# 行政院原子能委員會　100 年度

# 政府科技計畫(期末)成果效益報告

(100.1.1 ～ 100.12.31)

計畫名稱：太陽光發電系統技術發展

執行期間：

全　程：自 99 年 1 月 1 日至 102 年 12 月 31 日　止

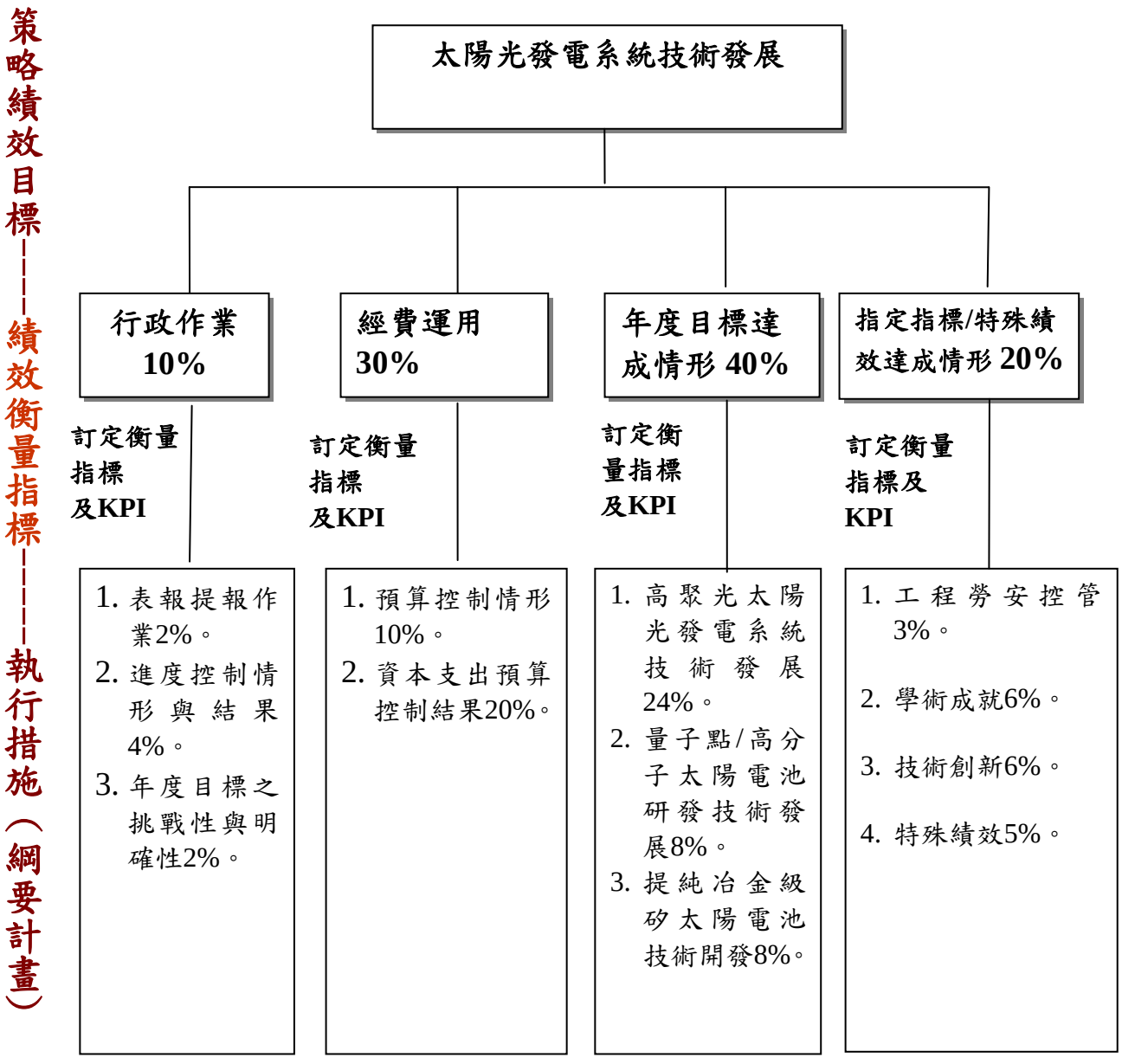
本年度：自 100 年 1 月 1 日至 100 年 12 月 31 日　止

執行單位：核能研究所

# 目　　錄

# 第二部分：政府科技計畫成果效益報告

## 壹、科技施政重點架構圖：



# 貳、基本資料

計畫名稱：太陽光發電系統技術發展

主 持 人：

審議編號：100-2001-02-癸-06

計畫期間(全程)：99 年 1 月 1 日至 102 年 12 月 31 日

年度經費：112,494 千元 全程經費規劃：603,140 千元

執行單位：核能研究所

# 參、計畫目的、計畫架構與主要內容

## 一、計畫目的與預期成效

本計畫致力於太陽光發電科技研發，包含：(1)高聚光太陽光發電系統技術發展、(2)量子點/高分子太陽電池技術發展，及(3)提純冶金級矽太陽電池技術開發等三個分項工作。計畫目的及預期成效分述於後。

計畫目的

1.高聚光太陽光發電系統技術發展

1-1 Ⅲ-V 族化合物半導體太陽電池研發

(1) 利用化合物半導體之磊晶系統，建立晶格匹配(Lattice Matched, LM)與晶格不匹配(Metamorphic, MM)之多接面化合物半導體太陽電池磊晶技術。

(2) 開發三接面串接式太陽電池製程，並使其能量轉換效率提升至39%以上。

(3) 開發適合聚光倍率達 1000 倍的電極構造與製作技術。

1-2 高效率聚光模組設計開發

(1) 模組轉換效率達 28%。

(2) 模組聚光倍率達 1000 倍。

(3) 模組通過 IEC68-2-52 先期測試。

1-3 大型太陽光追蹤器設計開發

太陽光追蹤器精度達±0.1 度。

1-4 系統整合與監控技術精進

運用網路插槽(Socket)完成異質作業系統之訊號交換，建立鏈結層及網路層架構。

1-5 聚光型太陽電池模組安規驗證

導入聚光型太陽電池模組安全規範測試技術，精進太陽電池模組性能測試技術，並建置太陽日照計校驗技術能量。

2.量子點/高分子太陽電池技術發展

(1) 開發低成本、具環保之量子點化學溶液製程技術。

(2) 開發新穎低能階導電高分子。
(3) 量子點/高分子太陽電池元件製作改善。
(4) 製作量子點/高分子太陽電池，光電轉換效率達 5~6%。
(5) 量子點/高分子太陽電池大面積製程開發。

3.提純冶金級矽太陽電池技術開發

研究開發實驗室等級提純冶金級矽太陽電池，其光電轉換效率相對於 99 年度平均值提升 10%。

預期成效

1.高聚光太陽光發電系統技術發展

1-1 Ⅲ-V 族化合物半導體太陽電池研發

(1) 建立高效率多接面太陽電池之磊晶及製程技術能力。
(2) 協助業界開發地面用之高效率、聚光型太陽電池量產技術。
(3) 提升我國太陽電池產業競爭力與擴大我國於全球太陽能市場的佔有率。

1-2 高效率聚光模組設計開發

開發高效率太陽電池模組之製作技術，不僅可減少原物料與材料上的使用，亦可帶動國內產業於太陽電池模組封裝與組裝上技術發展，提升國內太陽電池模組之總產能。

1-3 大型太陽光追蹤器設計開發

開發承載 20 kW 級聚光型太陽電池模組之太陽光追蹤器，追蹤精度達±0.1 度，作為高精度大型高聚光太陽光追蹤器發展基礎，並達到低耗電、低成本及易於維護目標，可大幅減少大型太陽光發電廠所需安裝之太陽光追蹤器數量。

1-4 系統整合與監控技術精進

運用網路插槽(Socket)完成異質作業系統之訊號交換，建立鏈結層及網路層架構，以配合跨平台作業，增加設計彈性、節省設計時程和經費。

1-5 聚光型太陽電池模組安規驗證

提供太陽電池模組性能驗證測試服務，建置太陽日照計校驗技術能量，以協助國內太陽光電產業與國際市場連結。

2.量子點/高分子太陽電池技術發展

開發無機量子點高分子溶液，進而建立大面積塗佈或噴射印刷量產技術製程，研製高效率且廉價的太陽電池。

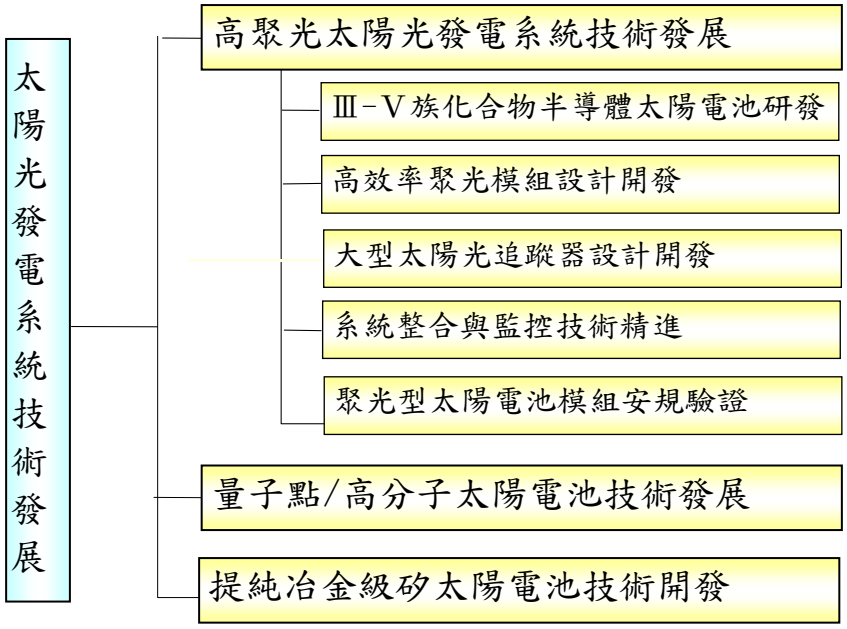
3.提純冶金級矽太陽電池技術開發

(1) 利用化學氣相沉積方法與設備，開發薄膜矽與光捕捉（light trapping）等相關技術與製程。
(2) 結合高品質矽薄膜製程與低成本提純冶金級矽(純度：≧4N－6N)基板等優點，開發新型薄膜矽太陽電池。

(3) 配合具相對低成本與低碳製程優勢的冶金法太陽能級矽材料（純度：~6 - 7N）之技術開發與進展，開發提純冶金級矽太陽電池。

(4) 布局非西門子技術之多晶矽材料太陽電池產品，與開發下一代矽太陽電池，合作開發與技轉。

## 二、計畫架構(含樹狀圖)




## 三、計畫主要內容

100 年度本計畫各分項工作內容如下：

(一) 高聚光太陽光發電系統技術發展

1. Ⅲ-Ⅴ族化合物半導體太陽電池研發

本計畫所需之無塵室及有機金屬化學氣相沉積系統業已於 98 年建立完成，並且展開各項基本磊晶材料及太陽電池結構之生長，與磊晶生長條件之建立。基於已建立完成之磊晶生長條件資料庫，以及持續精進之聚光型太陽電池磊晶技術，進行Ⅲ-Ⅴ族聚光型太陽電池開發，預計於 100 年在聚光條件下，所研製出的Ⅲ-Ⅴ族聚光型太陽電池可達 39%之轉換效率目標。

2. 高效率聚光模組設計開發

(1) 精進聚光倍率達1000倍之聚光模組製作技術：①優化模組規格之訂定，包含太陽電池面積、聚光透鏡面積、光學系統之工作距離、模組框架之設計與對位方法整合；②完成模組之製作與特性量測；③模組效率達28%。

(2) 精進散熱與封裝技術：①進行散熱材料最佳化幾何形狀設計，以增加散熱效率；②考慮工作溫度、散熱效果、重量及取得之難易，選擇合適之高導熱率之太陽電池封裝材料，有效降低熱阻；③改善元件封裝製程技術，太陽電池與陶瓷基板接面孔隙面積密度低於2%，提升太陽電池之可靠度。

3. 大型太陽光追蹤器設計開發

(1) 開發承載20 kW級聚光型太陽模組之太陽光追蹤器，模組化之支架、模組水平調整機制、單模組更換機構等易於安裝、調整與維護設計。

(2) 開發四象限太陽光位置感測器，解決遮影法在低日照時準確度不足的問題，利用針孔原理配合特殊治具，可降低外在環境的影響；研究強健切換控制(switch control)追蹤控制策略，克服環境的干擾，提升追蹤精度，使追蹤精度達±0.1度。

4. 系統整合與監控技術精進

(1) 運用網路插槽(Socket)完成異質作業系統之訊號交換，建立鏈結層及網路層架構，以配合跨平台作業，增加設計彈性，節省設計時程和經費。

(2) 為協助本所研究監控技術，有效完成系統整合工作，需委託國內相關學術單位進行研究探討分析。

(3) 聚光型太陽電池模組安規驗證

(1) 建立聚光型太陽電池模組安全測試技術

核能研究所太陽電池模組驗證實驗室以 IEC62108 規範為 CPV 模組驗證測試技術主軸，在 2009 年 6 月通過 TAF 實驗室認證查核，並於 2009 年 10 月正式獲得 UL 之太陽電池模組性能測試實驗室認可資格，UL 是目前唯一可提供 IEC(性能)+UL(安全)之太陽光電產品認證服務的認證機構，本所將接續探討模組可靠度與失效分析評估，並推廣聚光太陽電池模組安規測試技術，參與太陽光電相關檢證測試技術訓練，進行實驗室人員技術培訓，以協助國內太陽光電產業與國際市場連結。

(2) 太陽日照輻射計校驗技術建置

將持續蒐集台灣區域太陽照射能量監測資料，並於所內建置太陽日照計校驗技術，其中有關於國家級實驗室間校驗件比對能力建立是一門檻，將透過 UL 合作夥伴間的聯結，加強與相關實驗室間的聯繫，並配合實驗室現有日照氣象監測裝置與技術能量，確保太陽電池模組檢測精確性。

(二) 量子點/高分子太陽電池技術發展

1. 開發環保型量子點溶液化學製程技術，並可應用於塗佈或印刷技術

進行環保型量子點($TiO_2$，$Cu_2S$與$Bi_2S_3$)溶液化學特性參數之改良與表面改質，以利於與導電高分子混摻行為，用於未來大面積塗佈或印刷技術應用，其結果可用於與食衣住行環境相關之日常商用產品。

2. 開發商用大面積量子點/高分子太陽電池製作技術，建立相關噴塗製作設備(spray printing & injet printing)與功能測試參數評估
   現有之高分子太陽電池研究大都集中於小面積元件之製程技術開發與特性研究，鮮少有大面積之研究發表。大面積之有機太陽電池效率現今仍只有元件效率的一半以下，於商品化過程將會造成極大之影響，故應積極開發大面積太陽電池製作技術，以減少製程過程中造成之效率損耗。
3. 完成量子點/高分子混摻太陽電池製作，能量轉換效率達 5 ~ 6%，製作技術最佳化及可靠度提升
   進行量子點混摻高分子太陽電池製備，改變不同之混摻條件，以調整高分子之結構；並製作不同之元件結構，如增加電動阻擋層或barrier layer，以提高太陽電池之效率與可靠度。
4. 新型低能隙導電高分子之研究與開發
   導電高分子為傳導電子及電洞至電極的材料，好的低能階導電高分子材料可以降低電子電洞對的復合(recombination)時間，提升元件之效率。另一方面新型低能階之導電高分子之壽命較佳，且可避開已知材料之專利布局，對整體太陽電池研究極為重要。

(三) 提純冶金級矽太陽電池技術開發

1. 針對 5N 純度 UMG-Si 基板，電阻率~0.2-0.5Ω-㎝，開發 HCl-gas gettering 技術，以提升少數載子生命週期。
2. 開發無電鍍鎳技術，並利用照光方式來成長具低成本優勢之太陽電池電極鎳金屬薄膜。
3. 研製實驗室級提純冶金級矽太陽電池，光電轉換效率~11-12%，面積~16 $cm^2$。

## 四、計畫執行情形及績效成果

### (一)工作進度－本年度預期目標及達成情形

本段落屬機密性內容，故不公開

本段落屬機密性內容，故不公開

本段落屬機密性內容，故不公開

# 肆、計畫經費與人力執行情形

## 一、計畫經費執行情形：

### (一)計畫結構與經費

| 細部計畫(分支計畫) | | 研究計畫(分項計畫) | | 主持人 | 執行機關 | 備註 |
|---|---|---|---|---|---|---|
| 名稱 | 經費(千元) | 名稱 | 經費(千元) | | | |
| 太陽光發電系統技術發展 | 112,494 | | | | 核能研究所 | |
| | | 高聚光太陽光發電系統技術發展 | 88,115 | | 核能研究所 | |
| | | 量子點/高分子太陽電池研發技術發展 | 11,377 | | 核能研究所 | |
| | | 提純冶金級矽太陽電池技術開發 | 13,002 | | 核能研究所 | |

### (二)經資門經費表

**預算執行數統計截止日期：100.12.31**

| 項目 / 會計科目 | 預算數(執行數)/元 | | | | 備註 |
|---|---|---|---|---|---|
| | 主管機關預算(累計分配數) | 自籌款 | 合計 | | |
| | | | 流用後預算數(實際執行數) | 占總預算數%(執行率%) | |
| 一、經常支出 | | | | | |
| 1.人事費 | | | | | |
| 2.業務費 | 81,234,000 (72,394,448) | | 72,394,448 (71,475,694) | 64.35% (98.73%) | 業務費流出：8,839,552 元 |
| 3.差旅費 | | | | | |
| 4.管理費 | | | | | |
| 5.營業稅 | | | | | |
| 小計 | 81,234,000 (72,394,448) | | 72,394,448 (71,475,694) | 64.35% (98.73%) | |
| 二、資本支出 | | | | | |
| 1.設備費 | 31,260,000 (40,099,552) | | 40,099,552 (40,099,552) | 35.65% (100%) | 業務費流入：8,839,552 元 |
| 小計 | 31,260,000 (40,099,552) | | 40,099,552 (40,099,552) | 35.65% (100%) | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 合計 | 金額 | 112,494,000<br>(112,494,000) | | 112,494,000<br>(111,575,246) | 100%<br>(99.18%) | |
| | 占總經費%=<br>分配數÷預算數<br>(執行率=執行數÷流用後預算數) | 100% | | (99.18%) | | |

**請將預算數及執行數並列，以括弧表示執行數。**

**與原計畫規劃差異說明：**

**無**

## 二、計畫人力運用情形：

### (一)計畫人力(人年) 人力統計截止日期：100.12.20

| 計畫名稱 | 執行情形 | 總人力(人年) | 研究員級 | 副研究員級 | 助理研究員級 | 助理 |
|---|---|---|---|---|---|---|
| 太陽光發電系統技術發展 | 原訂(全年) | 68.5 | 2 | 10.4 | 41 | 15.1 |
| | 實際 | 67.1 | 2 | 10 | 40 | 15.1 |
| | 差異 | -1.4 | 0 | -0.4 | -1 | 0 |
| 1.高聚光太陽光發電系統技術發展 | 原訂(全年) | 47.5 | 1 | 5.4 | 29 | 12.1 |
| | 實際 | 47.5 | 1 | 5.4 | 29 | 12.1 |
| | 差異 | 0 | 0 | 0 | 0 | 0 |
| 2.量子點/高分子太陽電池研發技術發展 | 原訂(全年) | 10 | 0 | 5 | 4 | 1 |
| | 實際 | 8.6 | 0 | 4.6 | 3 | 1 |
| | 差異 | -1.4 | 0 | -0.4 | -1 | 0 |
| 3.提純冶金級矽太陽電池技術開發 | 原訂(全年) | 11 | 1 | 0 | 8 | 2 |
| | 實際 | 11 | 1 | 0 | 8 | 2 |
| | 差異 | 0 | 0 | 0 | 0 | 0 |

說明：

**研究員級**：研究員、教授、主治醫師、簡任技正、若非以上職稱則相當於博士滿三年、或碩士滿六年、或學士滿九年之研究經驗者。

**副研究員級**：副研究員、副教授、總醫師、薦任技正、若非以上職稱則相當於博士、碩士滿三年、學士滿六年以上之研究經驗者。

**助理研究員級**：助理研究員、講師、住院醫師、技士、若非以上職稱則相當於碩士、或學士滿三年以上之研究經驗者。

**助理**：研究助理、助教、實習醫師、若非以上職稱則相當於學士、或專科滿三年以上之研究經驗者。

## (二)主要人力投入情形(副研究員級以上)

| 姓名 | 計畫職稱 | 投入主要工作及人月數 | 學、經歷及專長 | |
|---|---|---|---|---|
| | 分支計畫主持人 | 2.4 人月<br>計畫管理 | 學 歷 | |
| | | | 經 歷 | |
| | | | 專 長 | |
| | 分項計畫主持人 | 6 人月<br>協助計畫推行及模組開發 | 學 歷 | |
| | | | 經 歷 | |
| | | | 專 長 | |
| | 子項計畫主持人 | 9.6 人月<br>高聚光倍率太陽電池研發規劃與督導 | 學 歷 | |
| | | | 經 歷 | |
| | | | 專 長 | |
| | 子項計畫主持人 | 7.2 人月<br>模組設計、製作與測試相關技術之開發，子項計畫管理與工作規劃 | 學 歷 | |
| | | | 經 歷 | |
| | | | 專 長 | |
| | 子項計畫主持人 | 12 人月<br>追蹤器及電力系統設計開發，子項計畫管理與工作規劃 | 學 歷 | |
| | | | 經 歷 | |
| | | | 專 長 | |
| | 子項計畫主持人 | 9.6 人月<br>系統整合，子項計畫管理 | 學 歷 | |
| | | | 經 歷 | |
| | | | 專 長 | |
| | 子項計畫主持人 | 7.2 人月<br>模組安規相關測試技術之建置，子項計畫管理與工作規劃 | 學 歷 | |
| | | | 經 歷 | |
| | | | 專 長 | |
| | 分項計畫主持人 | 6 人月<br>協助計畫推行及元件與材料分析 | 學 歷 | |
| | | | 經 歷 | |
| | | | 專 長 | |
| 陳長盈 | 分項計畫 | 6 人月 | 學 歷 | 博士 |

| 姓名 | 計畫職稱 | 投入主要工作及人月數 | 學、經歷及專長 | |
|---|---|---|---|---|
| | 共同主持人 | 協助計畫推行及太陽電池製作開發 | 經 歷 | |
| | | | 專 長 | |
| | 分項計畫主持人 | 12 人月<br>計畫規劃、執行與管理 | 學 歷 | |
| | | | 經 歷 | |
| | | | 專 長 | |
| | 研究人員 | 9.6 人月<br>追蹤器及電力系統設計開發 | 學 歷 | |
| | | | 經 歷 | |
| | | | 專 長 | |
| | 研究人員 | 7.2 人月<br>系統整合 | 學 歷 | |
| | | | 經 歷 | |
| | | | 專 長 | |

**與原計畫規劃差異說明：**

本段落屬機密性內容，故不公開

# 伍、計畫已獲得之主要成果與重大突破 (含量化成果 output)

## 一、本計畫主要成果及重大突破

(一) 學術成就

1. 完成 SCI 期刊論文共 24 篇，已發表 5 篇，投稿 19 篇。

(1) 發表於 Journal of Applied Physics，109 期，頁 73506，論著名稱為【Visible luminescence properties of $(Ga_{1-x}Zn_x)(N_{1-x}O_x)$ solid solution (x=0.22)】。

(2) 發表於 Japanese Journal of Applied Physics，卷 50，頁 092302-1~5，論著名稱為【Measuring the Junction Temperature of GaInP/GaInAs/Ge Multijunction Solar Cells Using Photoluminescence】。

(3) 發表於 Journal of Nanomaterials，卷 2011，期 10，頁 1~5，論著名稱為【Structural and optical characteristics of γ-$In_2Se_3$ nanorods grown on Si substrates】。

(4) 發表於 Optics Communications，卷 284，期 19，頁 4283~4288，論著名稱為【High concentration and homogenized Fresnel lens without secondary optics element】。

(5) 發表於 Journal of the American Chemical Society，卷 133，頁 13064－13073，論著名稱為【Efficient Two-stage Annealing and Structural Evolution of Nanoorganized Bulk Heterojunction Solar Cell Studied by Grazing-Incidence Small Angle X-ray Scattering】。

(6) 投稿於 Applied Physics Letters，論著名稱為【Oxygen sensors made by monolayer graphene under room temperature】。

(7) 投稿於 Japanese Journal of Applied Physics，論著名稱為【New Packing Structure of Concentration Solar Receiver】。

(8) 投稿於 Sensors，論著名稱為【The logic-based supervisor control for sun-tracking system of 1MW HCPV demo plant: study case】。

(9) 投稿於 Reliability Engineering & System Safety，論著名稱為【A Study of On-line Diagnostic Technology on HCPV System Using Fuzzy FMEA】。

(10) 投稿於 Energy Policy，論著名稱為【Evaluation of Installing Integrated Sustainable Energy System in Taiwan】。

(11) 投稿於 Journal of Applied Physics，論著名稱為【Structural and Optical Characterization of ZnSeO Films Grown on GaAs by Molecular Beam Epitaxy】。

(12) 投稿於 Reliability Engineering & System Safety，論著名稱為【Controllability Enhancements of HCPV Array under Wind Loads

using Adaptive Neural Fuzzy Inference Systems】。

(13) 投稿於 Renewable Energy，論著名稱為【Numerical Investigation of High-Concentration Photovoltaic Module Heat Dissipation】。

(14) 投稿於 Carbon，論著名稱為【Synthesis, morphology and physical properties of multi-walled carbon nanotube/biphenyl liquid crystalline epoxy composites】，已接受。

(15) 投稿於 The Journal of Physical Chemistry，論著名稱為【Small and Wide Angle X-ray Scattering Characterization of Bulk Heterojunction Polymer Solar Cells with Different Fullerene Derivatives】。

(16) 投稿於 Journal of the American Chemical Society，論著名稱為【Formation Mechanism and Kinetics of Organic-Capped Anatase $TiO_2$ Nanorod Studied by Small-Angle X-Ray Scattering】。

(17) 投稿於 Applied physics letters，論著名稱為【Self-Vertical Phase Separation Study of Nanoparticle/Polymer Solar Cells by Introducing Fluoro-Containing Additives】。

(18) 投稿於 Chemical Communications，論著名稱為【Synthesis and characterization of (4,5-diaza-9,9'-spirobifluorene) functionalized donor/acceptor conjugated oligomers for hybrid solar cell application】。

(19) 投稿於 Thin Solid Films，論著名稱為【An Innovative Method of Nickel Plating on n/p Diode】。

(20) 投稿於 International Journal of Nanotechnology，論著名稱為【Study on thin film epitaxial silicon solar cells at INER】。

(21) 投稿於 Thin Solid Films，論著名稱為【Study and characterization of advanced $SiN_x$ film with LF-PECVD】。

(22) 投稿於 Journal of the Electrochemical Society，論著名稱為【Fabrication of silicon sub-micro wires based solar cells on UMG-Si substrates using nickel catalyst】。

(23) 投稿於 Physica Status Solid A-Applications and Materials Science，論著名稱為【Investigating of Arsenic-doped ZnO thin films grown on Si substrate by MOCVD】。

(24) 投稿於 International Journal of Nanotechnology，論著名稱為【Reduction of defects in amorphous silicon thin films using a cyanide solution treatment】。

2. 發表國內期刊論文 1 篇。

發表於台電工程月刊，期 758，頁 90~96，論著名稱為【太陽光追蹤器開發】。

3. 完成國際會議論文 12 篇。

(1) 發表於 2011 年 2 月 16 日~17 日 Photovoltaic Module Reliability

Workshop (PVMRW)，論著名稱為【Accelerated test method and statistics model analysis of degradation performance for PV module lifetime prediction】。

(2) 發表於 2011 年 4 月 1 日~3 日 2011 International Conference on Fluid Dynamics and Thermodynamics Technologies，論著名稱為【Conjugate Natural Convective Heat Transfer from Photovoltaic Cells on the Bottom Wall of a Horizontal Cabinet to Ambient Air Stream】。

(3) 發表於 2011 年 4 月 4 日~6 日第 7 屆 International Conference on Concentrating Photovoltaic Systems，論著名稱為【Effect of Spectral Response on Energy Conversion Efficiency of Solar Cell】。

(4) 發表於 2011 年 10 月 12 日~15 日 2011 The International Conference on Green Technologies，論著名稱為【On-site Measurement of a HCPV Module in NPUST】。

(5) 發表於 2011 年 11 月 17 日~18 日 International Electron Devices and Materials Symposium 2011(IEDMS 2011)，論著名稱為【Characteristics of Ti/Al/Ni/Au Ohmic Contacts on Ga-Doped ZnO Films】。

(6) 發表於 2011 年 4 月 25 日~29 日 2011 年 MRS Spring Meeting and Exhibit 會議，論著名稱為【Synthesis and Characterization of (4,5-diaza-9,9'-spirobifluorene) Functionalized Donor/acceptor Conjugated Polymer for Solar Cell Application】。

(7) 發表於 2011 年 9 月 19 日~22 日 2011 年國際材料亞洲大會(IUMRS-ICA)會議，論著名稱為【Ultrasonic Spray Deposition for Production of Organic Solar Cells】。

(8) 發表於 2011 年 9 月 19 日~22 日 2011 年國際材料亞洲大會(IUMRS-ICA)會議，論著名稱為【Surface Modification of $TiO_2$ by (4,5-diaza- 9,9'-spirobifluorene) Functionalized Donor/acceptor Conjugated Polymers for P3HT/ $TiO_2$ Hybrid Solar Cell】。

(9) 發表於 2011 年 6 月 21 日~24 日 4th IEEE International NanoElectronics Conference (INEC)，論著名稱為【Reduction of Defects in Amorphous Silicon Thin Films Using a Cyanide Solution Treatment】。

(10) 發表於 2011 年 11 月 20 日~23 日 TACT 2011 International Thin Films Conference，論著名稱為【Study on Thin Film Epitaxial Silicon Solar Cells at INER】。

(11) 發表於 2011 年 11 月 20 日~23 日 TACT 2011 International Thin Films Conference，論著名稱為【An Innovative Method of Nickel Plating on n/p Diode】。

(12) 發表於 2011 年 11 月 20 日~23 日 TACT 2011 International Thin Films Conference，論著名稱為【Study and Characterization of Advanced SiNx Film with LF-PECVD】。

4. 完成國內會議論文 6 篇。

(1) 發表於 2011 年 5 月 20 日第九屆微電子技術發展與應用研討會，論著名稱為【Effect of Quantum Efficiency on Short Current of MJ Compound Solar Cell/多接面太陽電池之短路電流與量子效率影響分析】。

(2) 發表於 2011 年 5 月 28 日第十二屆電子化企業經營管理理論暨實務研討會，論著名稱為【應用虛擬實境技術於高聚光型太陽光發電廠建置之研究】。

(3) 發表於 2011 年 7 月 21 日~23 日第 29 屆光譜技術與表面科學研討會，論著名稱分別為為【ZnO 熱聲子效應】、【利用電激發螢光定義 p-i-n 砷化鎵】、【利用光激螢光量測 p-i-n 型砷化鎵太陽能電池】、【Optimization of antireflection coating design for Ⅲ-V multijunction solar cell)】。

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6. 2011 年 6 月 29 日於龍潭渴望園區渴望會館國際演講廳辦理「聚光型太陽光電系統檢驗標準研討會」，邀請兩岸對於聚光型太陽能電池研究最具有權威的研究單位，並同時邀請到美國優力的首席華人研究員分享對於聚光型太陽能模組檢驗上的心得，希望能促成兩岸聚光型太陽能模組檢驗規範要求上的一致性，讓兩岸無論業界或是學界能夠討論出共同的基準點，對日後兩岸聚光型太陽能產業發展能夠有所幫助。

本段落屬機密性內容，故不公開

本段落屬機密性內容，故不公開

本段落屬機密性內容，故不公開

本段落屬機密性內容，故不公開

(四) 社會影響

1. 協助國內業者聚光型太陽電池、聚光模組、太陽光追蹤器、中央監控系統產品精進改良，輔助產品開發，提升品質及效能，以利拓展海外市場，加速產業發展，增加就業之機會。
2. 持續改良 HCPV 系統技術，減少二氧化碳排放，發揮節能減碳效益，

並透過學界合作研發，發揮教學功能。

3. 於核研所太陽電池模組驗證實驗室完成日照計比對測試平台架設，初期將逐步對本所在台灣區域各地所架設之戶外氣象監測站，進行直射日照計比對測試，後續將可提供國內太陽光電產業進行日照計比對測試技術服務。
4. 本計畫需求光電、材料、物理、資訊及機械等方面人才，推展促進了國內太陽電池技術的發展，並培育 21 位國防訓儲/替代役及 22 位專業支援人力，達到培育太陽光電技術人才之目的；另外，有 7 位國防訓儲/研發替代役退役後，投入國內太陽光電相關產業界，貢獻所長，提升國內產業競爭力。

(五) 其它效益

1. 2011 年 6 月 1 日參與經濟部標檢局太陽電池模組 CNS 標準審查會議，內容涵蓋聚光型(IEC62108)與薄膜(IEC61646)太陽電池模組檢測規範審查。
2. 本所太陽電池模組驗證實驗室通過 CPV 模組安全規範驗證認可，為亞洲區域唯一通過 UL 認證之 CPV 模組性能(IEC 62108)與安規(UL 8703)驗證測試實驗室，可提供國內業界 CPV 模組完整(同時符合性能與安規)之驗證測試服務，裨益國際市場之開拓。並與 UL 實驗室研討太陽光追蹤器平台驗證(UL 3703)規範，評估檢測技術建置效益。
3. 與北京鑒衡認證中心技術交流，評估太陽電池模組驗證實驗室導入金太陽 CGC 認證體系事宜，以協助國內太陽光電產品行銷大陸市場。
4. 2011 年 9 月 13 日、10 月 17 日分別與澳洲太陽能研究所(Australian Solar Institute, ASI)、澳洲聯邦科學暨工業研究院(Commonwealth Scientific and Industrial Research Organization, CSIRO)人員，就 8 月 12~13 日在澳洲舉行之第 17 屆台澳能礦諮商會議所簽訂之 MOU 簽署事項有關太陽能發電部分，進行討論。已獲澳洲太陽能研究所初步回應，將繼續討論可行方案、步驟及時程。

# 二、績效指標項目初級產出、效益及重大突破

| | 績效指標 | 預期績效指標 | 初級產出量化值 | 效益說明 | 重大突破 |
|---|---|---|---|---|---|
| 學術成就(科技基礎研究) | A 論文 | 國內外會議論文、國內期刊：7 篇<br>國外期刊：8 篇。 | SCI 期刊：24 篇(發表 5 篇，投稿 19 篇)<br>國內期刊：1 篇<br>國際研討會：12 篇<br>國內研討會：6 篇 | 藉由論文發表於國內外期刊或會議，提高核研所在相關太陽電池技術研發之能見度，並促進學術交流。 | |
| | B 研究團隊養成 | 1. 建立高聚光太陽光發電系統技術發展研究團隊。<br>2. 建立核能研究所-量子點/高分子太陽電池研究團隊，並與台灣大學研究團隊合作開發新型量子點高分子材料。<br>3. 建立核能研究所—磊晶矽薄膜太陽電池發電系統研究團隊。 | 1. 與中原大學合作建立「Ⅲ-V族多接面太陽電池的轉換效率機制研究」研究團隊。<br>2. 與交通大學合作建立「新式HCPV太陽電池模組散熱機制研究與系統最佳化設計」研究團隊。<br>3. 與成功大學合作建立「太陽光發電影像追蹤技術研發」研究團隊。<br>4. 與萬能科技大學合作建立「資料探勘技術在HCPV系統上之應用」研究團隊。<br>5. 與屏東科技大學合作建立「太陽能電池模組溫度量測與預測技術建立」研究團隊。<br>6. 與屏東科技大學合作建立「HCPV太陽能發電模組效能與耐久性實地測試評估」研究團隊。<br>7. 與台大材料系合作組成有機太陽電池研究團隊。由台大負責上游材料之開發與合成，本計畫執行中、下游製程與產品之研發。<br>8. 與中原大學合作建 | 精進太陽光發電相關技術。 | |

| | 績效指標 | 預期績效指標 | 初級產出量化值 | 效益說明 | 重大突破 |
|---|---|---|---|---|---|
| | | | 立「新型冶金級矽太陽電池技術(PERL、SHJ-IBC)研究與開發」研究團隊。 | | |
| | C 博碩士培育 | 參與計畫執行之碩士研究生 4 位,博士研究生 8 位 | 參與計畫之執行,共培育博士研究生 3 人,碩士研究生 10 人。 | 經由與學校之合作研究,由基礎研究突破技術障礙,培育太陽光發電領域人才,作為研發後盾。 | |
| | D 研究報告 | 所內報告 25 篇。 | 31 篇 | 研究成果可提供後續參與人員的參考,及技術傳承。 | |
| | E 辦理學術活動 | | 2 場 | 2011 年 6 月 29 日舉辦「聚光型太陽光電系統檢驗標準研討會」,2011年9月20日舉辦「Ⅲ-V族太陽能電池先進技術研討會」,促進太陽光電產業、學界資訊與技術交流,普受外界肯定,後續已有數家廠商洽談技轉或技服案。 | |
| 技術創新(科技整合創新) | G 專利 | 本段落屬機密性內容,故不公開 | | | |

| | 績效指標 | 預期績效指標 | 初級產出量化值 | 效益說明 | 重大突破 |
|---|---|---|---|---|---|
| | H 技術報告 | 11 篇 | 12 篇 | 記載研發的歷程及標準作業程序，以利技術傳承；後續的研發可在既有的基礎上，繼續發揚光大。 | |
| | I 技術活動 | 3 場 | 論文發表於國內或國外研討會 12 場次。 | 促進研發成果交流。 | |
| | J 技術移轉 | 本段落屬機密性內容，故不公開 | | | |
| | S 技術服務 | | | | |

| | 績效指標 | 預期績效指標 | 初級產出量化值 | 效益說明 | 重大突破 |
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| 經濟效益（產業經濟發展） | N協助提昇我國產業全球地位或產業競爭力 | 本段落屬機密性內容，故不公開 | | | |

# 陸、主要成就及成果之價值與貢獻度(outcome)

## 一、學術成就(科技基礎研究) (權重_30_%)

(一) 藉由 SCI 期刊、國際研討會及國內研討會論文發表，促進國內外相關研究單位交流，進而提升我國在太陽光發電的國際學術研究地位。SCI 期刊及會議論文摘述如下：

| 項次 | 論文名稱 | 作者 | 論文出處 | 摘要 |
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| 1. | Visible luminescence properties of $(Ga_{1-x}Zn_x)(N_{1-x}Ox)$ solid solution (x=0.22) | | 已發表<br>期刊：0021-8979, Journal of Applied Physics<br>期刊期：109<br>頁數：73506<br>出版年月：2011-04-01 | Temperature-dependent photoluminescence (PL) and time-resolved photoluminescence (TRPL)are measured for the $(Ga_{1-x}Zn_x)(N_{1-x}O_x)$ solid solution with x=0.22 to study its luminescence properties. PL result shows that the material exhibits visible luminescence at around 1.87 eV(663 nm)with a broad emission band even at room temperature. The origin of luminescence mechanism can be attributed to the radiative recombination of the electrons bound to donors and the holes bound to acceptors. The investigation from the integrated PL intensity and TRPL as a function of temperature indicates that the activation energy for thermalizing the electrons bound to a donor dominates the luminescence behavior in the $(Ga_{1-x}Zn_x)(N_{1-x}O_x)$ solid solution. |
| 2. | Measuring the Junction Temperature of GaInP/GaInAs/Ge Multijunction Solar Cells Using Photoluminescence | | 已發表<br>期刊：0021-4922, Japanese Journal of Applied Physics<br>期刊卷：50<br>頁數：092302-1~5<br>出版年月：2011-09-20 | The junction temperatures of the three individual subcells of InGaP/InGaAs/Ge solar cells were measured using photoluminescence (PL) with three different excitation lasers. With the illumination of an extra xenon–mercury lamp, the linear relationship between the PL energy and the illumination level is clearly observed and advantageously used for deriving the junction temperature. Using the Varshni relationship between the PL peak energy and the heat-sink temperature allows us to determine the junction temperature in each subcell. |
| 3. | Structural and optical characteristics of $\gamma$-$In_2Se_3$ nanorods grown on Si substrates | | 已發表<br>期刊：1687-4110, Journal of Nanomaterials<br>期刊卷：2011<br>期刊期：10<br>頁數：1~5<br>出版年月：2011-08-09 | We have grown the single phase $\gamma$-$In_2Se_3$ nanorods on Si (111) substrates by the metalorganic chemical vapor deposition (MOCVD). High-resolution transmission electron microscopy (HRTEM), and selected-area electron diffraction (SAED) confirm that the $In_2Se_3$ nanorods are singly crystallized in the $\gamma$ phase. The visible photoluminescence (PL) of $\gamma$-$In_2Se_3$ nanorods at 15 K was referred to as the free and bound exciton emissions. The band-gap energy of the $\gamma$-$In_2Se_3$ nanorods at room temperature was determined to be ~ 1.99 eV. A PL peak in the infrared spectral range was observed and attributed to the donor-acceptor pair transition. |
| 4. | High concentration and homogenized Fresnel lens without secondary optics element | | 已發表<br>期刊：0030-4018, Optics Communications<br>期刊卷：284<br>期刊期：19<br>頁數：4283~4288<br>出版年月：2011-09-01 | In this paper, we design a single concentrator to homogenize and concentrate the solar energy. The proposed concentrator only consisted of an array of refraction prisms. In order to homogenize the irradiance, all pitches of the Fresnel concentrator focus on the different position of the receiver. Finally, the Fresnel lens that achieves the uniformity of U is 14.6. An acceptance angle of 0.305° is achieved without using additional secondary optics. Full Width at Half Maximum (FWHM) of illumination distribution is 1.4 mm. |

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| 5. | Efficient Two-stage Annealing and Structural Evolution of Nanoorganized Bulk Heterojunction Solar Cell Studied by Grazing-Incidence Small Angle X-ray Scattering | | 已發表<br>期刊:0002-7863 Journal of the American Chemical Society<br>期刊卷:133<br>頁數:13064~13073,<br>出版年月:2011-07-14 | This study employed the improved grazing-incidence small-angle X-ray scattering (GISAXS) analysis with a combination of grazing-incidence X-ray diffraction (GIXRD) to resolve the various structures of self-organized poly(3-hexylthiophene) /C61-butyric acid methylester (P3HT/PCBM) solar cell. Tuning the various length scales of PCBM-related structures by two-step annealing is shown to be a potential method for improving the device performance. The quantitative structural characterization includes (1) the mean size, volume fraction and size distribution of aggregated PCBM clusters, (2) the specific interface area between PCBM and P3HT, (3) the local cluster agglomeration, and (4) the correlation length of PCBM molecules' network within P3HT phase. The above terms are correlated to the device performance. The various structural evolutions and transformations (growth and dissolution) between them with the variation of annealing history are demonstrated here. The detailed result significantly extends the current knowledge. This work established a useful SAXS approach to present an insight into the modeling of the morphology of P3HT/PCBM film. In situ GISAXS measurement was also conducted to provide the informative result about the details of thermal behavior and temporal evolution of PCBM-related structures during phase. |
| 6. | Oxygen sensors made by monolayer graphene under room temperature | | 已投稿<br>期刊：0003-6951, Applied Physics Letters | The electrical resistivity of monolayer graphene exhibit significant changes upon expose to different concentration of oxygen ($O_2$) at room temperature. The monolayer graphene, grown by chemical vapor deposition (CVD) with perfect uniformity within 1cm×1cm will attach $O_2$ molecules and enhance the hole conductivity, which will lead to a change of resistivity of graphene thin film. We quantified the change of resistivity of graphene versus different $O_2$ concentration and the detection limit of the simple $O_2$ sensor was 1.25% in volume ratio. |
| 7. | New Packing Structure of Concentration Solar Receiver | | 已投稿<br>期刊：0021-8979, Japanese Journal of Applied Physics<br>Manuscript No: T14269 | This paper presents a solution to the temperature issue in High Concentration Photovoltaic (HCPV) module device by using different thermal conductive material and packing structure. In general, the open-circuited voltage of a device reduces with the increase of temperature and therefore degrades its efficiency. The thermal conductive material we use in this paper, silicon, has a high thermal conductive coefficient (149 W/m·K) and steady semiconductor properties which are suitable for the application of solar receiver in HCPV module. Solar cell was soldered on a metal-plated Si substrate with a thicker $SiO_2$ film which acts as an insulating layer. Then it was mounted on an Al-based plate to obtain a better heat dissipating result. |
| 8. | The logic-based supervisor control for sun-tracking system of 1MW HCPV demo plant: study case | | 已投稿<br>期刊：1424-8220, Sensors<br>Manuscript No.：SENSORS-11972 | This paper presents a logic-based supervisor controller designed for trackers of 1MW HCPV demo plant at Taiwan. Sun position sensor on the tracker is used for detects the sun position, but the sensor is sensitive for intensity of sun light. The signal output of sensor will partially or all blocked by the cloud, and which it's hard controlled by the traditional PID control. We use a logic-based supervisor (LBS) control allowing for switching PID control in the sunny conditions to sun trajectory in cloudy conditions. To verify the stability of the proposed control, an experiment was performed; the results show that the proposed control can efficiently achieve the stabilizing trackers of 1MW HCPV demo plant. |

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| 9. | A Study of On-line Diagnostic Technology on HCPV System Using Fuzzy FMEA | | 已投稿<br>期刊：0951-8320, Reliability Engineering & System Safety<br>Manuscript No.：RESS-D-11-00467 | Maintenance could take a lot of system operational cost after HCPV system established. To reduce the maintenance cost and to foster system availability, on-line diagnostic technology with Fuzzy FMEA counts. The spirit of ad hoc technology depends on real time and historical data. FMEA takes those data to predict failure modes, analyze causes of failed components in order for management level to schedule a maintenance plan in advance. In this study, authors worked the technology on the 100 kW HCPV system established by INER in 2007, and created a method for the subject title study. |
| 10. | Evaluation of Installing Integrated Sustainable Energy System in Taiwan | | 已投稿<br>期刊：0301-4215, Energy Policy<br>Manuscript No.：JEPO-D-11-01569 | The purpose of this study is to evaluate the possibility of stabilizing sustainable power supplies by installing three different kinds of energy systems including photovoltaic, wind power generators, and fuel cells. Energy produced by both photovoltaic and wind power generators are highly dependent on unpredictable meteorological conditions. To fulfill the aim of stabilizing these power sources, it is necessary to add the other sustainable power generator – fuel cells which can run continuously regardless of the weather condition. The method of evaluation is to fix the capacity of wind power generated in different locations as the primary parameter, and then to calculate the capacities of both photovoltaic and fuel cells installed at equivalent sites. As is well known, energy produced by wind power and photovoltaic is a function of wind speed and solar radiation. Accordingly, meteorological data are considered in the evaluation. Meteorological data are collected and input into formulas as the method of evaluation in this paper. |
| 11. | Structural and Optical Characterization of ZnSeO Films Grown on GaAs by Molecular Beam Epitaxy | | 已投稿<br>期刊：0021-8979, Journal of Applied Physics | $ZnSe_{1-x}O_x$ alloys with various O contents (2.7 %< x <9.3 %) have been successfully grown on GaAs by plasma-assisted molecular beam epitaxy. The degradation in the surface morphology and crystal quality is found highly correlated with increasing O composition. The optical properties show that low temperature band edge photoluminescence of the ZnSeO well follows the O-induced band-gap reduction. An S-shaped temperature-dependent photoluminescence behavior is observed on ZnSeO films and is attributed to the delocalization of local excitons. The decrease of temperature dependence of the band gap of ZnSeO films can be found. With increasing O content in ZnSeO, the fitting in energy reduction still follows well by the band anticrossing model. Different recombination paths in this material have also been clarified by time-resolved photoluminescence measurements. The long decay time at low temperature results from the trapping of carriers by the localized states. At higher temperatures, the radiative recombination is dominated by the FEs, which exhibit a fast PL decay time. |

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| 12. | Controllability Enhancements of HCPV Array under Wind Loads using Adaptive Neural Fuzzy Inference Systems | | 已投稿<br>期刊：0951-8320, Reliability Engineering & System Safety | The high concentration photovoltaic (HCPV) system has sophisticated solar-tracking mechanism. In order to avoid damage to critical components, each panel of HCPV will be horizontally placed when the wind speed is greater than a predetermined threshold value. Such a consideration seems to be reasonable though, there exist two problems. The first lies in that if the wind speed is constantly changing in the vicinity of threshold value, the motor of solar tracker will be forced to switch between on and off frequently. The reliability of the solar-tracking system will be deteriorated after year-around operations. The second is about serious performance degradation that is, even in the sunny days, as long as the wind speed is greater than the threshold value, the solar tracking device will be triggered to stop working to protect the mechanical parts from being damaged, which leads to loss of power generation. In this paper we integrated the raw data such: wind speed, wind direction and the change rate of maximum wind speed as multiple input factors at first, and then we use the adaptive neural fuzzy inference system (ANFIS) to solve the problem of the excessive mechanical response to wind loads. Simulations indicated that such design has obtained significant results. |
| 13. | Numerical Investigation of High-Concentration Photovoltaic Module Heat Dissipation | | 已投稿<br>期刊：0960-1481, Renewable Energy | The present study performs a series of simulations based on the Reynolds Averaged Navier-Stokes equations, the RNG k-ε turbulence model, and the P1 radiation model to investigate the passive cooling of high-concentration photovoltaic (HCPV) solar cell modules. The simulations focus specifically on the effects of the direct normal irradiance, the ambient temperature, the module elevation angle and the wind speed on the thermal management performance of the HCPV module. The results have shown that the maximum cell temperature within the HCPV module reduces as the wind speed increases. Moreover, the heat dissipation performance of the HCPV module is significantly dependent upon the wind speed for wind speeds below 1 m/s. In addition, the maximum cell temperature is a linear function of the ambient temperature and direct normal irradiance. Finally, the simulations have shown that the temperature distribution and flow-field phenomena in the HCPV module possess distinct three-dimensional asymmetrical characteristics. In other words, simulation models based on symmetrical boundaries, periodic boundaries, or two-dimensional geometries are insufficient to investigate the thermal management performance of real-world HCPV modules. |

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| 14. | Synthesis, morphology and physical properties of multi-walled carbon nanotube/biphenyl liquid crystalline epoxy composites | | 已接受<br>期刊:0008-6223<br>Carbon | We have developed multi-walled carbon nanotube/liquid crystalline epoxy composites and studied the effects of incorporation carbon nanotubes (CNTs) on the morphology, thermal and mechanical properties of the composites. The CNTs are functionalized by liquid crystalline (LC) 4,4'-bis(2,3-epoxypropoxy) biphenyl (BP) epoxy resin for the ease of dispersion and the formation of long range ordered structure. The epoxy functionalized CNT (ef-CNT) were dispersed in the LC BP epoxy resin that can be thermal cured with an equivalent of 4,4'-diamino-diphenylsulfone to form composite. The curing process was monitored by polarized optical microscopy. The results indicate the LC resin was aligned along the CNTs to form fiber with dendritic structure initially then further on to obtain micro-sized spherical crystalline along with fibrous crystalline. With homogeneous dispersion and strong interaction between nanotubes and matrix, the composite containing 2.00 wt% ef-CNT exhibits excellent thermal and mechanical properties. When the amount of ef-CNT exceeds 2.00 wt%, vitrification stage of curing is fast reached, which lowers the degree of conversion. As compared with the neat resin, the composite containing 2.00 wt% ef-CNT increases the glass transition temperature by 70.0 ℃, the decomposition temperature by 13.8 ℃, the storage modulus by 40.9 %, and the microhardness by 63.3 %. |
| 15. | Small and Wide angle X-ray Scattering Characterization of Bulk Heterojunction Polymer Solar Cells with Different Fullerene Derivatives | | 已投稿<br>期刊:1089-5639<br>The Journal of Physical Chemistry | The aim of this study is to quantitatively investigate the various structures in the bulk heterojunction solar cells consisted of P3HT/PC60BM and P3HT/PC70BM without thermal annealing. The nanostructure resulted from the phase separation of P3HT/PCxBM was characterized by the grazing-incidence small- and wide- angle X-ray scattering (GISAXS and GIWAXD). We obtained the structural parameters, such as the size, volume fraction and spatial distribution of aggregated PCxBM cluster by model fitting and model-independent method. Meanwhile, the characterization of P3HT crystallite and network structure of PCxBM molecules dispersed in amorphous P3HT chains was also included in this study. The effect of fullerene derivatives on the self-organized structures is discussed. The correlation between nanostructures and performance is presented here for both P3HT/PC60BM and P3HT/PC70BM devices. |

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| 16. | Formation Mechanism and Kinetics of Organic-Capped Anatase $TiO_2$ Nanorod Studied by Small-Angle X-Ray Scattering | | 已投稿<br>期刊：0002-7863 Journal of the American Chemical Society | The structural evolution and temporal behavior of nucleation and anisotropic growth of organic-capped anatase $TiO_2$ nanorod in the colloidal solution was studied by small-angle X-ray scattering (SAXS) and other tools. The direct and detailed SAXS characterization quantitatively and qualitatively provides a general knowledge about the structural evolution, inter-particle interaction and spatial orientation of nanoparticles formed during the nucleation and growth. The present study demonstrates a spatial factor driving the development of oriented attachment mechanism except for the effect of surface surfactants. An ordered lamellar structure in the solution constructed by the balance of interaction forces among different surface ligands, function groups and solvent molecules serves as a natural 3D template. It allows the spatial aggregation and alignment of spherical primary particles into an ordered chain arrays, effectively facilitating the almost simultaneous transformation from spherical to rod shape via proximity attachment. This template also assists the further coalescence between nanorods. The model proposed herein can give the insight into the detailed understanding of oriented attachment mechanism based on the thermodynamics and kinetic interpretations. The multistep mechanism of formation of anatase $TiO_2$ nanorod revealed by this study is helpful to understand the fundamental details and gap in the currently known knowledge on the respective mechanisms. The result about the natural template and multistep mechanism can provide the potential knowledge to flexibly tune the shape of rods or fabricate the highly ordered nanostructure and 3D nanowire network. |
| 17. | Self-Vertical Phase Separation Study of Nanoparticle/Polymer Solar Cells by Introducing Fluoro-Containing Additives | | 已投稿<br>期刊：0003-6951 Applied physics letters | The hybrid material made from poly(3-hexylthiophene) (P3HT) and $TiO_2$ nanorod is a useful solution processable photoactive material for flexible hybrid solar cells with the bulk heterojunction structure. The morphology of this hybrid material plays a determinant role in the power conversion efficiency (PCE) of the hybrid solar cell. Two fluoro-containing additives were introduced in the hybrid material respectively to observe the morphology changes. They are tris(perfluorophenyl)borane (BCF) and 2,6-(2,3,5,6-ditetrafluorobenzonitrile) - 4,4'- dihexyl- 4H-cyclopenta [2,1-b:3,4-b'] dithiophene (GW). The cross section images of scanning electron microscopy (SEM) of hybrid material containing 1% additive indicate the occurrence of vertical phase separation in the hybrid film. We deduce the vertical phase separation is due to the vertical shear force generated from fluoro-containing additives during spin coating process. A vertical gradient structure of hybrid film being P3HT rich to $TiO_2$ rich is created from the bottom layer of PEDOT: PSS to the top layer of Al electrode. The gradient structure improves not only P3HT crystallinity but also the charge transport efficiency to the opposite electrodes, thus the PCE of solar cell is increased. The order of improvement in the PCE of the hybrid solar cell using different additive is BCF (0.92%) > GW (0.78%) > none (0.22%) when a hybrid of P3HT/$TiO_2$ = 43/57 (wt/wt) is used. The power conversion efficiency is expected to be further increased by optimizing the processing. |

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| 18. | Synthesis and characterization of (4,5-diaza-9,9'-spirobifluorene) functionalized donor/ acceptor conjugated oligomers for hybrid solar cell application | | 已投稿<br>期刊:1359-7345 Chemical Communications | The series of (4,5-diaza-9,9'-spirobifluorene) functionalized donor/ acceptor (D/A) conjugated oligomers were synthesized via Stille coupling. The pyridine-like moiety of the oligomers exhibited good affinity towards hydrophilic $TiO_2$ nanorod and enhanced the efficiency of P3HT-$TiO_2$ hybrid solar cells. |
| 19. | An Innovative Method of Nickel Plating on n/p Diode | | 已投稿<br>期刊:0040-6090, Thin Solid Films | The studies of nickel plating by using an electroplating and electroless plating methods have been widely discussed due to its multiple applications. All current plating processes mainly use an applied current or the reducing agent to reduce metal ions from a solution. In this study, a new mechanism of nickel plating process on n/p diode in the plating solution is displayed. Using the characteristic of n/p diode that has a built-in potential, the electrons and holes will generate in the diode when illuminated, meanwhile, they will flow to the opposite direction separately under the action of built-in potential. The nickel film is plated on the n-type surface by the reduction of photoelectron flow, and there is no any reducing agent used in this processes. This innovative approach can simplify of the traditional electroplating process. It can also be applied to silicon solar cells of the front contact Ni/Cu plating. |
| 20. | Study on thin film epitaxial silicon solar cells at INER | | 已投稿<br>期 刊 :1475-7435, International Journal of Nanotechnology | Thin film epitaxial silicon solar cells are considered potentially viable alternatives to low-cost, low efficiency amorphous silicon solar cells as well as high-cost, high-efficiency bulk crystalline silicon solar cells. This work is aimed at reporting on the study of thin-film epitaxial silicon solar cells at the Institute of Nuclear Energy Research (INER) in Taiwan. The material selected for the substrate is inexpensive ＜ 5N purity upgraded metallurgical grade silicon (UMG-Si), which is considered too "dirty" to be suitable for solar cell production directly. A home-made 2-inch vacuum-free atmospheric pressure chemical vapor deposition (APCVD) system is used. In-situ HCl gas gettering of a 4×4 $cm^2$ UMG-Si substrate is first performed with subsequent deposition of a ~ 20 μm thick high quality epitaxial layer on top of the gettered UMG-Si substrate at 1150℃ . The resultant product, often referred to as an epitaxial wafer equivalent (EpiWE), 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 13.18% is achieved at present. In addition, in order to study large area thin film epitaxial silicon solar cells, a 6-inch epitaxial APCVD system is also under construction. |
| 21. | Study and characterization of advanced SiNx film with LF-PECVD | | 已投稿<br>期 刊 :0040-6090, Thin Solid Films | In this paper, we will discuss the relation of chemical effect and field effect in passivation. We used low frequency plasma enhanced chemical vapor deposition (LF-PECVD) system to deposit SiNx film at the temperature of 300℃ and a low frequency of 50kHz with 40W rf power and then anneal the sample with RTA. The minority carrier lifetime ($\tau_{eff}$), the fixed charge ($Q_f$), and IR spectrum are measured. We find out that the annealing procedure will decrease field effect, but the hydrogen diffusion will increase the minority carrier lifetime. |

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| 22. | Fabrication of silicon sub-micro wires based solar cells on UMG-Si substrates using nickel catalyst | | 已投稿<br>期 刊 :0013-4651, Journal of the Electrochemical Society | The growth of silicon sub-micron wires on upgraded metallurgical grade Si(UMG-Si) substrates was catalyzed by nickel(Ni) using chemical vapor deposition technique. A favorable growth condition of silicon sub-micron wires has been examined by varying the annealing temperature and time duration of Ni film in the ranges 900-975℃ and 2-12 min, respectively. Moreover, the output characteristics of the silicon sub-micron wires based (Si-SMWs) solar cells were analyzed and compared. It was found that silicon wires with the magnitude of diameter ranging from 0.2 to 0.8 μm could be grown with the present technique. Moreover, a conversion efficiency over 1% could be achieved for the Si-SMWs solar cells fabricated with the Ni catalytic film annealed at 950℃. In particular, by annealing the Ni catalytic film for a short duration of 2 min for growing sub-micron wire structure, the solar cell produced thereon further demonstrated an efficiency as high as 2.06%. |
| 23. | Investigating of Arsenic-doped ZnO thin films grown on Si substrate by MOCVD | | 已投稿<br>期 刊 :1862-6300, Physica Status Solid A-Applications and Materials Science | Zinc oxide (ZnO) thin film was grown on semi-insulated Si substrate using $AsH_3$ as precursor by atmospheric pressure metal-organic chemical vapor deposition (AP-MOCVD). As well known, the doping mechanism of As-doped ZnO thin film are explained as As substitution for oxygen (Aso) or As substitution for Zn and As combined with two Zn vacancies (AsZn-2VZn). In this study, we control the in-situ annealing ambient into two conditions, Zn-rich and O-rich, respectively. And we expect that will help to create Aso and AsZn-2VZn. The ZnO thin film after in-situthermal annealing with $H_2O$ vapor ambient at 550 ℃ and 750℃ show p-type conductivity with hole concentration of $2.651\times10^{17}$ and $1.782\times10^{18}$ $cm^{-3}$, the Hall mobility of 10.08 and 5.402 $cm^2$/Vs, the resistivity of 2.368 and 0.6485 Ωcm. |
| 24. | Reduction of defects in amorphous silicon thin films using a cyanide solution treatment | | 已投稿<br>期 刊 :1475-7435, International Journal of Nanotechnology | A KCN aqueous solution is used in a cyanide treatment for the reduction of defect states in hydrogenated amorphous silicon (a-Si:H) thin films. The concentration of the KCN aqueous solution is probed to find the optimum conditions that will improve the electrical properties of a-Si:H thin film. After the cyanide treatment, the combination between silicon atoms and cyanide ions is confirmed by observing the binding energy of N 1s (in 395 eV ~ 406 eV) through X-ray photoelectron spectroscopy (XPS) measurement. Furthermore, the N 1s signal can be detected down to a depth of 15 nm into the a-Si:H thin film. Low temperature cathodoluminescence (CL) measurement shows that using a higher concentration KCN treatment produces a stronger radiation signal, which indicates that the cyanide ions reduce the defect states in a-Si:H thin films. As an important parameter for solar cells, the ratio between photo-current and dark-current reaches its maximum when the a-Si:H thin film is immersed in a 0.4 M KCN aqueous solution for one minute. |

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| 25. | 太陽光追蹤器開發 | | 已發表<br>期刊：台電工程月刊<br>期刊期：758 期<br>頁數：90~ 96<br>出版年月：2011-10-03 | 聚光型太陽能發電技術，被認為是太陽能發電未來發展趨勢的第三代技術。聚光型太陽能使用的多接面太陽電池具有高的光電轉換效率，目前的世界紀錄已達到 43.5%，是晶矽電池效率的兩倍以上，而效率是成本的重要因素，我們相信太陽能發電系統中成本下降最有潛力的，當推聚光型太陽能發電系統。太陽光追蹤器是高聚光太陽能發電系統中最重要的子系統之一，本文提出太陽光追蹤器設計概念，並以核能研究所自行開發的太陽光追蹤器為例子，說明太陽光追蹤器特色及功能。太陽光追蹤器重要指標為追蹤精度，文中亦有描述高追蹤精度之優點。目前，研發出的太陽光追蹤器，其追蹤精度低於±0.2 度，未來將繼續精進追蹤技術，以達到國際水準±0.1 度的目標。 |
| 26. | Accelerated test method and statistics model analysis of degradation performance for PV module lifetime prediction. | | 國際會議<br>名稱：2011 Photovoltaic Module Reliability Workshop (PVMRW)<br>地點：Golden, Colorado,USA<br>日期：2011-02-16~17 | The reliability of crystalline silicon PV modules has improved dramatically in recent years. Today, manufacturers are usually asked to provide their customers with reliability information about degradation rate of PV module power. However, module power degrades very slowly at the normally used condition. Accelerated degradation tests are used widely to obtain timely information on the reliability of module. Accelerated degradation tests for assessing the long-term reliability and performance of photovoltaic modules were conducted as follows. The damp heat tests were run at high levels of temperature and relative humidity to accelerate the hydrolytic and corrosive action of hot, humid environments and obtain degradation data more quickly. In our tests, the 2 x 2 cell modules were fabricated in the same type of crystalline silicon cells, glass and back sheet foil. Before the damp heat tests, the modules were exposed by UV 15 KWhr as the pre-test mentioned in IEC61215. Those small modules were tested as the process flow which are then divided into five conditions. Damp heat test were plan to keep going non-less than 2000 hrs. The tests of IV-characteristics and a visual control were carried out, and measurements were made at specific times so as to obtain the degradation ration of power loss. The performance of a degradation model depends strongly on the appropriateness of the model describing a product’s degradation path. we propose a relationship between the product’s lifetime and stress variables. The method can be used for highly reliable products. |
| 27. | Conjugate Natural Convective Heat Transfer from Photovoltaic Cells on the Bottom Wall of a Horizontal Cabinet to Ambient Air Stream | | 國際會議<br>名稱：2011 International Conference on Fluid Dynamics and Thermodynamics Technologies<br>地點：South Kuta, Bali-Indonesia<br>日期：2011-04-01~03 | This study proposes a model to investigate the detailed behaviors of natural convective cooling of photovoltaic cells mounted discretely on the bottom wall of a horizontal cabinet. The numerical computation domain covers the cabinet and surrounding area, so that the temperature and velocity fields of the combined regions are solved simultaneously. Results show that the temperature differences among the photovoltaic cells can be up to 28% for all the investigated cases when $106 \leqq Ra \leqq 108$, $1000 \leqq Kef \leqq 6300$, Cx = 7.5 and N = 6. The maximum difference in hot spot temperatures of photovoltaic cells is about 26% among the cases with various Kef. |

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| 28. | Effect of Spectral Response on Energy Conversion Efficiency of Solar Cell | | 國際會議<br>名稱：7th International Conference on Concentrating Photovoltaic Systems<br>地點：Las Vegas, USA<br>日期：2011-04-04~06 | The change of triple-junction solar cell conversion efficiency under varied spectra was studied. By changing the intensity of incident spectrum and integrating with the spectral response data of InGaP/InGaAs/Ge triple-junction solar cell, we could recognize which layer was the current limiting cell and obtain its relationship between conversion efficiency. The current limiting cell was InGaAs middle cell initially when it was under AM1.5 simulated solar spectrum, and modulating the long wavelength intensity caused very limited variation on the short circuit current and conversion efficiency. Once the InGaP top cell became the current limiting cell, the conversion efficiency decreased drastically with reducing short wavelength intensity. We ascribed this decrease to the reduction of short circuit current. When it was InGaAs layer being the current limiting cell, the decrease of conversion efficiency was not sensitive to the spectrum as compared to the InGaP top cell. |
| 29. | On-site Measurement of a HCPV Module in NPUST | | 國際會議<br>名稱：2011 The International Conference on Green Technologies<br>地點：Taiwan<br>日期：2011-10-12~15 | The subject of study in this work is a 135 Wp high concentration photovoltaic module with Ⅲ-V solar cells. The module is currently installed in NPUST. Three equation forms for module temperature prediction were investigated. The simplest form predicts the module temperature quite well. Among these forms, the third form which takes into account the direct normal radiation yields the least error. The efficiency of the module is about 21% between 10:00 a.m. and 3:00 p.m. and the amount of power the module generates is linearly dependent on the electricity current. |
| 30. | Characteristics of Ti/Al/Ni/Au Ohmic Contacts on Ga-Doped ZnO Films | | 國際會議<br>名稱：International Electron Devices and Materials Symposium 2011 (IEDMS 2011)<br>地點：Taiwan<br>日期：2011-11-17~18 | Ti/Al/Ni/Au metal scheme is employed as the ohmic contact on n-type Ga-doped ZnO films. After 300 ℃ annealing, specific contact resistivity of 5.1×E-5 Ohm-cm and 2.6×E-7 Ohm-cm has been achieved on GZO films with carrier concentration of 5×E17 $cm^{-3}$ and 2.4×E20 $cm^{-3}$, respectively. The ohmic behavior could be attributed to the formation of Ti-O and Ni-O phases. However, after 500 ℃ annealing deterioration of contact is observed and is attributed to the oxidation of Al on the surface as well as the in-diffusion of Au to the metal-semiconductor interface. |
| 31. | Synthesis and characterization of (4,5-diaza-9,9'-spirobifluorene) functionalized donor/acceptor conjugated polymer for solar cell application | | 國際會議<br>名稱:2011 年 MRS Spring Meeting and Exhibit 會議<br>地點：San Francisco, California<br>日期：2011-04-25~29 | Two novel (4,5-diaza-9,9'-spirobifluorene) functionalized donor/ acceptor low bandgap conjugated polymers PZFDPP (K117) and PZFBTZ(K108) have been synthesized via Stille coupling. Their band gaps were determined by absorption spectroscopy and cyclic voltammetry to be ~1.5 eV and ~2.0 eV for K117 and K108 respectively. The pyridine moiety of the copolymer exhibited good affinity toward hydrophilic $TiO_2$ nanorods, so they were used to modify the surface of $TiO_2$ nanorods. The modified nanorods were blended with P3HT to fabricate hybrid solar cell. An increase of power conversion efficiency was observed at 2.6 times and 2.3 times for K108 and K117 respectively as compared with that of pyridine modified $TiO_2$ nanorods. The results are due to the reduced charge recombination. |

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| 32. | Ultrasonic spray deposition for production of organic solar cells | | 國際會議<br>名稱：國際亞洲材料大會<br>地點：<br>台北南港展覽館<br>日期：<br>2011-09-19~23 | In this study, we report the organic solar cells with spray coated active layers. Conventionally, the performance of organic solar cell is primarily influenced by the inherent film morphology of spin-coating polymer-blend active layers. In our work, the thickness and roughness of the spray-coated active layer were about 540 and 110 nm respectively, which is significantly different from that of the conventional polymer solar cell. However, the performance of the polymer solar cells based on poly(3-hexylthiophene):[6,6]-phenyl C61 butyric acid methyl ester (P3HT/PCBM) spray-coated using this deposition method deliver a power conversion efficiency of 2.6% is comparable to those of the polymer solar cell that are fabricated using the spin-coated method under identical conditions. Therefore, the cheap, simple and low material loss spray process to directly deposit thin films on flexible substrates from their solutions can be a potential technology to fabricate large area organic solar cells. |
| 33. | Surface modification of $TiO_2$ by (4,5-diaza-9,9'-spirobifluorene) functionalized donor/acceptor conjugated polymers for P3HT/ $TiO_2$ hybrid solar cell | | 國際會議<br>名稱：國際亞洲材料大會<br>地點：<br>台北南港展覽館<br>日期：<br>2011-09-19~23 | Two novel (4,5-diaza-9,9'-spirobifluorene) functionalized donor/ acceptor low bandgap conjugated polymers PZFDPP (K117) and PZFBTZ(K108) have been synthesized via Stille coupling. Their band gaps were determined by absorption spectroscopy and cyclic voltammetry to be ~1.5 eV and ~2.0 eV for K117 and K108 respectively. The pyridine moiety of the copolymer exhibited good affinity toward hydrophilic $TiO_2$ nanorods, so they were used to modify the surface of $TiO_2$ nanorods. The modified nanorods were blended with P3HT to fabricate hybrid solar cell. An increase of power conversion efficiency was observed at 2.6 times and 2.3 times for K108 and K117 respectively as compared with that of pyridine modified $TiO_2$ nanorods. The results are due to the reduced charge recombination. |
| 34. | Defects Aeduction of Amorphous Silicon Thin Film in Cyanide Solution Treatment | | 國際會議<br>名稱：4th IEEE International NanoElectronics Conference (INEC)<br>地點：<br>桃園長庚大學<br>日期：<br>2011-06-21~24 | The KCN aqueous solution is used as the cyanide treatment for the reduction of defect states in amorphous silicon (a-Si:H) thin films. The concentration of the KCN aqueous solution and immersing time are probed to find the optimum condition to improve a-Si:H thin film. After cyanide treatment, the combination between silicon atoms and cyanide ions is confirmed by observing the binding energy of N 1s through x-ray photoelectron spectroscopy (XPS) measurement in 395eV ~ 406 eV. In order to determine the penetrating depth of cyanide ions into a-Si:H thin film, the XPS measurement is also applied to detect the N 1s signal after etching processes ; the N 1s signal can be detected from surface to the depth of 15 nm. Through the measurement of low temperature cathodoluminescence (CL), higher concentration KCN treatment makes stronger radiation intensity indicates that the reduction of defect states in a-Si:H thin films by the cyanide ions. The ratio between photo-current and dark-current is maximum when a-Si:H thin film is immersed in 0.4 M KCN aqueous solution in two minutes. |

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| 35. | The Study Status of Thin Film Epitaxial Silicon Solar Cells at INER | | 國際會議<br>名稱：TACT 2011 International Thin Films Conference<br>地點：<br>屏東墾丁<br>日期：<br>2011-11-20~23 | Thin film epitaxial silicon solar cells are considered potentially viable alternatives to low-cost, low efficiency amorphous silicon solar cells as well as high-cost, high-efficiency bulk crystalline silicon solar cells. This work is aimed at reporting on the study of thin film epitaxial silicon solar cells at the Institute of Nuclear Energy Research (INER) in Taiwan. The material selected for the substrate is inexpensive ＜ 5N purity Upgraded Metallurgical Grade Silicon (UMG-Si), which is considered too “dirty” to be suitable for solar cell production directly. A home-made 2-inch vacuum-free Atmospheric Pressure Chemical Vapor Deposition (APCVD) system is used. In-situ HCl gas gettering of a 4×4cm$^2$ UMG-Si substrate is first performed with subsequent deposition of a ~20μm thick high quality epitaxial layer on top of the gettered UMG-Si substrate at 1150℃. The resultant product, often referred to as Epitaxial Wafer Equivalent (EpiWE), 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 13.18% is achieved at present. |
| 36. | An Innovative Method of Nickel Plating on n/p Diode | | 國際會議<br>名稱：TACT 2011 International Thin Films Conference<br>地點：<br>屏東墾丁<br>日期：<br>2011-11-20~23 | The studies of nickel plating by using an electroplating and electroless plating methods have been widely discussed due to its multiple applications. All current plating processes mainly use an applied current or the reducing agent to reduce metal ions from a solution. In this study, a new mechanism of nickel plating process on n/p diode in the plating solution is displayed. Using the characteristic of n/p diode that has a built-in potential, the electrons and holes will generate in the diode when illuminated, meanwhile, they will flow to the opposite direction separately under the action of built-in potential. The nickel film is plated on the n-type surface by the reduction of photoelectron flow, and there is no any reducing agent used in this processes. This innovative approach can simplify of the traditional electroplating process. It can also be applied to silicon solar cells of the front contact Ni/Cu plating. |
| 37. | Study and Characterization of Advanced $SiN_x$ Film with Low Frequency -PECVD | | 國際會議<br>名稱：TACT 2011 International Thin Films Conference<br>地點：<br>屏東墾丁<br>日期：<br>2011-11-20~23 | In this paper, the relations of chemical and field-effect passivation are studied. A low frequency plasma enhanced chemical vapor deposition system is used to deposit $SiN_x$:H film at the temperature of 300℃ and a frequency of 50 kHz with 40W power, and then the sample is annealed. The effective minority carrier lifetime ($\tau_{eff}$), the fixed charge ($Q_f$), and IR spectrum are measured. The study shows that the $Q_f$ is decreased at the post-annealing process, but the $\tau_{eff}$ is increased by the diffusion of hydrogen, and thus the annealing process plays a crucial role in passivation mechanism. |

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| 38. | Effect of Quantum Efficiency on Short Current of MJ compound Solar Cell | | 國內會議<br>名稱：2011 第九屆微電子技術發展與應用研討會<br>地點：海洋科技大學<br>日期：2011-05-20 | For Ⅲ-V group solar cells, one way of improving conversion efficiency is the use of multi-junction solar cells. These devices have the advantage of converting the solar energy more efficiently because the conversion of solar energy is realized by using several subcells with their respective conversion range specified from the strongest band of solar spectrum. However, the drawback is that multi-junction solar cells are known to be sensitive to the solar spectrum variation. As known, the solar spectrum changes seasonally and daily, it also easily varies due to the changes in air mass and atmospheric composition. Therefore for multi-juction solar cells any spectrum changes would result in the problem of current mismatch and thus reduce the short circuit current because the top, middle and bottom subcells are connected in series . However, it is impossible for a multi-junction solar cell to derive the short-circuit current of each subcell directly from the I-V characteristics measurement. Fortunately, the spectral response (SR) measurement can provide the data of each subcell. SR data are used for various purposes and in different ways. To interpret SR data in regard to the optimization of device fabrication, absolute data are often needed. In this paper, the effects of spectral variation on the performance of GaInP/(In)GaAs/Ge triple-junction solar cell are explored. The relationship between the solar spectrum and the SR of solar cell is examined systematically. Through the knowledge of the corresponding variation in short circuit current due to the change of SR for each subcell of multi-junction solar cell, the current limiting subcell can be resolved and the conversion efficiency of the multi-junction solar cell can be improved in a more effective way. |
| 39. | 應用虛擬實境技術於高聚光型太陽光發電廠建置之研究 | | 國內會議<br>名稱：第十二屆電子化企業經營管理理論暨實務研討會<br>地點：大葉大學<br>日期：2011-05-28 | 選擇高聚光型太陽光發電系統建置場址，需依照自然資源、生態環境、社會人文、建置成本等因素進行通盤性考量，才能做出最佳決策，提高選址的正確性與可靠性。本研究旨在提出一個以分析層級演算法及貝氏信心網路演算法為基礎的輔助選址模式，呈現最佳決策建議。另外，使用虛擬實境技術的特性，開發互動式高聚光型太陽光發電廠場景及影像動態模擬系統，利用程式設計、影像處理、3D 物件繪圖等技術，模擬太陽移動軌跡及太陽光追蹤系統之運作。本研究之模擬系統，擁有高度互動性與參與感的開發平台，設計人員可模擬於不同的時間、地點或條件下，觀看模擬之建置效果。本研究提供最有效率的設計流程與方法，達到即時、互動、多樣化設計功能，減少不必要的錯誤，縮短設計時間、提高建置效率與降低開發成本。 |
| 40. | ZnO 熱聲子效應 | | 國內會議<br>名稱：第 29 屆光譜技術與表面科學研討會<br>地點：救國團溪頭青年活動中心<br>日期：2011-07-21~23 | 本文利用光激螢光光譜來討論氧化鋅磊晶層的載子鬆弛機制。實驗中獲得在不同電壓下的電子氣體溫度變化，熱電子損失能量鬆弛至導帶的主要機制是以電子-光學聲子和電子-聲學聲子交互作用的理論模型來解釋。我們發現氧化鋅磊晶層在低溫時，可以觀察到氧化鋅的熱電子損失能量是以聲學聲子散射為主。隨溫度上升，光學聲子散射將大於聲學聲子散射。 |

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| 41. | 利用電激發螢光定義 p-i-n 砷化鎵 | | 國內會議<br>名稱：第 29 屆光譜技術與表面科學研討會<br>地點：救國團溪頭青年活動中心<br>日　　期：2011-07-21~23 | 利用電激螢光實驗探討不同本質層（i-layer）厚度的砷化鎵太陽能電池。量測砷化鎵太陽能電池的電激螢光和外量子效率，並使用互換定理，可計算出非輻射複合開路電壓與不同本質層（i-layer）厚度的關係。隨著本質層厚度的增加，發現太陽電池的轉換效率有下降的趨勢。當本質層厚度為 1 nm 時，其非輻射複合開路電壓為最低。 |
| 42. | 利用光激螢光量測 p-i-n 型砷化鎵太陽能電池 | | 國內會議<br>名稱：第 29 屆光譜技術與表面科學研討會<br>地點：救國團溪頭青年活動中心<br>日　　期：2011-07-21~23 | 利用光激螢光技術量測單接面砷化鎵太陽能電池的接面溫度，此技術運用不同脈衝寬度的雷射激發以及光激螢光的光譜對於溫度的依賴性，duty cycle 會使得光激螢光的能量有明顯變異，可推得與接面溫度的相關連性。變化 duty cycle 從 10%到 75%導致單接面砷化鎵太陽能電池的接面溫度上升增量 2.9K。研究證實接面層的載子溫度是可用不同脈衝寬度的雷射激發的光激螢光光譜量測。 |
| 43. | Optimization of Antireflection Coating Design for Ⅲ-Ⅴ Multijunction Solar Cell | | 國內會議<br>名稱：第 29 屆光譜技術與表面科學研討會<br>地點：救國團溪頭青年活動中心<br>日　　期：2011-07-21~23 | Different types of antireflection coating (ARC) designs were applied on Ⅲ-Ⅴ multijunction solar cell device in this study. Through the refined simulation for reflectance spectrum of Ⅲ-Ⅴ multijunction solar cell to acquire the optimal ARC design for solar cells, and deposited onto real Ⅲ-Ⅴ multijunction solar cells device. Spectral response and I-V measurement were used for obtaining external quantum efficiency and opto-electrical characteristic. The results illustrated the solar cell performance was effected by reflectance spectrum of solar cell device. It also shows that ARC can be used for optimizing the current matching between different tandem cells by different designs. Among the samples, the Jsc performed 32.2 % enhancement and efficiency can achieved 27.3% enhancement as well with the optimal design of ARC for Ⅲ-Ⅴ multijunction solar cell under 476X geometrical concentration. |

(二) 透過與學界合作促進國內相關研究單位交流，共培育博士研究生 3 人，碩士研究生 10 人，培育國內太陽光發電領域的人才。合作工作內容如下所述：

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## 四、社會影響(民生社會發展、環境安全永續) (權重 5 %)

(一) 本計畫目的在研究開發低成本與高效率之新型太陽能發電系統，其研發結果與未來影響，將包括減緩地球環境的變遷，提升國家能源安全與自產比例，及永續綠色能源的需求等。

(二) 太陽光電為未來再生能源之主流，具減碳特性，而第三代可撓性量子點/高分子太陽電池，不但具成本低之優點，其產品可更廣泛結合於汽車、建物、衣服及周遭環境上，未來本所開發之環保型（不具毒性物質）之太陽電池更易會民生相結合，其普及性應較第一及第二代太陽能電池廣。

(三) 研究與開發具有低成本、低能耗與低碳製程之提純冶金級矽太陽電池產品，具有使太陽電池應用早日普及化，降低環境污染，及增進人類生存環境與生活品質的提升等功能。

## 五、其它效益(科技政策管理及其它) (權重 5 %)

(一) 參與 SEMI HCPV SIG 2011 Regular Meeting，負責 SEMI「HCPV 發展推動小組」之標準與認證工作項目，旨在協助制定國內 HCPV 產業標準及推動國際認證，涵蓋(1)Module Qualification，(2)CPV Performance Rating，(3)Tracker Qualification，(4)CPV Safety Qualification，及(5)Cell Qualification 等項目。

(二) 核能研究所於 2011 年度參與國內舉辦之太陽光電相關展覽，除響應政府推動節能減碳政策，展示核能研究所研發成果，達成教育與宣導功能，並引導廠商投入 HCPV 產業。

| 日期 | 展覽名稱 | 主辦單位 | 地點 | 展出型態 | 展示目的/效益 |
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| 2011 年 6 月 14~16 日 | 2011 年光電展 | 光電協進會 | 台北南展館 | 海報、實體、DM 與現場解說 | 推廣核能研究所 HCPV技術，冀協助相關業者加強產製能力。 |
| 2011 年 9 月 29~10 月 2 日 | 第 7 屆「台北國際發明暨技術交易展 | 中華民國對外貿易發展協會 | 台北世貿一館館 | 海報、實體、DM 與現場解說 | 推廣核能研究所研發成果，以期協助產業界邁向技術商品化。 |
| 2011 年 10 月 5~7 日 | PV Taiwan 2011 | 外貿協會會 | 台北世貿一館館 | 海報、實體、DM 與現場解說 | 提升核能研究所之能見度，推廣HCPV技術。 |
| 2011 年 11 月 23 日 | 桃園縣綠能科技產業創新研發論壇 | 國防部軍備局中山科學研究 | 桃園縣政府 | 海報、實體與現場解說 | 推廣核能研究所之計畫成果，落實於民生應用。 |

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| | | 院、桃園縣政府工商發展投資策進會、SBIR暨傳統產業計畫推動辦公室、行政院原子能委員會核能研究所 | | | |

## 柒、與相關計畫之配合

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# 附錄一、佐證資料表

## 計畫名稱：太陽光發電系統技術發展

【A 學術成就表】

| 中文題名 | 第一作者 | 發表年(西元年) | 文獻類別 | 引用情形 | 獲獎情形 | 論文出處 |
|---|---|---|---|---|---|---|
| Visible luminescence properties of $(Ga_{1-x}Zn_x)(N_{1-x}O_x)$ solid solution (x=0.22) | | 2011 | d | N | N | Journal of Applied Physics，109 期，頁 73506 |
| Measuring the Junction Temperature of GaInP/GaInAs/Ge Multijunction Solar Cells Using Photoluminescence | | 2011 | d | N | N | Japanese Journal of Applied Physics，卷 50，頁 092302-1~5 |
| Structural and optical characteristics of γ-$In_2Se_3$ nanorods grown on Si substrates | | 2011 | d | N | N | Journal of Nanomaterials，卷 2011，期 10，頁 1~5 |
| High concentration and homogenized Fresnel lens without secondary optics element | | 2011 | d | N | N | Optics Communications，卷 284，期 19，頁 4283~4288 |
| Efficient Two-stage Annealing and Structural Evolution of Nanoorganized Bulk Heterojunction Solar Cell Studied by Grazing-Incidence Small Angle X-ray Scattering | | 2011 | d | N | N | J. Am. Chem. Soc. 卷 133, 頁 13064–13073, 2011 |
| Oxygen sensors made by monolayer graphene under room temperature | | | d | | | submitted to Applied Physics Letters |
| New Packing Structure of Concentration Solar Receiver | | | d | | | submitted to Japanese Journal of Applied Physics |
| The logic-based supervisor control for sun-tracking system of 1MW HCPV demo plant: study case | | | d | | | submitted to Sensors |
| A Study of On-line Diagnostic Technology on HCPV System Using Fuzzy FMEA | | | d | | | submitted to Reliability Engineering & System Safety |
| Evaluation of Installing Integrated sustainable Energy | | | d | | | submitted to Energy Policy |

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| System in Taiwan | | | | | | |
| Structural and Optical Characterization of ZnSeO Films Grown on GaAs by Molecular Beam Epitaxy | | | d | | | submitted to Journal of Applied Physics |
| Controllability Enhancements of HCPV Array under Wind Loads using Adaptive Neural Fuzzy Inference Systems | | | d | | | submitted to Reliability Engineering & System Safety |
| Numerical Investigation of High-Concentration Photovoltaic Module Heat Dissipation | | | d | | | submitted to Renewable Energy |
| Synthesis, Morphology and Physical Properties of Multi-walled Carbon Nanotube/biphenyl Liquid Crystalline Epoxy Composites | | | d | | | submitted to Carbon (accepted) |
| Small and Wide angle X-ray Scattering Characterization of Bulk Heterojunction Polymer Solar Cells with Different Fullerene Derivatives | | | d | | | submitted to The Journal of Physical Chemistry |
| Formation Mechanism and Kinetics of Organic-Capped Anatase $TiO_2$ Nanorod Studied by Small-Angle X-Ray Scattering | | | d | | | submitted to Journal of the American Chemical Society |
| Self-Vertical Phase Separation Study of Nanoparticle/Polymer Solar Cells by Introducing Fluoro-Containing Additives | | | d | | | Submitted to Applied physics letters |
| Synthesis and Characterization of (4,5-diaza-9,9'-spirobifluorene) Functionalized Donor/acceptor Conjugated Oligomers for Hybrid Solar Cell Application | | | d | | | Submitted to Chemical Communications |
| n/p 二極體之新型鍍鎳技術 | | | d | | | Submitted to Surface & Coatings Technology |
| 核能研究所薄膜磊晶矽太陽電池之研究 | | | d | | | Submitted to Thin Solid Films |
| 低頻 PECVD 製備氮化矽薄膜之研究與特性鑑別 | | | d | | | Submitted to Surface & Coatings Technology |
| 以 UMG-Si 作為基板,以 Ni 作為催化劑研製次微米線之太陽電池 | | | d | | | Submitted to Journal of the Electrochemical Society |

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| 以常壓式金屬有機化學氣相沉積法於矽基板上生長砷摻雜 氧化鋅薄膜之研究 | | | d | | | Submitted to Physica Status Solidi A-Applications and Materials Science |
| 非晶矽薄膜氟化處理 | | | d | | | Submitted to International Journal of Nanotechnology |
| 太陽光追蹤器開發 | | 2011 | b | N | N | 台電工程月刊，期 758，頁 90~ 96 |
| Accelerated Test Method and Statistics Model Analysis of degradation Performance for PV Module Lifetime Prediction. | | 2011 | f | N | N | 2011 Photovoltaic Module Reliability Workshop (PVMRW) |
| Conjugate Natural Convective Heat Transfer from Photovoltaic Cells on the Bottom Wall of a Horizontal Cabinet to Ambient Air Stream | | 2011 | f | N | N | 2011 International Conference on Fluid Dynamics and Thermodynamics Technologies |
| Effect of Spectral Response on Energy Conversion Efficiency of Solar Cell | | 2011 | f | N | N | 7th International Conference on Concentrating Photovoltaic Systems |
| On-site Measurement of a HCPV Module in NPUST | | 2011 | f | N | N | 2011 The International Conference on Green Technologies |
| Characteristics of Ti/Al/Ni/Au Ohmic Contacts on Ga-Doped ZnO Films | | 2011 | f | N | N | International Electron Devices and Materials Symposium 2011 (IEDMS 2011) |
| Synthesis and Characterization of (4,5-diaza-9,9'-spirobifluorene) Functionalized Donor/acceptor Conjugated Polymer for Solar Cell Application | | 2011 | f | N | N | 2011 年 MRS Spring Meeting and Exhibit 會議 |
| Ultrasonic Spray Deposition for Production of Organic Solar Cells | | 2011 | f | N | N | 2011 年國際材料亞洲大會(IUMRS-ICA)會議 |
| Surface Modification of $TiO_2$ by (4,5-diaza-9,9'-spirobifluorene) Functionalized Donor/acceptor Conjugated Polymers for P3HT/ $TiO_2$ Hybrid Solar Cell | | 2011 | f | N | N | 2011 年國際材料亞洲大會(IUMRS-ICA)會議 |
| 非晶矽薄膜氟化處理 | | 2011 | f | N | N | 4th IEEE International |

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| | | | | | | NanoElectronics Conference (INEC) |
| 核能研究所薄膜磊晶矽太陽電池之研究 | | 2011 | f | N | N | TACT 2011 International Thin Films Conference |
| 低頻 PECVD 製備氮化矽薄膜之研究與特性鑑別 | | 2011 | f | N | N | TACT 2011 International Thin Films Conference |
| n/p 二極體之新型鍍鎳技術 | | 2011 | f | N | N | TACT 2011 International Thin Films Conference |
| Effect of Quantum Efficiency on Short Current of MJ Compound Solar Cell | | 2011 | e | N | N | 2011 第九屆微電子技術發展與應用研討會 |
| 應用虛擬實境技術於高聚光型太陽光發電廠建置之研究 | | 2011 | e | N | N | 第十二屆電子化企業經營管理理論暨實務研討會 |
| ZnO 熱聲子效應 | | 2011 | e | N | N | 第 29 屆光譜技術與表面科學研討會 |
| 利用電激發螢光定義 p-i-n 砷化鎵 | | 2011 | e | N | N | 第 29 屆光譜技術與表面科學研討會 |
| 利用光激螢光量測 p-i-n 型砷化鎵太陽能電池 | | 2011 | e | N | N | 第 29 屆光譜技術與表面科學研討會 |
| Optimization of Antireflection Coating Design for Ⅲ-V Multijunction Solar Cell | | 2011 | e | N | N | 第 29 屆光譜技術與表面科學研討會 |

註：文獻類別分成 a 國內一般期刊、b 國內重要期刊、c 國外一般期刊、d 國外重要期刊、e 國內研討會、f 國際研討會、g 著作專書；引用情形分成 Y1 被論文引用、Y2 被專利引用、N 否；獲獎情形分成 Y 有獲獎、N 否；論文出處列出期刊名稱，卷期，頁(如科學發展月刊，409 期，頁 6-15)

**【B 研究團隊表】**

| 團隊名稱 | 團隊所屬機構 | 團隊性質 | 成立時間(西元年) |
|---|---|---|---|
| 「Ⅲ-V 族多接面太陽電池的轉換效率機制」研究團隊 | 核研所與中原大學 | b | 2011 |
| 「新式 HCPV 太陽電池模組散熱機制研究與系統最佳化設計」研究團隊 | 核研所與交通大學 | b | 2011 |
| 「太陽光發電影像追蹤技術研發」研究團隊 | 核研所與成功大學 | b | 2011 |
| 「資料探勘技術在 HCPV 系統上之應用」研究團隊 | 核研所與萬能科技大學 | b | 2011 |
| 「太陽能電池模組溫度量測與預測技術建立」研究團隊 | 核研所與屏東科技大學 | b | 2011 |

| | | | |
|---|---|---|---|
| 「HCPV 太陽能發電模組效能與耐久性實地測試評估」研究團隊 | 核研所與屏東科技大學 | b | 2011 |
| 「高效率奈米結構量子點高分子太陽能電池之研究」研究團隊 | 核研所與台灣大學 | b | 2011 |
| 「新型冶金級矽太陽電池技術(PERL、SHJ-IBC)研究與開發」 | 核研所與中原大學 | b | 2011 |

註：團隊性質分成 a 機構內跨領域合作、b 跨機構合作、c 跨國合作、d 研究中心、e 實驗室

**【C 培育人才表】**

| 姓名 | 學歷 | 機構名稱 | 指導教授 |
|---|---|---|---|
| ○○○ | b | 中原大學物理研究所 | |
| ○○○ | b | 中原大學電子工程系 | |
| ○○○ | a | 國立成功大學航太所 | |
| ○○○ | b | 國立成功大學航太所 | |
| ○○○ | b | 屏東科技大學 | |
| ○○○ | b | 屏東科技大學 | |
| ○○○ | b | 中原大學電子工程系 | |
| ○○○ | b | 中原大學電子工程系 | |
| ○○○ | b | 中原大學物理系 | |
| ○○○ | a | 國立台灣大學材料科學與工程學系暨研究所 | |
| ○○○ | b | 國立台灣大學材料科學與工程學系暨研究所 | |
| ○○○ | a | 中原大學電子工程研究所 | |
| ○○○ | b | 中原大學電子工程研究所 | |

註：學歷分成 a 博士、b 碩士

**【D 研究報告表】**

| 報告名稱 | 作者姓名 | 出版年(西元年) | 出版單位 |
|---|---|---|---|
| 變溫霍爾量測實驗 | 涉個資內容，故不公開 | 2011 | 核研所 |
| 太陽電池上子電池於陰極發光譜量測之溫度效應研究 | | 2011 | 核研所 |
| 含銅正型砷化鎵歐姆接觸電極電性研究及其應用 | | 2011 | 核研所 |
| 三五族太陽電池抗反射鍍膜設計 | | 2011 | 核研所 |

| | | | |
|---|---|---|---|
| 與製鍍 | | | |
| 太陽光發電系統之遮蔽效應 | | 2011 | 核研所 |
| MW 級路竹 HCPV 示範場聚光模組研發與製作 | | 2011 | 核研所 |
| Analysis of Abnormal Characteristics of III-V Compound/III-V 族多接面太陽電池於聚光下異常特性分析 | | 2011 | 核研所 |
| 聚光型太陽電池模組均光器研究 | | 2011 | 核研所 |
| 聚光型太陽電池接收器各式基板比較 | | 2011 | 核研所 |
| 聚光型太陽電池模組鹽霧測試 | | 2011 | 核研所 |
| 高聚光太陽能發電系統之遮蔽效應分析 | | 2011 | 核研所 |
| 20 kW 級太陽光追蹤器結構設計與分析 | | 2011 | 核研所 |
| 15 kW 級太陽光追蹤器模組支架結構設計與分析 | | 2011 | 核研所 |
| 高精度小型太陽位置感測器設計報告 | | 2011 | 核研所 |
| 大型太陽光追蹤控制系統建置 | | 2011 | 核研所 |
| 嵌入式前端擷取系統在 HCPV 系統上的應用 | | 2011 | 核研所 |
| 太陽電池模組溫度係數量測技術 | | 2011 | 核研所 |
| Ⅲ-V 族太陽電池磊晶剝離技術開發 | | 2011 | 核研所 |
| Ⅲ-V 族多接面太陽能電池的轉換效率機制研究 | | 2011 | 核研所 |
| HCPV 太陽能發電模組效能與耐久性實地測試評估 | | 2011 | 核研所 |
| 太陽能電池模組溫度量測與預測技術建立 | | 2011 | 核研所 |
| 以小角及廣角散射分析混摻不同富勒烯衍生物之太陽能電池 | | 2011 | 核研所 |
| 合成與鑑定其異靛藍組成之導電 | | 2011 | 核研所 |

涉個資內容，故不公開

| | | | |
|---|---|---|---|
| 高分子延伸物並應用於高分子太陽能電池元件 | | | |
| 利用超音波噴塗與噴墨印刷技術製備有機太陽電池 | | 2011 | 核研所 |
| 利用超音波噴塗進行太陽能電池主動層元件製備及大面積製程開發 | | 2011 | 核研所 |
| 核能研究所薄膜磊晶矽太陽電池之發展 | | 2011 | 核研所 |
| 先進鈍化氮化矽薄膜材料的製備與分析 | | 2011 | 核研所 |
| 以鎳作催化劑在提純冶金級矽基板上製作奈米線太陽能電池 | | 2011 | 核研所 |
| n/p 二極體之新型鍍鎳技術 | | 2011 | 核研所 |
| 利用射頻濺鍍系統沉積摻鋁氧化鋅薄膜之特性分析 | | 2011 | 核研所 |
| 新型精練冶金級矽太陽電池技術(PERL、SHJ-IBC)研究與開發 | | 2011 | 核研所 |

涉個資內容，故不公開

**【E 學術活動表】**

| 研討會名稱 | 性質 | 舉辦(起-迄)日期 (YYYY/MM/DD) | 主/協辦單位 |
|---|---|---|---|
| 聚光型太陽光電系統檢驗標準研討會 | b | 2011/06/29 | 核研所 |
| Ⅲ-V 族太陽能電池先進技術研討會 | a | 2011/09/20 | 核研所 |

註：性質分成 a 國內研討會、b 國際研討會、c 兩岸研討會

**【G 智財資料表】**

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【H 技術報告表】

| 報告名稱 | 作者姓名 | 出版年(西元年) | 出版單位 |
|---|---|---|---|
| 傅立葉轉換紅外線光譜儀中文操作手冊 | 涉個資內容，故不公開 | 2011 | 核研所 |
| 電激光譜量測原理說明與應用於太陽電池之分析 | | 2011 | 核研所 |
| Fresnel 透鏡表面鍍易潔膜對 HCPV 模組效率之影響 | | 2011 | 核研所 |
| 矽膠玻璃聚光透鏡合作開發暨技術授權結案報告 | | 2011 | 核研所 |
| Helios 3198® 太陽電池模組模擬測試平台操作手冊 | | 2011 | 核研所 |
| 路竹示範場電力系統維護及改善 | | 2011 | 核研所 |
| 微型換流器應用評估 | | 2011 | 核研所 |
| 大型太陽光追蹤控制系統軟體設計 | | 2011 | 核研所 |
| HCPV 網頁監測系統更新軟體設計文件 | | 2011 | 核研所 |
| 太陽電池量測系統操作手冊 | | 2011 | 核研所 |
| 高聚光太陽光示範場運轉維護管理 | | 2011 | 核研所 |
| 超音波噴塗機操作手冊 | | 2011 | 核研所 |

【I 技術活動表】

| 技術論文名稱 | 研討會名稱 | 性質 | 舉辦(起-迄)日期 (YYYY/MM/DD) | 主/協辦單位 |
|---|---|---|---|---|
| Effect of Quantum Efficiency on Short Current of MJ compound Solar Cell | 第九屆微電子技術發展與應用研討會 | a | 2011/05/20 | 海洋科技大學 |
| 應用虛擬實境技術於高聚光型太陽光發電廠建置之研究 | 第十二屆電子化企業經營管理理論暨實務研討會 | a | 2011/05/28 | 大葉大學 |
| ZnO 熱聲子效應 | 第 29 屆光譜技術與表面科學研討會 | a | 2011/07/21-2011/07/23 | 交通大學 |
| 利用電激發螢光定義 p-i-n 砷化鎵 | 第 29 屆光譜技術與表面科學研討會 | a | 2011/07/21-2011/07/23 | 交通大學 |
| 利用光激螢光量測 p-i-n 型砷化鎵太陽能電池 | 第 29 屆光譜技術與表面科學研討會 | a | 2011/07/21-2011/07/23 | 交通大學 |
| Optimization of antireflection coating design for Ⅲ-V | 第 29 屆光譜技術與表面科學研討會 | a | 2011/07/21-2011/07/23 | 交通大學 |

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|---|---|---|---|---|
| multijunction solar cell | | | | |
| Accelerated test method and statistics model analysis of degradation performance for PV module lifetime prediction. | 2011 Photovoltaic Module Reliability Workshop (PVMRW) | b | 2011/02/16-17 | NREL |
| Conjugate Natural Convective Heat Transfer from Photovoltaic Cells on the Bottom Wall of a Horizontal Cabinet to Ambient Air Stream | 2011 International Conference on Fluid Dynamics and Thermodynamics Technologies | b | 2011/04/01-2011/04/03 | IEEE |
| Effect of Spectral Response on Energy Conversion Efficiency of Solar Cell | 7th International Conference on Concentrating Photovoltaic Systems | b | 2011/04/04-2011/04/06 | NREL |
| On-site Measurement of a HCPV Module in NPUST | 2011 The International Conference on Green Technologies | b | 2011/10/12-2011/10/15 | 屏東科技大學 |
| Characteristics of Ti/Al/Ni/Au Ohmic Contacts on Ga-Doped ZnO Films | International Electron Devices and Materials Symposium 2011 (IEDMS 2011) | b | 2011/11/17-2011/11/18 | 中央大學 |
| Synthesis and characterization of (4,5-diaza-9,9'-spirobifluorene) functionalized donor/ acceptor conjugated polymer for solar cell application | MRS Spring Meeting and Exhibit | b | 2011/4/25-2011/4/29 | Materials Research Society |
| Ultrasonic spray deposition for production of organic solar cells | 2011 年國際材料亞洲大會(IUMRS-ICA)會議 | b | 2011/9/19-2011/9/22 | 中國材料學會 |
| Surface modification of $TiO_2$ by (4,5-diaza- 9,9'-spirobifluorene) functionalized donor/ acceptor conjugated polymers for P3HT/ $TiO_2$ hybrid solar cell | 2011 年國際材料亞洲大會(IUMRS-ICA)會議 | b | 2011/9/19-2011/9/22 | 中國材料學會 |
| Defects Aeduction of Amorphous Silicon Thin Film in Cyanide Solution Treatment | 4th IEEE International NanoElectronics Conference (INEC) | a | 2011/6/21-2011/6/24 | 長庚大學電子工程學系 |
| Study on thin film epitaxial silicon solar cells at INER | TACT 2011 International Thin Films Conference | b | 2011/11/20-2011/11/23 | 台灣鍍膜科技協會 |
| An Innovative Method of Nickel Plating on n/p Diode | TACT 2011 International Thin Films Conference | b | 2011/11/20-2011/11/23 | 台灣鍍膜科技協會 |
| Study and Characterization of Advanced $SiN_x$ Film with Low Frequency -PECVD | TACT 2011 International Thin Films Conference | b | 2011/11/20-2011/11/23 | 台灣鍍膜科技協會 |

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**附錄二、佐證圖表**

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