 2008.01.23-2018.01.22.
45. Chang, Hwei-Liang, Cheng, Hen-Rong, Shieh, Kuo-Lon, Cheng, Bee-Shin, "Apparatus For Making Tubular Film Transistors", Japan, Patent4961596, 2008.01.28-2018.01.27.
46. Cheng, Tsung-Chieh, Chi, Yu-Chin, Chen, Ming-Huei, "Control Loop For A Power Plant", Japan, Patent5048533, 2008.01.28-2018.01.27.
47. Cheng, Jun-Tsai, Huang, Wan-Min, "Method For Making Membrane Fuel Cell Electrodes By Low-Voltage Electrophoretic Deposition of Carbon Nanomaterial-Supported Catalysts", US, US8,273,230B2, 2008.02.15-2018.02.14.
48. Yu, Yuan-Chang, Yeh, Hong-Yih, Huang, Hui-Wen, Chen, Ming-Huei, "Apparatus of Simulating Data Certification With Safe Network Communication", R.O.C, Patent I363526, 2012.05.01-2018.03.05.
49. Wang, Jun-Shou, Lee, Maw-Chwain, Lin, Tai-Nan,Cheng, Yan-Jung, Kao, Wei-Xin, Lin, Li-Fu, "Innovation Process For Anode Treatment of Solid Oxide Fuel Cell-Membrane Electrode Assembly To Upgrade Power Density In Performance Test", Japan, Patent5166080, 2008.03.12-2018.03.11.
50. Huang, Po-Shoun, Ou Yang, Chii-Neng, Hsu, Yi-Ru, Hsu, Yao-Tung, Lin, Tsung-Te, "Apparatus For Measuring The Strength of Solar Cells", R.O.C, Patent I367320, 2012.07.01-2018.04.02.
51. Chung, Jen-Chren, Shih, Shu-Min, Chen, Yueh-Sheng, "Method For Producing Catalyst For Wastewater Treatment", R.O.C, Patent I359698, 2012.03.11-2018.04.21.
52. Lin, Deng-Lain, Tzeng, Chin-Ching, "Direct Current Steam Plasma Torch and Method For Reducing The Erosion of Electrodes Thereof ", US, US8,269,134B2, 2008.04.25-2018.04.24.
53. Chen, Jun-Chin, Hsu, Ning-Yih, Chiou, Shean-Du, Lin, Su-Hsine, "Method For Making Ru-Se Nanometer Catalyst", R.O.C, Patent I365565, 2012.06.01-2018.06.05.
54. Shih, Zun-Hao, Hong, Hwen-Fen, Lin, Kou-Shin, "Insulating Device of Concentration Photovoltaic Heat Sink", US, US8,263,852B2, 2008.06.23-2018.06.22.
55. Zen, Tain-Shi, Chuang, Shyh-Fang, Feng, Shang-Yao, "System Engineered Safety Feature Instruments", R.O.C, Patent I358070, 2012.02.11-2018.06.25.
56. Li, Ming-Hsin, Lin, Wuu-Jyh, "Method For Automated Formulation Process For Production of Radiopharmaceutical Injection Medicine and Evaluation Thereof ", R.O.C, Patent I362928, 2012.05.01-2018.07.06.
57. Lin, Sue-Ray, Hong, Sien-How, Kan, Long-Chen, "Method for Evaluating the Safety Of Class-1 Piping in a Nuclear Power Plant", R.O.C, Patent I368920, 2012.07.21-2018.07.09,
58. Chen, Charn-Ying, Chang, Chun-Lung, Liu, De-Sin, Shu, Ji-Uen, Wang, Re-Sheng, "Method For Supplying Fuel To Fuel Cell", R.O.C, Patent I371887, 2012.09.01-2018.07.10.
59. Chang, Kang-Wei, Tu, Yean-Hung, Lee, Shih-Ying, Chen, Jenn-Tzong, Chen, Chia-Chieh, Lin, Wuu-Jyh, "Automatic Process For Synthesizing F-18-FDDNP", R.O.C, Patent I359673, 2012.03.11-2018.07.16.
60. Cheng, Yan-Jung, Lee, Maw-Chwain, Wang, Jun-Shou, Lin, Tai-Nan, Kao, Wei-Xin, "Formulation of Nano-Scale Electrolyte Suspensions and Its Application Process For Fabrication of Solid Oxide Fuel Cell-Membrane Electrode Assembly (SOFC-MEA)", US, US8,158,304B2, 2008.07.22-2018.07.21.
61. Yeh, Chin-Hsien, Yuan, Ming-Chen, "Structure For A Rod Radiation Source and Its Calibration Phantom", R.O.C, Patent I374289, 2012.10.11-2018.07.24.
62. Tsao, Cheng-S, Yu, Ming-Shen, Tzeng, Yi-Ren, Wang, Chen-Yo, Wu, Shou-Chu, Chung, Tsui-Yun, Chen, Jun-Chin, Lin, Li-Fu, "High Capacity Hydrogen Storage Material and Method of Making The Same", R.O.C, Patent I369246, 2012.08.01-2018.07.24.
63. Kao, Hong-Jun, Lou, I-Ren, Chen, Chia-Chieh, Lin, Wuu-Jyh, Shen, Lie-Hang, "Automatic Process For Synthesizing I-123-ADAM", R.O.C, Patent I359672, 2012.03.11-2018.08.06.
64. Tsai, Chun-Huang, Hwang, Chang-Sing, "Fuel Cell Measurement Apparatus", R.O.C, Patent I364127, 2012.05.11-2018.08.14.

65. Yu, Dung-Di, Cheng, Yung-Neng, Lee, Ruey-Yi, Lee, Chien-Hsiung, "Fuel Cell Assembly Structure", R.O.C, Patent I369023, 2012.07.21-2018.08.28.

66. Peng, Chen-Chzu, "Apparatus For Restraining A Squeezed CRD Blade", R.O.C, Patent I373052, 2012.09.21-2018.09.03.

67. Cheng, Yan-Jung, Lee, Maw-Chwain, Wang, Jun-Shou, Lin, Tai-Nan, Kao, Wei-Xin, "Formulation of Nano-Scale Electrolyte Suspensions and Its Application Process For Fabrication of Solid Oxide Fuel Cell-Membrane Electrode Assembly (SOFC-MEA)", EU, EP2166602A1, 2008.09.11-2018.09.10.

68. Luo, Tsai-Yueh, Chen, Jen-Wen, Tang, I-Chung, Shu, Gue-Lun, Wu, Yu-Lung, Liu, Chin-Jen, Liang, Te-Sheng, Lin, Jin-Jenn, Shen, Tsan-Maou, Shu, Ji-Do, "Radioactive Material Containing Chitosan For Inhibiting Cancer and Preparation Method Thereof", R.O.C, Patent I375569, 2012.11.01-2018.09.15.

69. Hong, Wen-Tang, Tsai, Yu-Ching, Wang, Hong-Yu, Yen, Tzu-Shang, Lee, Chien-Hsiung, Huang, Wei-Ping, Lin, Ming-Da, Lai, Chen-Po, Huang, Cheng-Nan, " Solid Oxide Fuel Cell System", R.O.C, Patent I366300, 2012.06.11-2018.09.24.

70. Liao, Ben-Jin, Yu, Yuan-Chang, Huang, Hui-Wen, Cheng, Tsung-Chieh, Chen, Ming-Huei, "System of Testing Engineered Safety Feature Instruments", R.O.C, Patent I365457, 2012.06.01-2018.09.24.

71. Tang, I-Chung, Luo, Tsai-Yueh, Wu, Yu-Lung, Shu, Gue-Lun, Lin, Jen-Sheng, Lin, Jin-Jenn, Shen, Tsan-Maou, Liang, Te-Sheng, Shu, Ji-Do, Liu, Chin-Jen, "Radioactive Mixture and Manufacturing Method Thereof", R.O.C, Patent I355277, 2012.01.01-2018.10.07.

72. Hwang, Chang-Sing, Tsai, Chun-Huang, "Solid Oxide Fuel Cell and Manufacturing Method Thereof", R.O.C, Patent I373880, 2012.10.01-2018.10.15.

73. Chao, Chun-Chang, Chen, Meng-Chi, "Fault Tree Analysis System For The Instrument Control Process For Nuclear Power Plant With Advanced Boiling Water Reactor Background", R.O.C, Patent I380322, 2012.12.21-2018.10.16.

74. Lin, Hung-Hsiang, Lee, Ruey-Yi, Cheng, Yung-Neng, "Load Device For SOFC Stack and A High-Temperature Furnace Using The Same", R.O.C, Patent I369809, 2012.08.01-2018.10.21.

75. Wu, Ming-Wen, Hsueh, Tien-Hsiang, Hsieh, Cheng-Chang, Ai, Chi-Fong, "Measurement System of Planar Fuel Cell", R.O.C, Patent I361238, 2012.04.01-2018.10.21.

76. Lin, Wei-Fang, Liu, I-Sou, Huang, Kuo-Dong, Wu, Ming-Choung, Yang, Tsun-Neng, Tsao, Cheng-Si, "Coating For Solar Cell and "Method For Making The Same", R.O.C, Patent I369789, 2012.08.01-2018.10.23.

77. Liang, Hsin-Chin, "Method For Identifying 3-D Location of Gamma Interaction and Flat Panel Gamma Imaging Head Apparatus Using The Same", R.O.C, Patent I356689, 2012.01.21-2018.10.28.

78. Chao, Chun-Chang, Lin, Jyh-Der, "An Improved All-Round Operating Default Risk Rating System of Boiling Water-Type Nuclear Power Plants", R.O.C, Patent I378470, 2012.12.01-2018.10.29.

79. Cheng, Yung-Neng, Lee, Ruey-Yi, Lin, Hung-Hsiang, "An Online Height Measurement System of Planar Fuel Cell", R.O.C, Patent I372486, 2012.09.11-2018.10.29.

80. Tsai, Yu-Ching, Hong, Wen-Tang, Wangi, Hong-Yu, Lee, Ruey-Yi, Huang, Wei-Ping, "Environmentally Friendly, Energy-Economic System For Testing Fuel Cell Stacks", R.O.C, Patent I372953, 2012.09.21-2018.10.29.

81. Yen, Z-Shang, Hong, Wen-Tang, Tsai, Yu-Ching, Wangi, Hong-Yu, Huang, Wei-Ping, Lin, Ming-Da, Lai, Chen-Po, Huang, Cheng-Nan, "Fuel Cell System", R.O.C, Patent I364131, 2012.05.11-2018.10.29.

82. Chu, Guan-Hwei, "A Thermal Performance Diagnostics Apparatus For Nuclear Power Plant", R.O.C, Patent I372323, 2012.09.11-2018.10.29.

83. Wang, Hong-Yu, Tsai, Yu-Ching, Hong, Wen-Tang, Yen, Tzu-Shang, Huang, Cheng-Nan, Huang, Wei-Ping, "Apparatus For Monitoring A Schedule For Testing A Fuel Cell", US, US8,244,382B2, 2010.01.11-2020.01.10.

84. Chyou, Shang-Lee, Lung, I-Tao, Yang, Shiu-Ju, "Controlling Apparatus For A Concentration Photovoltaic System", US, US8,297,273B2, 2009.02.08-2019.02.07.

85. Liang, Yi-Ping, Lin, Kou-Shin, Hong, Hwen-Fen, Shin, Hwa-Yuh, Kuo, Cherng-Tsong, "Cable For Concentrating Photovoltaic Module", US, US8,145,021B2, 2010.01.13-2020.01.12.

86. Yen, Z-Shang, Hong, Wen-Tang, Tsai, Yu-Ching, Wang, Hong-Yu, Huang, Wei-Ping, Lin, Ming-Da, Lai, Chen-Po, Huang, Cheng-Nan, "Fuel Cell System", US, US8,197,975B2, 2010.01.19-2020.01.18.

87. Lee, Wen-Cheng, Chen, Ching-Liang, Li, Chin-Hua, Liu, Guan-Ting, Wu, Show-Wen, Yen, Shen-You, "Method For Recovering Gold, Silver, Copper and Iron From Valuable Metal-Containing Plasma-Caused Slag ", R.O.C, Patent I372662, 2012.09.21-2019.04.02.

88. Yang, Tsun-Neng, "Method of Fabricating Zinc Oxide Film Having Matching Crystal Orientation To Silicon Substrate", R.O.C, Patent I379345, 2012.12.11-2020.04.15.

89. Yang, Tsun-Neng, "Method of Fabricating Thin Film Interface For Internal Light Reflection and Impurities Isolation", R.O.C, Patent I379430, 2012.12.11-2019.04.15.

90. Shin, Hwa-Yuh, Hong, Hwen-Fen, Kou, Hong-Ren, Chiu, Hung-Sheng, Chen, Jun-I, "Lens For Concentration Photovoltaic Module", US, US8,194,331B2, 2009.12.15-2020.08.08.

91. Peng, Chen-Chzu, "Apparatus For Restraining A Squeezed CRD Blade", US, US8,091,185B2, 2009.12.15-2019.12.14.

92. Chang, Hwei-Liang, Chang, Ron-Show, "A Method and Apparatus For Continuous Coating With A Rotational Extrusion Die In Which Coating Materials Flow In A Radial Direction", R.O.C, Patent I372660, 2012.09.21-2019.05.06.

93. Wu, Chih-Hung, "Ohmic Contact Having Silver Material", R.O.C, Patent I377645, 2012.11.21-2019.05.06.

94. Yu, Ching-Tsung, "Method of Fabricating Layered Nanomaterial Used For Mid-High Temperature CO_2 Capture", US, US8,168,156B2, 2010.02.09-2020.02.08.

95. Lin, Hung-Hsiang, Lee, Ruey-Yi, Cheng, Yung-Neng, "Device For Transporting Planar SOFC Stack", US, US8,146,890B2, 2012.04.03-2020.08.11.

96. Lin, Hung-Hsiang, Lee, Ruey-Yi, Cheng, Yung-Neng, "Load Device For SOFC Stack and A High-Temperature Furnace Using The Same", US, US8,250,929B2, 2012.08.28-2021.04.18.

97. Yang, Tsun-Neng, "Method of Fabricating Thin Film Interface For Internal Light Reflection and Impurities Isolation", US, US8,273,650B2, 2009.11.16-2019.11.16.

98. Hwang, Chang-Sing, Tsai, Chun-Huang, "Solid Oxide Fuel Cell and Manufacturing Method Thereof", US, US8,241,812 B2, 2009.06.12-2019.06.11.

99. Chen, Tsao-Yu, Chen, Shiaw-Huei, "Plasma-Assisted Catalytic Reforming Apparatus and Method", R.O.C, Patent I379710, 2012.12.21-2019.06.22.

100. Tzeng, Chin-Ching, "Dynamically Adaptive Trammel Screen System", US, US8,091,711B2, 2009.06.24-2019.06.23.

101. Yang, Sheng-Fu, Wang, To-Mei, Lee, Wen-Cheng, Tzeng, Chin-Ching, "Method For Porous Baffle Board Fabrication", R.O.C, Patent I374963, 2012.10.21-2019.06.24.

102. Huang, Chi-Wen, Chu, Sin-Chi, Wu, Yao-Kuo, "Maintenance Mechanism For Lighting Equipment In A Closed Space of High Radiation Activity", R.O.C, Patent I379968, 2012.12.21-2019.06.25.

103. Tzeng, Chin-Ching," Two-Stage Granular Moving-Bed Apparatus", US, US8,142,730B2, 2012.03.27-2020.01.17.

104. Wang, To-Mei, Ge, Ming-Deh, Ho, Guan-Shu, Sun, Kin-Seng, Lee, Wen-Cheng, Yang, Sheng-Fu, Tzeng, Chin-Ching, "Method of Fabricating Slag Fiber Friction Material", US, US8,158,049B2, 2009.12.22-2019.12.21.

105. Liu, Shiu-Wen, Lin, Jen-Sheng, "Method For Preparing Precursor of Radioactive 3-Iodobenzylguanidine", R.O.C, Patent I364296, 2012.05.21-2019.07.13.

106. Yeh, Hong-Yih, "Horizontal Solar Tracker Apparatus", R.O.C, Patent I363171, 2012.05.01-2019.07.15.

107. Hsu, Yi-Ru, Ou Yang, Chii-Neng, Lin, Tsung-Te, Hsu, Yao-Tung, "Device of Testing Robustness of Photovoltaic Module Terminal", US, US8,186,203B2, 2009.12.15-2019.12.14.

108. Chen, Jenn-Tzong, Lin, Wuu-Jyh, "Device For Separating Out Radioisotope Thallium-201", US, US8,157,998B2, 2009.11.19-2019.11.18.

109. Chang, Kuo-Yuan, Chiao, Ling-Huan, Hsu, Chin-Teng, Chu Ko, Chih-Chun, Wu, Yao-Kuo, "Filtration Separation Method For Waste Resin Containing Highly Radioactive Uranium Powder and Device Thereof", US, US8,333,893B2, 2009.07.31-2019.07.30.

110. Huang, Chi-Wen, Chu, Sin-Chi, Wu, Yao-Kuo, "Maintenance Mechanism For Lighting Equipment In A Closed Space of High Radiation Activity", US, US8,100,590B2, 2009.07.31-2019.07.30.
111. Yu, Yuan-Chang, Huang, Hui-Wen, Cheng, Tsung-Chieh, "Diversity and Defense-In-Depth Simulation Apparatus", US, US8,249,840B2, 2009.09.09-2019.09.08.
112. Perng, Kang-Neng, Liu, Ching-Shih, Hwang, Kang-Lin, "Eddy Current Probe Having Magnetic Gap", US, US8,203,336B2, 2009.09.13-2019.09.12.
113. Li, Ming-Hsin, Duh, Ting-Shien, Lin, Wuu-Jyh, "Process Parameter Assessment Method For The Solid Target For Gallium (Ga)-68/Germanium (Ge)-68 Generator", US, US8,239,159B2, 2009.09.30-2019.09.29.
114. Chung, Jen-Chren, Zeng, Yu-Zhen, Liu, Yu-Chang, "Method For Making Metal/Titania Pulp and Photocatalyst", US, US8,241,604B2, 2009.09.30-2019.09.29.
115. Lin, Ting-Shiang, "Method of Enhanced Conversion Efficiency In Xylose Fermentation of Lignocellulosic Hydrolysate", R.O.C, Patent I376419, 2012.11.11-2019.10.21.
116. Chung, Jen-Chren, Liu, Yu-Chang, "Wastewater Treatment Apparatus and Method With Stair-Like Heat Treatment Tanks", US, US8,187,429B2, 2009.10.22-2019.10.21.
117. Liu, Gon-Den, Hsia, Yi-Chih, Lin, Tai-Sheng, Chen, Chia-Chieh, Shen, Lie-Hang, "Method For Analyzing Structure and Purity of Serotonin Transporter Imaging Agent[^{123}I] Adam and Precursor SnADAM ", US, US8,153,441B2, 2009.10.23-2019.10.22.
118. Hsu, Yi-Ru, Lin, Tsung-Te, Hsu, Yao-Tung, "Apparatus For Measuring The Temperature Coefficients of A Concentrator Photovoltaic Module", R.O.C, Patent I379424, 2012.12.11-2019.10.29.
119. Chen, Wen-Hua, "Hydrothermal Apparatus and Method of Lignocellulosic Biomass Pretreatment For The Production of Cellulosic Ethanol", R.O.C, Patent I364427, 2012.05.21-2019.10.29.
120. Lin, Hung-Hsiang, Lee, Ruey-Yi, Cheng, Yung-Neng, "System For Transporting Planar SOFC Stack", R.O.C, Patent I373872, 2012.10.01-2019.11.05.
121. Zen, Tain-Shi, Chen, Wen-Hua, "Apparatus is Used To Disassemble and Rough-Cut The Package of Rice Stem", R.O.C, Patent I36944, 2012.08.11-2019.11.29.
122. Wang, Jun-Shou, Lee, Maw-Chwain, Lin, Tai-Nan, Cheng, Yan-Jung, Kao, Wei-Xin, "Process To Produce Fine Ceramic Powder Through A Chemical Reactor With Powder Collection Device", US, US8,287,813B2, 2009.12.01-2019.11.30.
123. Yu, Dung-Di, Cheng, Yung-Neng, Lee, Ruey-Yi, "Thermal Management System For High-Temperature Fuel Cell ", US, US8,216,735B2, 2009.12.01-2019.11.30.
124. Chen, Jun-I, Shin, Hwa-Yuh, Chiu, Hung-Sheng, "Outer Frame Drainage Structure of Concentrator Type Solar Cell Module", R.O.C, Patent I368470, 2012.07.11-2019.12.03.
125. Chu, Sin-Chi, Chu Ko, Chih-Chun, Zen, Tain-Shi, Feng, Shang-Yao, Huang, Chi-Wen, "Collection Can For Precipitated Powder Substance and The Use Thereof ", US, US8,123,939B2, 2009.10.14-2019.10.13.
126. Lin, Hung-Hsiang, Lee, Ruey-Yi, Cheng, Yung-Neng, "System For Transporting Planar SOFC Stack", US, US8,251,632B2, 2012.08.28-2020.11.25.
127. Chyou, Yau-Pin, "Multiple-Stage Granular Moving Bed Apparatus", US, US8,163,249 B2, 2010.01.15-2020.01.14.
128. Ou, Ting-Chia, "DC Power System Using HCPV and BIPV Modules", US, US8,314,512 B2, 2010.01.20-2020.01.19.
129. Hsu, Yi-Ru, Lin, Tsung-Te, Hsu, Yao-Tung, "Apparatus For Measuring The Temperature Coefficients of A Concentrator Photovoltaic Module", US, US8,308,351 B2, 2012.11.13-2020.02.11.
130. Chen, Jun-Chin, Chiou, Shean-Du, Lin, Su-Hsine, Huang, Wan-Min, Hsu, Ning-Yih, "Gas Reaction Device Having Four Reaction States", US, US8,128,894B2, 2010.03.15-2020.03.14.
131. Yu, Ching-Tsung, Chyou, Yau-Pin, "Method of Fabricating Layered Nano-Carbonate Used For Medium-High Temperature CO_2 Sorbent", US, US8,207,086B2, 2010.04.07-2020.04.06.
132. Shin, Hwa-Yuh, Chen, Jun-I, Kou, Hong-Ren, "Manufacturing Process For Silicone Glass Concentrator Lens", US, US8,128,852B2, 2010.05.07-2020.05.06.

133. Chen, Jun-Chin, Hsu, Ning-Yih, "Method of Manufacturing Nano-Platinum Catalyst On Nano-Size Silicon Dioxide", US, US8,168,558B2, 2010.05.19-2020.05.18.

134. Huang, Chiung-Fang, Chen, Wei-Hsi, Lin, Ting-Shiang , Chen, Wen-Hen, "Method of Cultivating Yeast For Enhancing Pentitol Production ", US, US8,278,078B2, 2010.05.28-2020.05.27.

135. Liu, Mao-Chen, Lin, Chung-Zen, Lin, Kuo-Jen, "Radioactivity Measuring Apparatus With Rotating Stage For Waste Drums", US, US8,304,741B2, 2012.11.06-2021.05.30.

136. Liu, Shiu-Wen, Lin, Jen-Sheng, "Bifunctional Compound with Monomeric Sugars and N2S2 Ligands Method For Preparing and The Use Thereof", R.O.C, Patent I378939, 2012.12.11-2020.07.08.

137. Yang, Tsun-Neng, "Method of Fabricating Silicon Nanowire Solar Cell Device Having Upgraded Metallurgical Grade Silicon Substrate", US, US8,207,013B2, 2010.09.17-2020.09.16.

138. Kuo, Hung-Ta, "Nut Driver For Electrical Terminal and Method of Using The Same", R.O.C, Patent I373396, 2012.10.01-2020.10.05.

139. Liu, Shiu-Wen, Lin, Jen-Sheng, "Method For Preparation of N-Methyl-3-(2-Tributylstannylphenoxy)-3-Phenylpropanamine and Use Therof", US, US8,258,331B2, 2012.09.04-2021.04.15.

140. Wei, Hwa-Jou, "A Device That Can Be Operated In Liquid and Vapor Phase For Ethanol Dehydration", R.O.C, Utility Patentm425125, 2012.03.21-2022.10.13.

141. Chung, Jin-Sen, Wang, Shih-Jen, Yuann, Yng-Ruey, "A Safety/Relief Valve Discharge Line Header In A Boiling Water Reactor", R.O.C, Utility Patentm425370, 2012.03.21-2022.10.17.

142. Huang, Chin-Tsun, Chang, Ching-Tu, "Method For Solidifying and Stabilizing Waste Acid", US, US8,227,655B2, 2011.10.20-2021.10.19.

143. Chung, Jin-Sen, Wang, Shih-Jen, Yuann, Yng-Ruey, "A Safety/Relief Valve Discharge Line Header In A Boiling Water Reactor", Japan, 3173276, 2011.11.14-2022.11.14.

144. Lee, Yueh-Mu, Shih, Zun-Hao, Hong, Hwen-Fen, Shin, Hwa-Yuh, "The Structure of Preventive Electric Leakage For Concentrating Solar Aluminum Nitride Submount", R.O.C, Utility Patentm429997, 2012.05.21-2022.12.25.

2012 Annual Report
Institute of Nuclear Energy Research

Publisher: Institute of Nuclear Energy Research

Editor Group: Institute of Nuclear Energy Research

Address: No. 1000, Wenhua Rd., Jiaan Village, Longtan Township,
Taoyuan County 32546, Taiwan (R.O.C.)

Tel: 886-2-8231-7717 886-3-471-1400

Fax: 886-3-471-1064

URL: http://www.iner.gov.tw/

Price: NT$ 1,180

GPN: 2008200099

ISSN: 1812-3155

Published in June 2013

Fist Issued in June 1993

Frequency: Annual

Sales Outlet:

- **Government Publications Bookstore**
  1F, No.209, Sung Chiang Rd., Taipei City 10485, Taiwan (R.O.C.)
  TEL: 886-2-2518-0207
- **Wu-Nan Book Co. Ltd.**
  No. 600, Junfu 7th Rd., Beitun Dist., Taichung City 40642, Taiwan (R.O.C.)
  TEL: 886-4-2437-8010

Institute of Nuclear Energy Research
Atomic Energy Council, Executive Yuan

No.1000, Wenhua Rd., Jiaan Village, Longtan Township,
Taoyuan County, 32546, Taiwan (R.O.C.)
Tel: 886-2-8231-7717 886-3-471-1400
Fax: 886-3-471-1064
http://www.iner.gov.tw
e-mail: iner@iner.gov.tw

ISSN 1812-315-5
9 771812 315002
GPN:2008200099
Price: NT$1,180