



序 言

國家原子能科技研究院(國原院)依循政府施政方針，積極推展各項委託研究計畫，透過合作關係的建立，不僅可結合學術研究創新與機關實務應用需求，亦可有效支援政府科技政策規畫與相關業務推動之需求，在計畫主持人及研究團隊通力合作下，整體計畫執行成果卓著，充分展現計畫推動之具體成效。

114 年度的委託研究，承蒙國內多所大學與醫療機構等的鼎力協助，順利完成涵蓋電網韌性、醫學及輻射、綠能技術、半導體等 4 大領域之研究，產出 16 項研究成果。這些成果主題明確、內容嚴謹、論述周延，對於促進我國相關科技之創新發展，具備重要參考價值與推動效益。

為展示研究成效並接受各界評鑑，國原院辦理委託研究計畫成果發表會，除激勵研究團隊發表成果外，也提供產、官、學、研各界交流觀摩的機會，以促進相關研發領域研究人員互動，並彰顯委託研究計畫之整體價值。本次成果發表會共規劃 5 個專場，由計畫主持人進行成果簡報，分享研究重點與關鍵發現，並邀請院外專家蒞臨指導。有鑒於研發成果乃執行計畫團隊的心血結晶，深具參考價值，因此主辦單位特將各計畫之中、英文摘要彙編成冊，供各界參考。

最後感謝各研究團隊之辛勞與付出，使各項委託研究計畫得以順利完成，並期盼未來持續深化合作，作為擴大研發能量的參考或依據。

院長 高梓木

會議議程

時 間	議 程	地 點
09:00~09:30	報到	060 館各會場報到
09:30~12:10(11:30)	上午分組成果發表	各場次
12:10(11:30)~12:30	綜合討論(供應午餐)	各場次
13:00~16:00	下午分組成果發表 (含綜合討論)	各場次

會議場次

Oral 場次	會議地點	發表數
場次 A:電網韌性領域 1 (上午)	060 館 702 會議室	4
場次 B:電網韌性領域 2 (下午)	060 館 702 會議室	4
場次 C:醫學及輻射領域(上午)	060 館 315 會議室	3
場次 D:綠能技術領域(下午)	060 館 315 會議室	2
場次 E:半導體領域(上午)	060 館 309 會議室	3



114 年度國家原子能科技研究院委託研究計畫成果發表會議程

辦理時間：115 年 6 月 4 日

辦理地點：國原院 060 館

場次別： 場次 A:電網韌性領域 1 (上午 9:30~12:30)				
主持人：張永瑞副院長			評審委員:朱家齊、魏榮宗	
發表方式：口頭簡報及 QA (每場次報告 20 分鐘，問答 20 分鐘)			會場地點：702	
場序	時間	執行機關	計畫主持人	計畫名稱
1	9:30-10:10	國立彰化師範大學	黃維澤	配電饋線主幹負載之相別調整技術研究
2	10:10-10:50	國立中央大學	陳正一	以功率硬體迴圈實現區域電網電力品質控制之研究
3	10:50-11:30	國立中正大學	吳元康	微電網整合輸出電力輔助服務之研究
4	11:30-12:10	國立臺灣科技大學	郭政謙	變電所輸變電設備狀態基準維護研究
12:10-12:30 綜合討論 (逾時供應午餐)				
場次別： 場次 B:電網韌性領域 2 (下午 1:00~4:00)				
主持人：張永瑞副院長			評審委員:朱家齊、魏榮宗	
發表方式：口頭簡報及 QA (每場次報告 20 分鐘，問答 20 分鐘)			會場地點：702	
場序	時間	執行機關	計畫主持人	計畫名稱
1	1:00-1:40	中原大學	洪穎怡	整合能源系統之故障電流研究
2	1:40-2:20	國立中正大學	張文恭	小型高壓獨立供電系統功率補償策略研究
3	2:20-3:00	國立成功大學	黃朝偉	整合能源系統之熱電能動態模擬研究
4	3:00-3:40	國立高雄科技大學	詹東昇	區域電網之保護電驛協調及服務路徑優化研究
3:40-4:00 綜合討論				



場次別： <u>場次 C:醫學及輻射領域</u> (上午 09:30~12:30)				
主持人：王正忠副院長			評審委員:王昱豐、林武智	
發表方式：口頭簡報及 QA (每場次報告 20 分鐘，問答 20 分鐘)			會場地點：315	
場序	時間	執行機關	計畫主持人	計畫名稱
1	9:30-10:10	臺北醫學大學	張剛瑋	質子照射精準度對受測樣品影響研究
2	10:10-10:50	林口長庚醫院	黃炳勝	以鎳 68-多蕾克鎳動態正子造影評估 肝癌病人接受質子治療前後的肝臟殘 餘功能之前瞻性研究(1/2)
3	10:50-11:30	中山醫學大學 附設醫院	陳安芝	應用 123I-MIBG 及 99m Tc-MIBI 鑑 別糖尿病與退化性神經病變
11:30-12:30 綜合討論 (逾時供應午餐)				
場次別： <u>場次 D: 綠能技術領域</u> (下午 1:00~3:00)				
主持人：王正忠副院長			評審委員:李澤民、鄭世中	
發表方式：口頭簡報及 QA (每場次報告 20 分鐘，問答 20 分鐘)			會場地點：315	
場序	時間	執行機關	計畫主持人	計畫名稱
1	1:00-1:40	國立中央大學	林殿順	離岸三維地質模型參考案例建置
2	1:40-2:20	國立陽明交通 大學	蘭宜錚	生質循環減碳技術應用之評估研究
2:20-3:00 綜合討論				

場次別：場次 E:半導體領域(上午 09:30~12:30)				
主持人：林家德副院長			評審委員:辛裕明、郭倩丞	
發表方式：口頭簡報及 QA (每場次報告 20 分鐘，問答 20 分鐘)				會場地點：309
場序	時間	執行機關	計畫主持人	計畫名稱
1	9:30-10:10	中原大學	蔡東昇	氮化鎵材料缺陷與應力分析之研究
2	10:10-10:50	國立中正大學	陳永松	設計催化電極對鹼性電解槽之綠氫研究
3	10:50-11:30	國立臺東大學	陳孟炬	半導體功率元件太空質子輻射效應研究
11:30-12:30 綜合討論 (逾時供應午餐)				

場次 A:電網韌性領域 1

配電饋線主幹負載之相別調整技術研究	1
以功率硬體迴圈實現區域電網電力品質控制之研究	3
微電網整合輸出電力輔助服務之研究	5
變電所輸變電設備狀態基準維護研究	7

配電饋線主幹負載之相別調整技術研究

Study on Phase Switching Techniques of Loads on the Main Lines of Distribution Feeders

(計畫編號：114A013)

¹黃維澤、¹林韋辰、¹蕭耀賢、

²姜政綸、²張博荃

¹國立彰化師範大學 ²國家原子能科技研究院

摘要

隨著分散式再生能源、儲能系統的併入，以及電動車充放電與負載需量控制的發展，配電饋線的三相負載分配正面臨新的挑戰。這些變化可能降低台電三相四線多重接地系統的正常運轉效率，甚至導致既有放射狀饋線因中性線電流異常而發生接地過電流電驛誤動作。為此，本研究計畫開發配電主饋線的負載調整技術，透過長期運轉數據的分析，評估線路損耗、中性線電流與電壓不平衡率的分布，建構配電饋線主幹線的相別調整策略邏輯，並開發驗證相別調整策略演算法。

Abstract

With the integration of distributed renewable energy and energy storage systems, alongside developments in EV charging/discharging and load demand control, the three-phase load distribution of distribution feeders is facing new challenges. These shifts can diminish the operational efficiency of Taipower's three-phase four-wire multi-grounded systems and may even trigger nuisance tripping of ground overcurrent relays in existing radial feeders due to abnormal neutral current. Consequently, this research project aims to develop load adjustment technologies for primary distribution feeders. By analyzing long-term operational data, the study evaluates the distribution of line losses, neutral currents, and voltage unbalance rates. The goal is to establish a phase adjustment strategy logic for main feeders and develop a verified phase adjustment algorithm.

以功率硬體迴圈實現區域電網電力品質控制之研究
Research on Power Quality Control of Regional Power Grid by Using
Power Hardware-in-the-loop Platform

(計畫編號：114A015)

陳正一¹ 談光雄² 陳淑娟²

¹ 中央大學電機工程學系 ² 國防大學理工學院電機電子工程學系

摘要

本計畫因應全球能源轉型與再生能源滲透提升，針對風力與太陽能發電之間歇性與不穩定性對電網造成的影響，提出整合高壓供電系統、再生能源與儲能系統之解決方案。透過儲能系統於併網與孤島模式間的無縫切換，以及供需調節機制，可提升供電穩定性並降低電網負擔。同時，結合先進控制技術進行電力品質即時監測與調整，以減少電壓與頻率波動。整體目標為建立即時模擬與驗證平台，強化電網韌性與可靠度，並促進台灣能源轉型與永續發展。

Abstract

This project addresses the challenges posed by the increasing penetration of renewable energy and the global energy transition, particularly the intermittency and instability of wind and solar power and their impacts on power grids. It proposes an integrated solution combining high-voltage power systems, renewable energy, and energy storage systems. Through seamless switching of energy storage systems between grid-connected and islanded modes, along with supply–demand regulation mechanisms, the approach enhances power supply stability and reduces grid burden. In addition, advanced control technologies are applied for real-time monitoring and regulation of power quality to mitigate voltage and frequency fluctuations. The overall objective is to establish a real-time simulation and validation platform to improve grid resilience and reliability, while supporting Taiwan’s energy transition and sustainable development.

微電網整合輸出電力輔助服務之研究

Research of integrated generation outputs for ancillary services in microgrids

計畫編號：114A016

吳元康¹ 李嘉輝² 鄭秉和³

¹ 中正大學電機工程研究所 ² 中正大學電機工程研究所 ³ 中正大學電機工程研究所

摘要

本計畫分析不同輔助服務的需求與規範，並研究人工智慧技術在微電網控制與運營中的應用。接著，計畫建構微電網模型，設計並分析電壓源轉換器（Voltage source converter, VSC）的控制架構，包括電網形成型（Grid-forming, GFM）與電網跟隨型（Grid-following, GFL）控制策略，並進行微電網併網與孤島模式切換的模擬，探討如何利用控制策略來提高微電網運轉的穩定性。

Abstract

This project analyzes the requirements and specifications of various ancillary services and investigates the application of artificial intelligence technologies in microgrid control and operation. It then develops a microgrid model and designs and analyzes the control architecture of voltage source converters (VSCs), including both grid-forming (GFM) and grid-following (GFL) control strategies. In addition, simulations of transitions between grid-connected and islanded modes are conducted to examine how different control strategies can enhance the operational stability of the microgrid.



變電所輸變電設備狀態基準維護研究

Research on Condition-Based Maintenance for Substation Power
Transmission and Transformation Equipment

(計畫編號：114A017)

郭政謙¹ 林彥伯² 曾興嘉²¹ 國立臺灣科技大學電機工程系 ² 國家原子能科技研究院

摘要

在輸變電系統中，一旦設備出現故障，往往會造成嚴重的經濟損失，因此事先進行預防性監測格外重要。絕緣性能惡化的初期常伴隨局部放電，若能持續追蹤其特徵，就能及早察覺設備潛在風險。與傳統的定期檢測相比，長期趨勢追蹤能有效降低判斷錯誤並提升診斷準確性。

本研究將採用高頻比流器擷取放電信號，並進行後續波形分析。為強化辨識能力，將繪製局部放電的相位解析圖，完整記錄相位位置、放電強度及發生頻率，以揭示放電活動的分布特性。同時利用時域與頻域的特徵分析，可以有效辨識各類放電特徵，並進一步為輸電與變電設備建立對應的模型。

本研究會於現場設備進行長時間資料蒐集，累積大量放電紀錄並相互比較，以提煉出不同的放電模式。透過實測資料，可以檢視分析技術的準確與可靠程度，同時作為評估絕緣狀況的重要依據。本計畫旨在完成一個完整的局部放電監測與診斷架構，以確保設備長期穩定運作，減少突發故障，同時強化電力系統的可靠與安全。

Abstract

In power transmission and transformation systems, equipment failures can result in significant economic losses, making preventive monitoring particularly important. Partial discharge often accompanies the early stages of insulation degradation, and by continuously tracking its characteristics, potential risks can be detected at an early stage. Compared with traditional periodic inspections, long-term trend monitoring can effectively reduce diagnostic errors and improve accuracy.

This study uses high-frequency current transformers to capture discharge signals and perform waveform analysis. Phase-resolved partial discharge (PRPD) diagrams will be drawn to show phase, magnitude, and frequency, while time- and frequency-domain features will help distinguish discharge types and build models for transmission and substation equipment.

This study will collect long-term field data to extract discharge patterns and verify the accuracy and reliability of analysis methods. The results will support insulation assessment and lead to a complete partial discharge monitoring and diagnostic framework, ensuring stable operation and improving power system reliability and safety.

場次 B:電網韌性領域 2

整合能源系統之故障電流研究	1
小型高壓獨立供電系統功率補償策略研究	3
整合能源系統之熱電能動態模擬研究	5
區域電網之保護電驛協調及服務路徑優化研究	7

整合能源系統之故障電流研究

Studies on Fault Currents in Integrated Energy Systems

(計畫編號：114A008)

洪穎怡 許哲維

中原大學電機工程學系

摘要

隨著再生能源發電滲透率的提升，主動式配電系統中的故障電流與保護協調面臨顯著的不確定性挑戰。本文提出一種新穎的保護協調方法，能明確考慮由此類不確定性所產生的多種情境。在方法中，匯流排負載與再生能源發電的不確定性，透過隨機參數的期望值、標準差與偏態加以描述；同時，利用 Taguchi 正交實驗系統性地建構獨立情境集合。由不確定性引起的主保護與後備保護故障電流差異，於對應繼電器處進行分群，以利設計部分過電流電驛之非標準反時限特性，而其餘電驛則依據 IEC 60255 保持標準特性。接著，建立一個非線性規劃模型，在考慮所有正交情境下，同時決定非標準特性參數、時間倍率設定以及過電流繼電器的整定值（plug settings）。模擬結果顯示，在 IEEE 33 匯流排系統中，所提出方法的總計算時間為 186 秒，與點估計法（PEM）相當，但僅需蒙地卡羅模擬與既有線性規劃方法計算時間的 0.14% 與 0.85%。然而，儘管 PEM 計算簡單，其穩健性最差，在蒙地卡羅情境中出現 141,188 次協調時間間隔違反，以及 10,080 次電驛動作時間為負值的情形。

Abstract

Increasing penetration of renewable power generation introduces substantial uncertainty in fault currents and protection coordination in active distribution systems. This paper presents a novel protection coordination method that explicitly accounts for multiple scenarios arising from such uncertainties. The uncertainties in bus loads and renewable generation are characterized using the expected value, standard deviation, and skewness of stochastic parameters, while a set of Taguchi orthogonal experiments is employed to systematically represent independent scenarios. The anomaly differences between primary and backup fault currents caused by uncertainties at the corresponding relays are clustered to facilitate the design of non-standard inverse-time characteristics for selected overcurrent relays, whereas the remaining relays retain standard characteristics in accordance with IEC 60255. A nonlinear programming formulation is then adopted to jointly determine the parameters of the non-standard characteristics, time multiplier settings, and plug settings of overcurrent relays while considering all orthogonal scenarios. Simulation results indicate that the total execution time of the proposed method is 186 seconds for the IEEE 33-bus system, which is comparable to that of the point-estimation method (PEM), while requiring only 0.14% and 0.85% of the execution time of the Monte Carlo simulation and the existing linear programming-based method, respectively. Although computationally simple, the PEM exhibits the poorest robustness, with 141,188 coordination time interval violations and 10,080 negative relay operating times across the Monte Carlo scenarios.

小型高壓獨立供電系統功率補償策略研究

Research on power compensation strategy of small high-voltage
independent power supply system

(計畫編號：114A007)

黃薇芸 黃聖恩 郭景焜 江品齊 張文恭

國立中正大學電機工程研究所

摘要

在能源轉型與去碳化趨勢下，分散式能源系統與微電網逐漸成為電力系統的重要發展方向。此類系統通常包含多種電源形式，如再生能源與可調度電源，以提升供電穩定性與彈性。在眾多可調度電源中，小型模組化核反應器（SMR）因具備高安全性與靈活部署特性，逐漸被視為適合整合於分散式系統中的關鍵基載電源。SMR 通常指電力輸出低於 300 MWe 的反應器。由於其具備高度安全性、模組化建造與靈活部署的特性，能夠適應不同規模的電網需求，因此逐漸成為全球能源轉型過程中的重要選項。近年來，隨著能源安全與減碳意識的提升，多種類型的 SMR 相繼被開發、研究與應用，並在實際運行中證實其兼具經濟性與靈活性，能夠滿足偏遠地區供電、工業熱能供應及主電網輔助等多元需求。本文旨在建立壓水式小型模組化核反應器（PWR-SMR）的動態系統模型，並將此模型作為控制策略設計與驗證之核心模擬平台。基於電力系統觀點，本研究探討透過蒸汽調速閥進行控制 SMR 本體之負載跟隨機制。未來除了透過蒸汽調速閥進行外，亦可進一步考慮結合其他分散式電源（如再生能源與儲能系統）之功率輸出，形成多電源協同補償機制。透過適當的功率分配策略，不僅可降低 SMR 之調節負擔，亦能提升整體系統之動態響應能力與運行彈性。

Abstract

Amid the trends of energy transition and decarbonization, distributed energy systems and microgrids are increasingly becoming key development directions for modern power systems. Such systems typically incorporate a variety of generation sources, including renewable energy and dispatchable power, to enhance supply stability and operational flexibility. Among the available dispatchable sources, Small Modular Reactors (SMRs), owing to their high safety and flexible deployment characteristics, are gradually being regarded as a critical baseload option suitable for integration into distributed energy systems. Small Modular Reactors (SMRs) generally refer to nuclear reactors with an electric power output of less than 300 MWe. Owing to their high safety, modular construction, and flexible deployment, SMRs are capable of adapting to the needs of different scales of power grids and have gradually become an important option in the global energy transition. In recent years, driven by growing concerns over energy security and carbon reduction, various types of SMRs have been developed, studied, and applied. Practical operation has demonstrated their combined advantages of economic feasibility and operational flexibility, enabling them to meet diverse demands such as electricity supply for remote areas, industrial heat production, and grid support. This study aims to establish a dynamic system model of a pressurized water reactor-based SMR (PWR-SMR), which serves as a core platform for the design and verification of control strategies. From a power system perspective, this study investigates the load-following control mechanism of an SMR through the use of a steam governor valve. In addition to this approach, future work may further consider integrating the power outputs of other distributed energy resources, such as renewable energy and energy storage systems, to establish a multi-source coordinated compensation scheme. Through an appropriate power allocation strategy, this approach can not only reduce the regulation burden on the SMR but also enhance the overall system's dynamic response capability and operational flexibility.

整合能源系統之熱電能動態模擬研究

Dynamic Simulation Study of Thermal and Electrical Energy in
Integrated Energy Systems

(計畫編號：114A006)

廖德祿¹、侯易佑²、黃朝偉¹、劉羿群¹、傅蕙樺¹、林哲緯³、陳昌國³

¹ 國立成功大學工程科學系 ² 國立高雄科技大學智慧商務系 ³ 國家原子能科技研究院

摘要

在淨零排放趨勢下，本研究以 ORC 技術於 Dymola/Modelica 建立廢熱回收動態模擬平台。透過採用 ThermofluidStream 並導入狀態控制與動態簡化策略，成功解決 R245fa 造成的 DAE 數值問題。模型達 50 kW 輸出，與 Aspen HYSYS 誤差小於±3%。系統具熱電解耦與暫態分析能力，可應用於電網調度與分散式能源設計，並支援廢熱價值化發展。

Abstract

In the context of the net-zero transition, this study develops a dynamic ORC-based waste heat recovery simulation platform in Dymola/Modelica. By adopting ThermofluidStream and implementing state-control and dynamic-simplification strategies, numerical issues in DAEs caused by R245fa are resolved. The model achieves 50kW output, with deviations within $\pm 3\%$ compared to Aspen HYSYS. The platform enables thermoelectric decoupling and transient analysis, supporting grid operation, distributed energy design, and waste heat valorization.

區域電網之保護電驛協調及服務路徑優化研究

Study of OCR Protection Coordination and Service Route
Optimization of the Regional Power Grid

(計畫編號：114A014)

詹東昇¹ 紀俊杰¹ 姜政倫² 吳智雄²

¹國立高雄科技大學電機工程系 ²國家原子能科技研究院

摘要

本計畫首先針對區域電網進行饋線建模與案例分析，考慮當電網轉為孤島運轉後對其進行全網之故障電流分析，進而探討孤島系統中之電驛保護協調議題，提出以卷積神經網路為基礎之動態電驛保護協調決策系統，針對區域電網與市電端併網或孤島的狀態，檢討其保護協調，據以提出改善建議與調整策略，提供饋線操作員調整電驛之始動電流值與時間倍率設定值之參考。此外，本計畫亦提出以電流注入為基礎之電網狀態估測模型，能有效降低狀態估測誤差，能迅速、有效地進行電網狀態估測。為了能優化區域電網之電力傳送路徑參數，本計畫利用最佳化理論法求解線路參數校正演算法，當狀態估測值與量測值差異過大，經由饋線參數校正功能，修正路徑阻抗參數，降低狀態估測誤差，確保狀態估測之準確度。

Abstract

This project first conducts feeder modeling and case analysis for a regional power grid. It further considers a comprehensive fault current analysis of the entire grid after the system is switched to islanded operation, and then investigates relay protection coordination issues in the islanded system. Based on this, a dynamic relay protection coordination decision system using a convolutional neural network (CNN) is proposed. For both grid-connected and islanded operating conditions between the regional power grid and the utility grid, the protection coordination is examined, and corresponding improvement recommendations and adjustment strategies are proposed to provide feeder operators with references for adjusting relay pickup current settings (PCS) and time multiplier settings (TMS).

In addition, this project proposes an Equivalent Current Injection (ECI) based state estimation (SE) model that effectively reduces state estimation errors, enabling rapid and efficient grid state estimation. To optimize transmission path parameters of the regional power grid, this project utilizes optimization theory to develop a feeder parameter calibration algorithm. When a significant discrepancy arises between estimated and measured values, this feeder parameter calibration function corrects the line impedance parameters, thereby reducing the estimation error and ensuring the accuracy of the state estimation. °

場次 C:醫學及輻射領域

質子照射精準度對受測樣品影響研究	1
應用 ^{123}I -MIBG 及 $^{99\text{m}}\text{Tc}$ -MIBI 鑑別糖尿病與退化性神經病變	3



質子照射精準度對受測樣品影響研究

Impact of proton irradiation accuracy on tested samples

(計畫編號：114A005)

張剛瑋

臺北醫學大學研發處實驗動物中心

摘要

質子治療是利用高能粒子放射線摧毀癌細胞的局部定點治療方式，除直接殺死癌細胞外，還會誘導免疫反應並改變腫瘤微環境。本研究探討不同輻射劑量的 X 射線與高低能階質子輻射對生物體的精準度影響效應，並評估質子照射技術在醫療以外科研領域的應用可行性。

研究分為兩部分：第一部分藉由斑馬魚胚胎模式，比較質子束與 X 射線在不同劑量(0.5 Gy 與 2 Gy)及發育時期(0-3 dpf)下對胚胎的影響，結果顯示越早期胚胎對輻射越敏感，轉錄組分析亦揭示輻射誘導發炎反應、熱休克蛋白及組織修復相關基因上調。第二部分以 γ -H2AX ELISA 定量評估不同能量質子束(100 MeV 與 200 MeV)的 DNA 損傷程度與照射空間均勻度，結果顯示 100 MeV 因高線性能量轉移造成較嚴重 DNA 損傷(0.0721 ng/mL)，但劑量均勻性優異(CV = 7.99%)；200MeV 損傷較輕(0.0516 ng/mL)，卻呈現較大空間變異(CV = 113.6%)與「周邊高於中心」的劑量分布。

本研究首次系統性建立質子束照射精準度評估方法，研究成果可應用於精確放射治療的風險評估與劑量優化、太空輻射防護策略制定及太空元件測試品質保證，為原子能技術跨域應用提供科學依據。

Abstract

Proton therapy is a localized, targeted treatment using high-energy particle radiation to destroy cancer cells, while also inducing immune responses and altering the tumor microenvironment. This study investigates the precision effects of X-ray and high/low-energy proton irradiation at different doses on biological systems, and evaluates the feasibility of applying proton irradiation technology in research fields beyond medicine.

The study comprises two parts. The first employs a zebrafish embryo model to compare the effects of proton beams and X-rays at different doses (0.5Gy and 2Gy) across developmental stages (0-3dpf), demonstrating that earlier-stage embryos are more radiosensitive, with transcriptome analysis revealing upregulation of genes related to inflammation, heat shock response, and tissue repair. The second part uses γ -H2AX ELISA to assess DNA double-strand break damage and spatial dose uniformity for 100MeV and 200MeV proton beams. The 100 MeV beam caused greater DNA damage (0.0721ng/mL) but exhibited excellent dose uniformity (CV = 7.99%), while the 200 MeV beam showed less damage (0.0516ng/mL) but greater spatial variation (CV = 113.6%) with a periphery-higher-than-center dose distribution.

This study establishes the first systematic method for evaluating proton beam irradiation precision, contributing to dose optimization in radiation therapy, space radiation protection strategies, and quality assurance for space component testing.

應用 ^{123}I -MIBG 及 $^{99\text{m}}\text{Tc}$ -MIBI 鑑別糖尿病與退化性神經病變

^{123}I -MIBG and $^{99\text{m}}\text{Tc}$ -MIBI dual-isotope tracers in myocardial imaging to differentiating diabetes and neurodegenerative diseases

(計畫編號：114A010)

陳安芝¹ 呂宣屏² 高潘福² 鄭凱倫³

¹ 中山醫學大學附設醫院 神經科 ² 中山醫學大學附設醫院 核子醫學科

³ 中山醫學大學附設醫院 醫學影像部

摘要

鎘鋅碲化物 (cadmium zinc telluride, CZT) 半導體偵測頭單光子電腦斷層攝影儀(single photon emission computed tomography, SPECT)，能提升能量與空間解析度。本院研究團隊於民國 107 年起執行以 CZT 探頭，應用假體進行同時間 $^{99\text{m}}\text{Tc}$ 及 ^{123}I 雙核種 SPECT 造影，以評估影像收錄條件與雙核種間能窗重疊干擾所造成的影響。並於 108 年的科技部研究計畫中，應用 ^{123}I -MIBG 及 $^{99\text{m}}\text{Tc}$ -MIBI 雙核種示蹤劑同時間心肌造影在鑑別診斷巴金森症候群病患神經支配與血流灌注異常共病(計畫編號: MOST 108-2314-B-040-011-MY2)。在這三年期前瞻性研究，研究團隊將針對老年疑似巴金森症候群進行同時間 $^{99\text{m}}\text{Tc}$ -MIBI 及 ^{123}I -MIBG 心肌造影，以排除伴隨老化冠狀動脈心血管疾病造成心肌血流缺損，影響 ^{123}I -MIBG 心肌吸收降低，以鑑別診斷冠狀動脈血管性的疾病與單純交感神經支配的問題。本研究將使用 CZT 探頭 SPECT 掃描，採用多能窗同時收錄 $^{99\text{m}}\text{Tc}$ 和 ^{123}I 造影。造影分析將計算 $^{99\text{m}}\text{Tc}$ 與 ^{123}I 能量重疊干擾，以計算心肌攝取 $^{99\text{m}}\text{Tc}$ -MIBI 及 ^{123}I -MIBG 在不同血流灌注部位的心肌攝取比值。該次的研究提升 CZT 探頭 SPECT 造影診療技術，並減少動作障礙患者就診的不便，順利完成 36 例的巴金森症候群患者的檢查，無不良結果。在研究過程中，發現心血管疾病與單純巴金森共症較少，但在部



分有血管病史的個案有較多診斷價值。而血管和神經同時會影響的疾病，以糖尿病為首，而之前的研究較少相關的資料。並且，在神經退化的疾病中，糖尿病也是重要的共病之一。因此，對於糖尿病患者的心臟血流及神經之相關性，可提供臨床更多資料來釐清其中的變化，以利精確治療。

Abstract

Cadmium zinc telluride (CZT) semiconductor detection head single photon emission computed tomography (SPECT) can improve energy and spatial resolution. The research team of our hospital has been using CZT probes and prostheses to perform simultaneous ^{99m}Tc and ^{123}I dual-nucleus SPECT imaging since 1997 to evaluate the impact of image acquisition conditions and overlapped interference between dual-nucleus species. In the 2017 research project of the Ministry of Science and Technology, ^{123}I -MIBG and ^{99m}Tc -MIBI dual-core tracers were used to perform simultaneous myocardial angiography in the differential diagnosis of comorbidities of abnormal innervation and blood perfusion in patients with Parkinson's syndrome (Project No. : MOST 108-2314-B-040-011-MY2). In the three-year prospective study, the research team will conduct ^{99m}Tc -MIBI and ^{123}I -MIBG myocardial angiography at the same time for elderly patients with suspected Parkinson's syndrome to rule out myocardial blood flow defects caused by aging coronary cardiovascular disease and affect ^{123}I -MIBG. Myocardial absorption is reduced to differentiate between coronary vascular disease and simple sympathetic innervation. This study will use CZT probe SPECT scanning, using a multi-energy window to simultaneously capture ^{99m}Tc and ^{123}I contrast. The contrast analysis will calculate the overlapping interference of ^{99m}Tc and ^{123}I energy to calculate the myocardial uptake ratio of ^{99m}Tc -MIBI and ^{123}I -MIBG at different blood perfusion sites. This study improved the CZT probe SPECT imaging diagnosis and treatment technology and reduced the inconvenience of medical treatment for patients with movement disorders. The examination of 36 patients with parkinsonism was successfully completed without adverse results. During the study, it was



found that cardiovascular disease has fewer comorbidities with pure Parkinson disease but it has more diagnostic value in some cases with a history of vascular disease. Among the diseases that can affect blood vessels and nerves at the same time, diabetes mellitus is the first, and previous studies have limited relevant information. Moreover, among neurodegenerative diseases, diabetes mellitus is also one of the important comorbidities. Therefore, more clinical data can be provided to clarify the changes in cardiac blood flow and nerves in patients with diabetes to facilitate precise treatment.

場次 D:綠能技術領域

離岸三維地質模型參考案例建置	1
質循環減碳技術應用之評估研究	3

**離岸三維地質模型參考案例建置****Establishment of Reference Case for Offshore 3D Geological Models**

(計畫編號：114A002)

林殿順^{1,2} 林哲銓²¹國立中央大學地球科學學系 ²國立中央大學碳封存及地熱研究中心**摘要**

我國發展碳封存、風力發電及相關環境復育議題研究，近年來在離岸區域有更多地形與地質瞭解的需求。國家原子能科技研究院(簡稱國原院)欲針對台灣西岸及離岸地區進行地質調查資料文獻蒐集與研析，並建立離岸三維地質概念模型及相關區域地體構造論述。「離岸三維地質模型參考案例建置」(簡稱本計畫)針對台灣西部離岸至澎湖海域地區，以不同尺度之調查資料蒐整研析，發展離岸三維地質模型參考案例，以了解區域地層及構造三維空間分布、地層屬性特徵空間變化，完備離岸參考案例地下地質資訊評估、地質概念模型建置及地體架構論述等資訊。

Abstract

To support Taiwan's growing research in carbon capture and wind power, understanding offshore geology has become crucial. Consequently, the National Atomic Research Institute (NARI) launched the “Establishment of Reference Cases for Offshore 3D Geological Models” project. Focusing on the region from the western offshore to the Penghu Islands, the project analyzes geological literatures, topography, and seismic profiles of Mesozoic basement and overlying strata. By integrating subsurface data, the team constructs a 3D geological model on an island with exposed basement rocks. This model will clarify the 3D spatial distribution of stratigraphy and tectonic structures, providing essential data to evaluate subsurface geology for future offshore environmental and engineering assessments.

質循環減碳技術應用之評估研究

Assessment Study on the Application of Biomass Circular Carbon-
Reduction Technologies

(計畫編號：114A012)

林其壕¹ 李語婕¹ 洪嘉彥¹ 蘭宜錚*¹

¹ 國立陽明交通大學生物科技學系

摘要

為實現減碳與推動循環經濟的願景，本計畫致力於利用代謝工程技術開發高效的微生物發酵平台，以生產多樣化的生物基化學品與永續材料。本研究涵蓋兩大核心主軸：其一，以假單胞菌 (*Pseudomonas*) 作為宿主平台，建立並優化其基因操作工具，最終完成多個質體建構，進而應用於高價值化學品 L-乳酸之生產；其二，利用藍綠菌進行生質塑膠之合成，目標產物為聚-4-羥基丁酸(P4HB)，最終成功生產出乾細胞重 0.5 % 的 P4HB。本計畫不僅為具有潛力之宿主 *Pseudomonas* 開發出對應的基因工具，並成功建構以藍綠菌作為生質塑膠 PHA 之生產平台。

Abstract

To realize the vision of carbon reduction and promote a circular economy, this project aims to develop efficient microbial fermentation platforms using metabolic engineering to produce diverse bio-based chemicals and sustainable materials. The research focuses on two primary objectives. First, we established and optimized genetic manipulation tools using *Pseudomonas* as a host platform, applying them to produce the high-value chemical L-lactic acid. Second, we utilized cyanobacteria for the biosynthesis of bioplastics, specifically targeting poly-4-hydroxybutyrate(P4HB). Ultimately, we successfully achieved a P4HB production yield of 0.5% of the cell dry weight (CDW). This project not only developed corresponding genetic tools for the promising host *Pseudomonas*, but also successfully established a production platform for the bioplastic PHA using cyanobacteria.

場次 E:半導體領域

氮化鎵材料缺陷與應力分析之研究	1
設計催化電極對鹼性電解槽之綠氫研究	3
半導體功率元件太空質子輻射效應研究	5

氮化鎵材料缺陷與應力分析之研究

Defect and Stress Analysis of Gallium Nitride

(計畫編號：114A004)

蔡東昇^{1,2,*}，梁珮怡¹，吳承祐¹，吳家任¹，陳俊亦³，莊智閔³，施圳豪³，莊家翔^{1,2}，郭泰辰^{1,2*}

¹ 中原大學電子工程學系 ² 中原大學半導體材料與先進光學研究中心

³ 國家原子能科技研究院

摘要

本研究探討成長於矽基板上的 GaN 磊晶層，其應力分佈、缺陷密度與電子特性之間的相關性。研究中採用拉曼映像 (Raman mapping)、高解析度 X 光繞射 (HRXRD)、原子力顯微鏡 (AFM) 以及 van der Pauw 量測，來評估具有超晶格結構與否之 GaN-on-Si 樣品的結構與電性特性。

拉曼影像顯示，無超晶格結構的 GaN-on-Si 樣品呈現壓應力與張應力混合且高度不均勻的分佈，顯示其具有較明顯的位錯形成。相較之下，具有超晶格結構的樣品展現均勻的壓應力，顯示超晶格能有效減緩磊晶過程中的應變累積。HRXRD 量測結果顯示，加入超晶格結構後的總位錯密度從 $1.93 \times 10^9 \text{ cm}^{-2}$ 降至 $1.12 \times 10^9 \text{ cm}^{-2}$ ，與 AFM 蝕刻坑密度分析相一致。此外，含超晶格結構的樣品電子遷移率大幅提升至約 $1034 \text{ cm}^2/\text{V}\cdot\text{s}$ ，幾乎是未含超晶格結構樣品（約 $378 \text{ cm}^2/\text{V}\cdot\text{s}$ ）的三倍。

這些結果證實，超晶格工程在降低缺陷傳播與改善 GaN-on-Si 應力均勻性方面具有重要作用。研究亦顯示，拉曼映像能作為快速且可靠的晶圓級應力診斷工具，有助於優化 GaN-on-Si 的成長製程。

Abstract

This study investigates the correlation between stress distribution, defect density, and electronic properties in GaN epitaxial layers grown on silicon substrates. Raman mapping, high-resolution X-ray diffraction (HRXRD), atomic force microscopy (AFM), and van der Pauw measurements were employed to evaluate the structural and electrical characteristics of GaN-on-Si samples with and without a superlattice (SL) structure.

Raman mapping reveals that the GaN-on-Si sample without an SL structure exhibits mixed compressive and tensile stress with significant nonuniformity, indicating enhanced dislocation formation. In contrast, the sample with an SL structure demonstrates uniform compressive stress, suggesting that the SL effectively mitigates strain accumulation during epitaxy. HRXRD results show that the total dislocation density decreases from $1.93 \times 10^9 \text{ cm}^{-2}$ to $1.12 \times 10^9 \text{ cm}^{-2}$ when incorporating the SL, consistent with the AFM etch pit density analysis. Furthermore, the SL-containing sample exhibits a substantial improvement in electron mobility ($\sim 1034 \text{ cm}^2/\text{V}\cdot\text{s}$), nearly three times that of the sample without the SL ($\sim 378 \text{ cm}^2/\text{V}\cdot\text{s}$).

These findings confirm the important role of SL engineering in reducing defect propagation and improving stress uniformity in GaN-on-Si epitaxy. The results further demonstrate that Raman mapping provides a rapid and reliable diagnostic tool for monitoring wafer-scale stress distribution and optimizing GaN-on-Si growth processes.

設計催化電極對鹼性電解槽之綠氫研究

Study on the Catalytic Electrodes of Anion Exchange Membrane
Water Electrolyzers for Green Hydrogen Production

(計畫編號：114A003)

黃劼夫¹ 薛天翔² 陳柏聞² 陳永松¹

¹國立中正大學機械工程學系 ²國家原子能科技研究院

摘要

本研究探討大面積陰離子交換膜電解器之平行式、蛇形式與指叉型三種流道設計對極化曲線、電流密度表現及操作條件變化對電解槽性能之影響。當面積 100 cm²，系統性能對操作流率的反應趨勢與小尺寸條件有所差異，不同流道設計在氣體移除與流體分布方面呈現出明顯差別。實驗結果顯示，指叉型流道較其他兩種流道呈現出較佳的性能。本研究結果有助於理解系統放大過程中所面臨之傳質與反應行為變化，並作為後續結構設計與性能最佳化之參考依據。

Abstract

This study presents an investigation of the impact of three flow-field patterns—parallel, serpentine, and interdigitated on the performance of an anion exchange membrane electrolyzer. When the active area was 100 cm², the electrolyzer exhibited response trends to the operating flow rate that differed from those observed under small-area conditions, and clear distinctions among different flow-field designs emerged in terms of gas removal and fluid distribution. The experimental results indicate that the interdigitated flow field outperformed the other two configurations. These findings contribute to a better understanding of mass transport and reaction behavior during system scale-up and provide a reference for subsequent structural design and performance optimization.

半導體功率元件太空質子輻射效應研究

Research on Space Proton Radiation Effect of power semiconductor device

(計畫編號：114A011)

陳孟炬¹ 吳勝允²

¹ 臺東大學應用科學系 ² 東華大學物理學系

摘要

本研究探討低地球軌道（LEO）高能輻射對半導體光偵測元件可靠性的影響。透過 Co-60 γ 射線（60–300 Gy）與 20–200 MeV 質子照射，並結合 TRIM 與 NIEL 模擬，分析 Si、SiC、GaN 與 Ga₂O₃ 在電離效應（TID）與位移損傷（DD）下之退化行為。結果顯示，Si 元件於照射後出現光響應衰減與漏電流上升，對輻射高度敏感；SiC 與 GaN 則僅呈現輕微變化，展現優異抗輻射能力。顯示第三代半導體於太空光電應用具高度潛力。

Abstract

This study investigates the impact of high-energy radiation in the low Earth orbit (LEO) environment on the reliability of semiconductor photodetectors. Co-60 gamma irradiation (60–300 Gy) and proton irradiation (20–200 MeV) were applied, combined with TRIM and NIEL simulations to analyze the degradation behavior of Si, SiC, GaN, and Ga₂O₃ under total ionizing dose (TID) and displacement damage (DD). The results show that Si devices exhibit significant degradation after irradiation, including reduced photoresponse and increased leakage current, indicating high radiation sensitivity. In contrast, SiC and GaN show only minor changes, demonstrating superior radiation hardness. These findings highlight the strong potential of third-generation semiconductors for space optoelectronic applications.