INER-F0898 **INER-F0898**

出國報告（出國類別：其他）

赴美國參加「第 39 屆國際先進陶瓷與複合材料會議及展覽會」出國報告

服務機關：核能研究所
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派赴國家：美國
出國期間：104 年 1 月 23 日~104 年 2 月 2 日
報告日期：104 年 3 月 4 日

摘 要

核能研究所物理組劉建國博士與化工組林泰男博士奉派於 104/01/23~02/02 赴美國佛羅里達州代托納比奇市(Daytona Beach, FL)，參加第 39 屆國際先進陶瓷與複合材料會議及展覽會(The 39th International Conference and Exposition on Advanced Ceramics and Composites, ICACC’15)暨第 12 屆國際固態氧化物燃料電池材料、科學與技術研討會(12th International Symposium on Solid Oxide Fuel Cells (SOFC): Materials, Science and Technology, 12th IS-SOFC-MST)，並分別進行論文“Electrical and Microstructural Evolutions of $La_{0.67}Sr_{0.33}MnO_3$ Coated Ferritic Stainless Steels after Long-term Aging at 800°C”及“Fabrication of the Anode-supported Solid Oxide Fuel Cell with Composite Cathodes and the Performance Evaluation upon Long-term Operation”口頭發表。本屆會議計分 6 日進行，包括 6 項聚焦議程(Focused session)，以及 13 項專題研討會(Symposium)，其中第 12 屆國際固態氧化物燃料電池材料、科學與技術研討會，為國際發表 SOFC 最新研究進展之最重要會議之一，探討主題包括：SOFC 與 SOEC 之現狀與展望、SOFC 與 SOEC 材料、連接板與鍍膜、表面與界面反應、氧離子與質子混和導體、電性及機性可靠度、電化學效能與穩定性、劣化機制及模擬、新穎製程及設計等。本屆研討會發表多篇論文關於固態氧化物電池(Solid Oxide Cell, SOC)學理及實驗之研究，利用現有之 SOFC 技術或產品，進行逆反應探討固態氧化物電解電池(Solid Oxide Electrolysis Cell, SOEC)效能及變化機制，並改進電極材料之高溫抗氧化還原穩定性。固態氧化物電池系統不但可做為發電，亦可結合其他再生能源(如風力、太陽能等)做為儲能之應用，具極大潛力成為未來具全功能及抑低碳排放之新能源關鍵技術。核研所已建置完整之 SOFC 研發能量，可依此作為基礎，積極投入 SOEC 相關材料及系統之研發及測試。由美國陶瓷學會所主辦之此一會議，無論於研討內容及論文投稿與審核過程，均相當具學術性及嚴謹性，參與會議對於促進國際學術交流與提升技術水準，展現研發成果，以及對於研究創新的啟發，均有極大之正面效益。

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一、目的

美國陶瓷學會(The American Ceramic Society, ACerS)固定於每年 1 月下旬，在美國佛羅里達州代托納比奇市(Daytona Beach, Florida)舉辦「國際先進陶瓷及複合材料會議及展覽會」(International Conference and Exposition on Advanced Ceramics and Composites, ICACC)，此會議為國際研究陶瓷與複合材料領域之最重要會議之一。第 1 屆國際先進陶瓷及複合材料會議及展覽會於 1977 年舉辦，至本屆(ICACC'15)已為第 39 屆，本屆會議於 2015 年 1 月 25~30 日舉行，來自全球相關領域之專家學者齊聚一堂發表論文及交換研究心得，研討主題包括：陶瓷與複材機性與效能、先進陶瓷鍍膜、固態氧化物燃料電池、裝甲陶瓷、次世代生醫陶瓷與複材、能源轉換與儲存先進材料、奈米結構材料、先進製程與製造技術、多孔陶瓷、虛擬材料設計與陶瓷基因組、先進材料與創新製程、極端環境應用材料、永續核能先進陶瓷與複材等領域之尖端研究成果。本次大會中之第 12 屆國際固態氧化物燃料電池材料、科學與技術研討會(12^{th} IS-SOFC-MST)，為國際探討及發表 SOFC/SOEC 最新研究進展之最重要會議之一，探討主題例如：SOFC 與 SOEC 之現況與展望、SOFC 與 SOEC 材料、連接板與鍍膜、表面與界面反應、氧離子與氫質子混和導體、電性及機性可靠度、電化學效能與穩定性、劣化機制及模擬、新穎製程及設計等等，與本所積極研發之 SOFC/SOEC 關鍵材料及系統整合技術有重要之關聯性。

核研所開發高效率固態氧化物燃料電池及發電系統相關技術，從電池單元研製到發電系統組裝測試，成效顯著並受到國際肯定，本屆會議持續邀請本所及 SOFC 計畫主持人李瑞益博士為 12^{th} IS-SOFC-MST 之籌組單位及籌組委員(附錄一)。此外，本所劉建國博士與林泰男博士分別投稿本屆會議論文"Electrical and Microstructural Evolutions of $La_{0.67}Sr_{0.33}MnO_3$ Coated Ferritic Stainless Steels after Long-term Aging at 800°C"及"Fabrication of the Anode-supported Solid Oxide Fuel Cell with Composite Cathodes and the Performance Evaluation upon Long-term Operation"獲接受(附錄二、三)，並被排定為口頭論文發表(附錄四、五)。因此，派員參加本屆會議並發表論文，除為達成國際性學術研討會義務，以及彰顯本所於固態氧化物燃料電池相關領域研發成果之外，並可藉由會議平台之討論瞭解國際最新之相關研發現況，尋求可能之技術推廣及合作機會，強化合作關係及增益本所研發技術，俾利於本所研發計畫及執行相關委託研究計畫工作之順利及加速推動。

二、過程

本文作者劉建國博士與林泰男博士本次奉派於 104/01/23~02/02 赴美國佛羅里達州代托納比奇市(Daytona Beach, Florida)，參加由美國陶瓷學會所主辦之「第 39 屆國際先進陶瓷與複合材料會議及展覽會」(ICACC’15)暨「第 12 屆國際固態氧化物燃料電池材料、科學與技術研討會」(12th IS-SOFC-MST)。代托納比奇市(圖 1)位於佛羅里達州東岸，隸屬沃盧西亞郡(Volusia County)，緊鄰大西洋，該市素以國際賽車及美麗海灘聞名。國際先進陶瓷與複合材料會議及展覽會每年均固定於此市舉辦，第 1 屆於 1977 年舉辦，至本屆則為第 39 屆。本屆會議會場依例於該市之 Hilton Daytona Beach Resort / Ocean Walk Village (圖 2)，海報論文發表及廠商展覽(附錄六)則在議場對街之 Ocean Center (圖

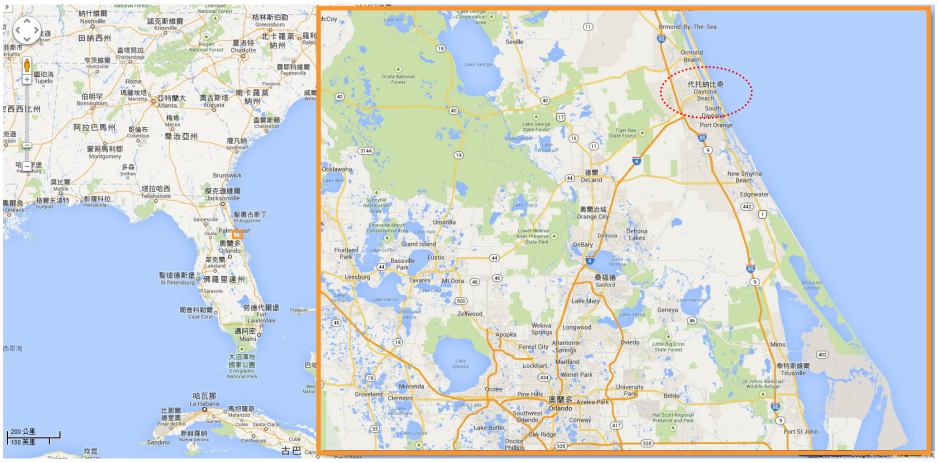

圖 1　佛羅里達州代托納比奇市。(Source: Google map)

圖 2　ICACC’15 會場。

圖 3　海報論文發表及展覽會會場。

3)進行。本次前往美國考量經費預算以及航班時間配合，採搭乘國籍航空與美國國內線之航班，單程時間約 20 小時。

（一）去程：

去程搭乘中華航空，由桃園直飛洛杉磯，轉乘美國達美航空飛亞特蘭大，再轉機飛抵代托納比奇市。

01/23(五) 搭乘中華航空(CI 8)，77W，直飛，航程 11 小時 35 分。

23:50 出發(實際時間 00:08)：台灣台北(TPE)桃園國際機場

19:25 抵達(實際時間 18:49)：美國洛杉磯(LAX)國際機場(圖 4)

隨即下機辦理入境及提領行李，出航站前至轉機區放置行李，而後前往第 5 航站等候轉機。

01/23(五) 搭乘達美航空(DL 1254)，波音 767-300，直飛，航程 4 小時 06 分。

23:55 出發(實際時間 00:14)：美國洛杉磯(LAX)國際機場

07:01 抵達(實際時間 06:59)：美國亞特蘭大(ATL)國際機場(圖 5)

隨即下機搭乘機場捷運至國內線 B 航站之登機門候機。

01/24(六) 轉搭達美航空(DL 2387)，M88，直飛，航程 1 小時 18 分。

09:30 出發(實際時間 09:45)：美國亞特蘭大(ATL)國際機場

10:48 抵達(實際時間 10:59)：美國代托納比奇(DAB)國際機場

隨即下機提領行李出海關後，搭乘計程車至住宿旅館(Hilton Daytona Beach Resort / Ocean Walk Village)辦理入住。

圖 4 洛杉磯國際機場。

圖 5 亞特蘭大國際機場。

（二）參加會議：

由美國陶瓷學會(The American Ceramic Society, ACerS)主辦之第 39 屆國際先進陶瓷與複合材料會議及展覽會(ICACC'15)於 2015/01/25~30 日，依例在美國佛羅里達州代托納比奇市舉行，會場設於 Hilton Daytona Beach Resort / Ocean Walk Village 及 Ocean Center。本屆會議計有 13 個不同陶瓷應用領域之研討會(Symposium)，包括：

S1: Mechanical Behavior and Performance of Ceramics & Composites

S2: Advanced Ceramic Coatings for Structural, Environmental, and Functional Applications

S3: 12th International Symposium on Solid Oxide Fuel Cells (SOFC): Materials, Science and Technology

S4: Armor Ceramics: Challenges and New Developments

S5: Next Generation Bioceramics and Biocomposites

S6: Advanced Materials and Technologies for Energy Generation, Conversion, and Rechargeable Energy Storage

S7: 9th International Symposium on Nanostructured Materials: Innovative Synthesis and Processing of Nanostructured, Nanocomposite and Hybrid Functional Materials for Energy, Health and Sustainability

S8: 9th International Symposium on Advanced Processing and Manufacturing Technologies for Structural and Multifunctional Materials and Systems (APMT9)

S9: Porous Ceramics: Novel Developments and Applications

S10: Virtual Materials (Computational) Design and Ceramic Genome

S11: Advanced Materials and Innovative Processing Ideas for the Industrial Root Technology

S12: Materials for Extreme Environments: Ultrahigh Temperature Ceramics (UHTCs) and Nano-laminated Ternary Carbides and Nitrides (MAX Phases)

S13: International Symposium on Advanced Ceramics and Composites for Sustainable Nuclear Energy and Fusion Energy

以及 6 個 Focused Session (FS)，包括：

FS1: Geopolymers, Chemically Bonded Ceramics, Eco-friendly and Sustainable

Materials

FS2: Advanced Ceramic Materials and Processing for Photonics and Energy

FS3: Materials Diagnostics and Structural Health Monitoring of Ceramic Components and Systems

FS4: Additive Manufacturing and 3D Printing Technologies

FS5: Single Crystalline Materials for Electrical, Optical and Medical Applications

FS6: Field Assisted Sintering and Related Phenomena at High Temperatures

以及 4th Global Young Investigator Forum 與 2nd European Union - USA Engineering Ceramics Summit 等。本所於本屆會議計發表口頭論文 2 篇、海報論文 1 篇，分別為：

劉建國等人之“Electrical and Microstructural Evolutions of $La_{0.67}Sr_{0.33}MnO_3$ Coated Ferritic Stainless Steels after Long-term Aging at 800°C”；

林泰男等人之“Fabrication of the Anode-supported Solid Oxide Fuel Cell with Composite Cathodes and the Performance Evaluation upon Long-term Operation”；

張鈞量等人之“Characteristics of protective LSM coatings on Cr-contained steels used as metallic interconnectors of intermediated temperature solid oxide fuel cells”。

值得一提的是本所 SOFC 計畫主持人李瑞益博士擔任本屆會議 S3 Symposium 之籌組委員。

大會議程包括註冊、開幕式、頒獎、專題演講、口頭及海報論文發表、廠商產品展覽等。以下大要分述本文作者參加各日之議程：(詳細之大會議程表可參

圖 6 大會報到及註冊。

圖 7 歡迎會。

見 會 議 網 站 http://ceramics.org/meetings/39th-international-conference-and-expo-on-advanced-ceramics-and-composites)

1 月 25 日：本日為會議註冊日(圖 6)，劉員與林員於是日進行報到、資料領取及會場環境熟悉等，晚間並參加大會辦理之歡迎會(Welcome reception)(圖 7)。

圖 8 大會會場。(攝於開幕式前)

1 月 26 日：早上 08:30 開始進行大會開幕式(圖 8)[註 1]，首先進行上屆會議(ICACC'14)之最佳論文及最佳海報獎頒獎，其中最佳論文獎依序為：

1st G. D. Quinn, "Fractographic Analysis of Broken Ceramic Dental Restorations"

2nd D. Pla, M. Salleras, I. Garbayo, A. Morata, N. Sabaté, N. J. Divins, J. Llorca, A. Tarancón, "Fabrication and Characterization of a Micro-Reformer Unit Fully Integrated in Silicon for Ethanol Conversion"

3rd H. Sarma, S. Ogunwumi, "Novel Low Temperature Ceramics for Co2 Capture"；

最佳海報獎則依序為：

1st T. Nozawa, K. Ozawa, H. Tanigawa, "Damage Monitoring of Silicon Carbide Matrix Composites by Digital Image Correlation"

2nd J. Mckee, H. Yang, J. Gou, "Vertically Aligned Carbon Nanotube Based Ceramic Nanocomposites with Anisotropic Thermal Properties"

3rd P. Colombo, M. S. Cilla, M. R. Morelli, "Geopolymer Foams by Gelcasting"。

而後由大會主席桐原聰秀(Soshu Kirihara)報告議程總覽，他提及本屆大會計有 13 個研討會(Symposium)以及 6 個聚焦議程(Focused session)同時進行。依大會統計資料顯示，本屆會議計有 1028 篇論文摘要投稿，以及 40 家廠商參展，參加會議人數約 1,050 人，分別來自 42 個國家，參與者半數以上來自美國本土之外。隨後頒發 2015 Global Star Award，得獎者分別為 Kiyoshi Shimamura (Japan), Palani Balaya (Singapore), Jerzy Lis (Poland), Sangmok Lee (Korea), Eugene Medvedovski

(Canada)等 5 人。此外，本屆會議並頒發第 2 屆之 Global Young Investigator Award，得獎人為 Ricardo H. R. Castro (USA)。

隨後進行開幕式之 4 場次專題演講，由 2015 James I. Mueller Award 得主之 Dr. David R. Clarke 講演“Materials Selection for the Next Generation Thermal Barrier Coatings”，他主要闡述熱阻障鍍膜(TBC)於氣渦輪機之應用，由於氣渦輪機輸出功率決定於渦輪進氣溫度，因此，應用 TBC 可提升氣渦輪機工作溫度與效率。他並舉例假如美國所有氣渦輪機提升 1%效率，則可取代美國用以發電之 30%的天然氣，或者 1%的效率提升相當於所有使用的再生能源。另如 2015 Bridge Building Award 得主之 Dr. Sanjay Mathur 講述“Chemically Processed Nanostructured Ceramics: Opportunities for Energy and Health Applications”，則提到 precursor chemistry 之重要，開發新的 precursors，即等同開發新的 materials。(會議進行至此發生會場火警警報驚響之插曲，所有與會者依語音指示被迫疏散，結果虛驚一場，不過已造成大會中斷約 20 分鐘)

而後繼續進行議程，Dr. Cato T. Laurencin 講述“Regenerative Engineering: The Theory and Practice of a Next Generation Field”，內容為組織工程之生醫材料應用。Dr. Kazushige Ohno 講述“Next Generation Diesel Particulate Filter (DPF) Development and Implementation Strategy”，則提到高孔隙率濾材的問題在於破裂韌性差，阻擋裂縫傳播的解決發法，Dr. Kazushige Ohno 提出 3 種方式：(1) Matrix technique:利用基材分錯排列，使得裂縫傳播受阻；(2) Surface film technique:使顆粒間因形成氧化膜而接著，造成強度增加；(3) Neck control technique: 顆粒間形成 neck 架橋連結，造成強度增加。

圖 9　S3 研討會論文發表會場。

是日下午開始各分項研討會之口頭論文發表議程，本文作者主要聽講 Symposium 3: 12th International Symposium on Solid Oxide Fuel Cells (SOFC): Materials, Science and

Technology 之議程，S3 研討會共計發表 68 篇論文，其中包括 61 篇口頭論文，以及 7 篇海報論文，本屆研討會除了邀請演講為 30 分鐘之外，其餘之口頭論文發表時間均為 20 分鐘，議場如圖 9。下午正式開始之之議程主題為“Status and Perspectives of SOFC and SOEC”，計有 7 篇口頭論文發表，分別為：

1. SECA Program Status - 2015 (Invited) (B. White, USA)
2. Recent Development of Micro CHP Systems for Household (ENE-FARM) in Japan (Invited) (Y. Mizutani, Japan)
3. AVL SOFC Systems for Stationary and Mobile Applications (Invited) (J. Rechberger et al., Austria)
4. Solid Oxide Fuel Cell Materials Development at PNNL (Invited) (J. Stevenson et al., USA)
5. High Efficiency Electrical Energy Storage Using Reversible Solid Oxide Cells (Invited) (S. Barnett, USA)
6. CFY-Stack operation and degradation in fuel cell and electrolysis mode (M. Kusnezoff et al., Germany)
7. Highly Efficient Solid Oxide Electrolyzer & Sabatier System (J. A. Olenick et al., USA)

[註 1]：本文作者於此必須特別說明，依據大會開幕式時提及之注意事項，以及議程中關於會議進行之規則，均明確限制會議進行中不允許未經授權之拍照、錄影或錄音等作為。“During oral sessions conducted during Society meetings, **unauthorized photography, videotaping and audio recording is prohibited.** Failure to comply may result in the removal of the offender from the session or from the remainder of the meeting.”節錄自議程表之 Meeting Regulations。

1 月 27 日：S3 研討會議程於 08:00 開始，今日上午之議程主題為“Materials for SOFC, Reversible (SOFC/SOE) and SOE Operation / Electrode Materials”，計有 8 篇口頭論文發表，分別為：

1. Reversible Solid Oxide Fuel Cells using Mixed Ionic-Electronic Conducting Electrolytes: Performance and Stability (Invited) (A. V. Virkar et al., USA)
2. Development of solid oxide cells and stack materials for intermediate

temperature SOFC and SOEC applications (Invited) (D. Montinaro et al., Italy)

3. Proton-Conducting Solid Oxide Electrolysis Cells (SOECs) with Chemically Stable Electrolytes (Invited) (E. Traversaet al., Saudi Arabia)
4. Dopant effects on $La_{0.4}Ce_{0.6}O_2$ sintering temperature for anode supported Solid Oxide Fuel Cells using $LaGaO_3$ electrolyte (Invited) (K. Hosoi et al., Japan)
5. Surface Segregation in LSCF: Effect of Atmosphere and Strontium Content (S. Basu et al., USA)
6. Durability of Lanthanum Strontium Cobalt Ferrite (LSCF) Cathodes in CO_2 and H_2O Containing Air (B. Hu et al., USA)
7. A New Curvature Relaxation Technique to Perform Simultaneous, In Situ Oxygen Surface Exchange Coefficient and Stress Measurements on Dense or Porous Films (J. D. Nicholas et al., USA)
8. Defect Equilibria and Reaction Kinetics of Pr Doped Ceria Thin Film by Simultaneous in situ Optical Absorption and Impedance Measurements (J. Kim et al., USA)

是日下午之議程主題為“Interconnects and Coatings”，計有 7 篇口頭論文發表(議程訂 8 篇，1 篇抽回)，分別為：

1. Chemical and Microstructural Investigations for Chromium Transport in Intermediate Temperature Solid Oxide Electrolysis Cells (Invited) (U. F. Vogt et al., Switzerland)
2. Electrical and Microstructural Evolutions of $La_{0.67}Sr_{0.33}MnO_3$ Coated Ferritic Stainless Steels after Long-term Aging at 800°C (C. Liu et al., Taiwan)
3. Long-term Validation of Surface Treatment of AISI441 Interconnect for SOFC Applications in a Generic Stack Fixture Test (Y. Chou et al., USA)
4. Process Dependent Microstructure and Electrical/Protective Performances of Plasma Sprayed MCO Coatings in SOFCs (S. Han et al., USA)
5. Development of Cost-Effective YSZ Coating Methods for SOFC Interconnects (C. Kim et al., USA)
6. Sintering, Mechanical, Electrical and Oxidation Properties of Ceramic Intermetallic TiC-Ti3Al Composites from Nano-TiC Particles (Z. Fu et al., USA)

7. Advanced Metallic Alloy Design for SOFC Interconnect Application (C. Hsu et al., Taiwan)

是日議程劉員與林員全程聽講，下午議程第 2 篇即為由劉員所發表(圖 10 及附錄七)。傍晚(17:00~20:00)至 Ocean Center 觀摩海報論文發表，惟今日並無排定 S3 研討會之海報論文。是日 18:45~20:00 於 Ocean Center 並循往例進行 SCHOTT Shot Glass 競賽(圖 11)，參賽者使用 SCHOTT 公司所提供之玻璃杯及 15 根塑膠吸管，將塑膠吸管組合設計將玻璃杯包護，再由 SCHOTT 公司人員於不同高度落下，逐一提升高度，最大高度不破者獲勝，為一考驗科技思考及設計實作之趣味競賽。

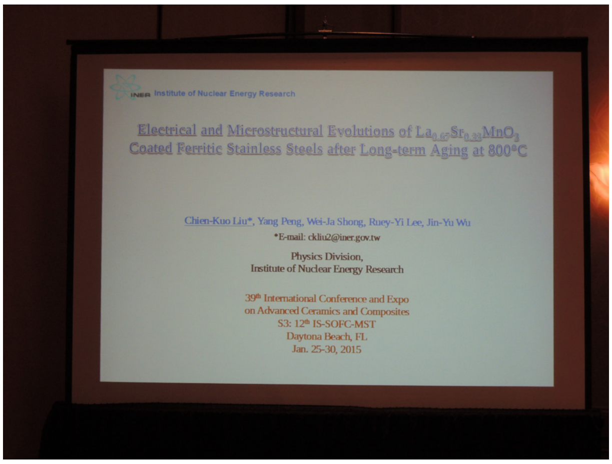

圖 10 劉員論文發表。

圖 11 SCHOTT Shot Glass Contest。

1 月 28 日：今日上午之議程自 08:00 開始，主題為“Surface and Interfacial Reactions”，計有 11 篇口頭論文發表，分別為：

1. Surface Reaction of Doped Lanthanum Cobaltite System (Invited) (K. Yashiro et al., Japan)
2. Ba deficient $NdBaCo_2O_{5+\delta}$ oxides for Intermediate Temperature Solid Oxide Fuel Cell Cathodes (R. Pelosatoet al., Italy)
3. The Enhancement of Surface Oxygen Exchange Constant in the Composite Electrode (R. A. Budiman., Japan)
4. Metallic Conductors for Cathode in Solid Oxide Fuel Cells and Their Electrochemical Properties (A. Stoeck et al., Germany)

5. Structural and Electrochemical Performance Stability of Perovskite - Fluorite Composite SOFC Electrode (S. Gupta et al., USA)
6. Bio-template Assisted Nano-catalyst Infiltration of Porous SOFC Electrodes (O. Ozmen et al., USA)
7. Development of Microtubular Solid Oxide Fuel Cells Using Hydrocarbon Fuels (Invited) (H. Sumi et al., Japan)
8. Interaction Between Glass-based Sealants and MnCo Spinel Coated Interconnects for Solid Oxide Cells (F. Smeacetto et al., Italy)
9. Sealants for SOFC/SOEC Stacks: Challenges of Sealing and Operating Temperature (J. C. Schilm et al., Germany)
10. Investigation on the Carbon Deposition Behavior of Ni-YSZ Cermet in Various Types of Hydrocarbon Gas (N. Ohmura et al., Japan)
11. Performance and Stability of LSM-based Cathode Infiltrated with Electrocatalyst (G. Tao et al., USA)

下午之議程主題為“Oxygen Ion, Proton and Mixed Conductors”，計有 8 篇口頭論文發表，分別為：

1. Sinterability and Chemical Stability of $BaZr_{0.1}Ce_{0.7}Y_{0.1}Yb_{0.1}O_{3-\delta}$ Proton Conducting Electrolyte for SOFCs (A. V. Mohammadi et al., USA)
2. Electronic Conductivity Measurement in Mixed Ionic and Electronic Conductors (MIEC) and Solid Electrolytes: A Transient Technique (L. Zhang et al., USA)
3. Electronic Conductivity Measurement in Mixed Ionic and Electronic Conductors (MIEC) and Solid Electrolytes: A Steady-state Technique (L. Zhu et al., USA)
4. A First-Principles Approach to the Attempt Frequency of Oxygen Ion Jumps in Doped Ceria (J. Koettgen et al., Germany)
5. Mixed Ionic and Electronic Conductivity of Terbium and Gadolinium Doped Ceria Solid Solutions (R. C. Pillai et al., USA)
6. Nonlinear Current-Voltage Characteristics of Individual Boundaries in Doped Ceria Based on Lamellae Studies (G. Baure et al., USA)
7. Initial Development of Oxygen Transport Membrane Technology at St Andrews

(Z. Dehaney-Steven et al., United Kingdom)

8. Strontium and Tungsten Incorporated $La_2Mo_2O_9$ Solid Electrolyte Synthesized via Polyol-mediated Route for IT-SOFC (P. Singh et al., India)

傍晚(17:00~20:00)並至海報論文會場觀摩，以及參觀廠商展覽(圖 12)。今日 S3 議程計有 7 篇海報論文發表，筆者亦代為張貼核能研究所張鈞量博士等人所發表之海報論文“Characteristics of protective LSM coatings on Cr-contained steels used as metallic interconnectors of intermediated temperature solid oxide fuel cells”(圖 13)。此外，發表本屆會議之海報論文發表議程及廠商參展僅只 2 天，皆於今日結束。

圖 12 廠商展覽。

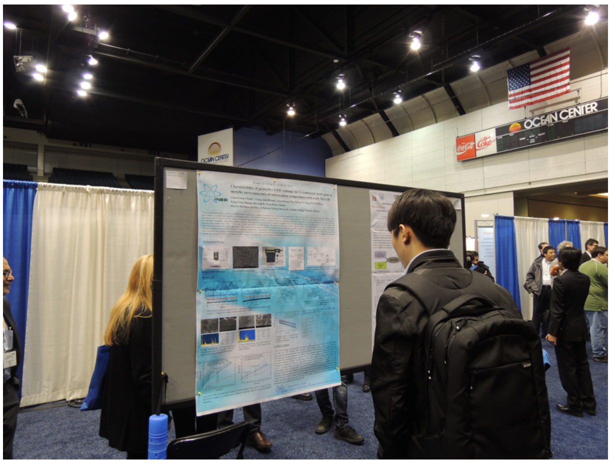

圖 13 張鈞量博士等人之海報論文發表。

1 月 29 日：上午之 S3 議程自 08:30 開始，論文發表主題為“Electrical and Mechanical Reliability / Electrochemical Performance and Stability”，計有 9 篇口頭論文發表，分別為：

1. Tailoring Chemo-Mechanical Coupling to Enhance Durability of Mixed Conducting Perovskite Electrodes (Invited) (N. H. Perry et al., Japan)
2. Mechanical Damping and Dielectric Relaxation of 8 mol% YSZ (P. Gao et al., USA)
3. Elastic Properties and Mechanical Loss of Doped Cerias Determined by Resonant Ultrasound Spectroscopy (A. M. Bolon et al., USA)
4. Mechanical Properties of Ni-YSZ Anode Materials for Solid Oxide Fuel Cells

(D. Ni et al., Denmark)

5. Fabrication of the Anode-supported Solid Oxide Fuel Cell with Composite Cathodes and the Performance Evaluation upon Long-term Operation (T. Lin et al., Taiwan)
6. Electrochemical Performance of Thermal Sprayed Metal Supported Solid Oxide Fuel Cells (M. Gupta et al., Switzerland)
7. Improving Power Density of Solid Oxide Fuel Cells: Role of Contact Resistance (L. Zhang et al., USA)
8. Development of LT-SOFCs: Limiting Factors and Concepts for Achieving High Performance at Low Temperatures (L. Zhu et al., USA)
9. Development of High Performance Anode-supported Solid Oxide Fuel Cells with Optimized Components (H. Shimada et al., Japan)

上列議程第 5 篇即為林員所發表(圖 14 及附錄八)，由於原定發表題目與內容另有發表考量，因此經大會同意更動題目，本次口頭發表主題針對具複合陰極之陽極支撐型電池片研製及長時效操作進行效能評估。

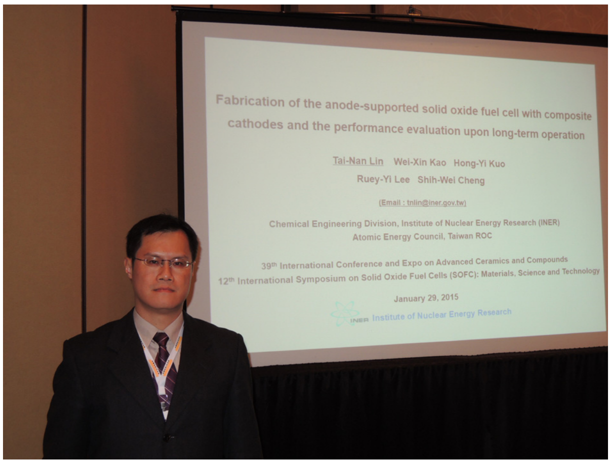

圖 14 林員論文發表。

是日下午之議程主題為 “Degradation, Modeling and Simulation / Novel Processing and Design”，計有 11 篇口頭論文發表，分別為：

1. Steam Electrolysis with Electrode and Electrolyte Supported Solid Oxide Cells: Stability Testing Focussing on the 5000+ Hours Time Scale (Invited) (J. Schefold et al., Germany)
2. NiO Behavior Observation in Ni-GDC Anode During Redox Cycle (K. Sato et al., Japan)
3. Application of Computational Thermodynamics in Solid Oxide Fuel Cell (Y. Zhong et al., USA)

4. Long-term Degradation Due to Cation Ordering in Rare Earth Doped Ceria (S. Grieshammer et al., Germany)
5. Improving Performance and Long-term Stability of Solid Oxide Cells by Integration of AA-CVD Thin Films (Invited) (M. V. Schlupp et al., Switzerland)
6. Application of Full Metal Fuel Cells (FMFCs) with Solid Oxide Thin Films in smartphone chargers (S. Kuehn et al., Germany)
7. Development of Flat-tubular Solid Oxide Fuel Cells and Stacks (T. Suzuki et al., Japan)
8. Ni-free Hybrid Metal-Ceramic Supported SOFC (R. Costa et al., Germany)
9. Manufacturing of Metal Foam Supported SOFCs with Graded Ceramic Layer Structure and Thin-film Electrolyte (F. Han et al., Germany)
10. Effect of Specific Surface Area and Particle Size Distribution of Gadolinium Doped Ceria Slurry on Densification During Sintering Process (K. M. Paciejewska et al., Germany)
11. The Effect of Precusor Gel Desiccation, Ceria Oxide Pre-Infiltration, and Solution Composition on the Size of Lanthanum Strontium Ferrite-Lanthanum Strontium Cobaltite Infiltrate Nano-Particles (T. Burye et al., USA)

S3 議程於是日結束，會議籌組主委 Dr. M. Kusnezoff 表示對參與會議者感謝之意，並預告明年大會為第 40 週年，預期將盛大舉辦。

1 月 30 日：本文作者聽講上午之議程，包括 S2、S5、S11 及 FS2 之陶瓷相關主題，而大會於是日中午圓滿完成。

（三）回程：

本屆會議於美東時間 104/01/30 中午結束，劉員與林員於 01/31 返程，回程路線及航班安排同來程，由代托納比奇市國際機場飛亞特蘭大，再飛洛杉磯，續飛返台灣桃園國際機場。

01/31(六) 搭乘達美航空(DL 2387)，麥道 MD-90，直飛，航程 1 小時 26 分。

11:30 出發(實際時間 11:42)：美國代托納比奇(DAB)國際機場

12:38 抵達(實際時間 12:42)：美國亞特蘭大(ATL)國際機場

隨即下機並搭乘機場捷運至 A 航廈轉機區候機(無需出海關或提領行

李)。

01/31(六) 轉搭達美航空(DL 81)，波音 757，直飛，航程 5 小時 05 分。

17:58 出發(實際時間 18:20)：美國亞特蘭大(ATL)國際機場

20:03 抵達(實際時間 19:32)：美國洛杉磯(LAX)國際機場

隨即下機至第 3 航站 Check-in 後過安檢至登機門候機。

01/31(六) 轉搭中華航空(CI 7)，波音 77W，直飛，航程 14 小時 25 分。

23:25 出發(實際時間 23:57)：美國洛杉磯(LAX)國際機場

02/02(一) 05:50 抵達(實際時間 05:12)：台灣台北(TPE)桃園國際機場

三、心得

（一） 劉員與林員本次赴美國佛羅里達州代托納比奇市參加 2015 ICACC 會議並順利完成論文發表。今年大會舉辦包括 13 項研討會及 6 項聚焦議程，共計收到 1028 篇論文摘要投稿，以及 40 家廠商參展，會議註冊人數約 1,050 人，分別來自 42 個國家，而其中半數以上參與者來自美國本土之外。世界最先端得的科技資訊，藉由此一平台交流，對於主辦國而言，無啻提供最佳的資訊管道。參加會議之餘，亦了解到美國之長處為致力於將全世界最優秀之人才轉變為美國人，可見科技強國實乃強於能海納百川。該會議每年均於同一地點舉辦，下一屆會議將於 2016 年 1 月 24~29 日舉行，由於下一屆會議為第 40 屆，可預期將盛大舉辦。作者認為由美國陶瓷學會所主辦之此一會議，無論於研討內容及論文投稿與審核過程，均相當具學術性及嚴謹性，參與會議對於促進國際學術交流與提升技術水準，以及啟發投稿人的研究創新，均有極大之正面效益。

（二） 本屆大會之 Symposium 3 之第 12 屆國際固態氧化物燃料電池材料、科學與技術研討會，共計發表 68 篇論文，包括 61 篇口頭論文，以及 7 篇海報論文。相較於上一屆研討會之 75 篇論文，數量已呈現減少。上屆會議來自台灣之論文貢獻數為 11 篇，占總論文數近 15%，然而本屆台灣作者投稿論文僅 4 篇(核研所 3 篇，國立清華大學 1 篇)，應亦是造成論文數下降之主因。由於台灣與會場之距離遙遠，往返交通所費不貲，倘無足夠預算，縱使有很好的研究成果，亦很難每年參加會議，形成於國際會議平台交流之障礙。此外，此 SOFC 研討會偏重材料研製及特性量測等學術性討論，論文發表及廠商參展並未見電池堆或系統之探討或展示，其他性質相同的研討會包括每逢西元奇數年舉辦之國際固態氧化物燃料電池研討會，及每逢西元偶數年舉辦之歐洲 SOFC 與 SOE 論壇，以及其他規模不等之氫能相關國際研討會，也稀釋了參加會議之論文數。

（三） 固態氧化物燃料電池(SOFC)是由固態陶瓷氧化物，包括陽極-電解質-陰極等結構組成之電能轉換元件，藉由陰極進料之氧化劑與由陽極進料之燃料氣體於電池中產生化學反應，直接將化學能轉換為電能。SOFC 具有高能源轉換效率及可使用燃料多元化之優點，儼然已成為橋接化石能源至次世代能源之重要電力選項之一。除了產能之外，儲能亦為重要之課題，固態氧化物電解電池(Solid

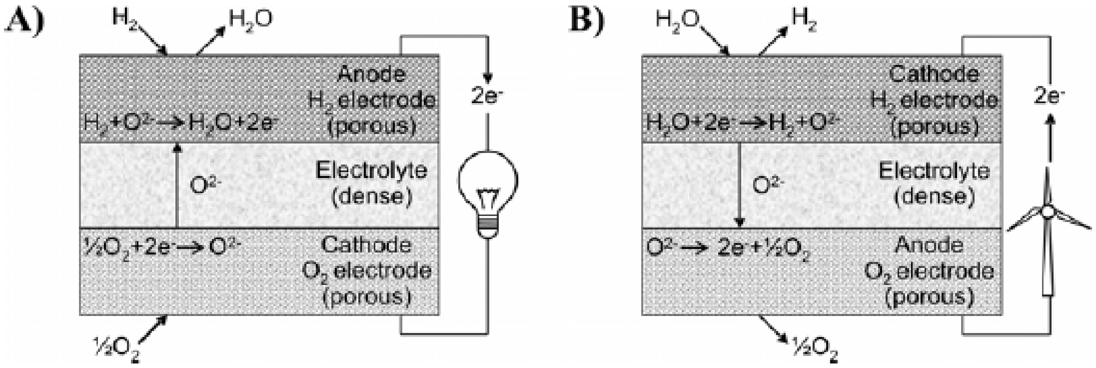

圖 15　(A)SOFC 及 SOEC(B)操作原理示意圖。(參考自：A. Hauch et al., "Durability of Solid Oxide Electrolysis Cells for Hydrogen Production," Risø-R-1608 (EN))

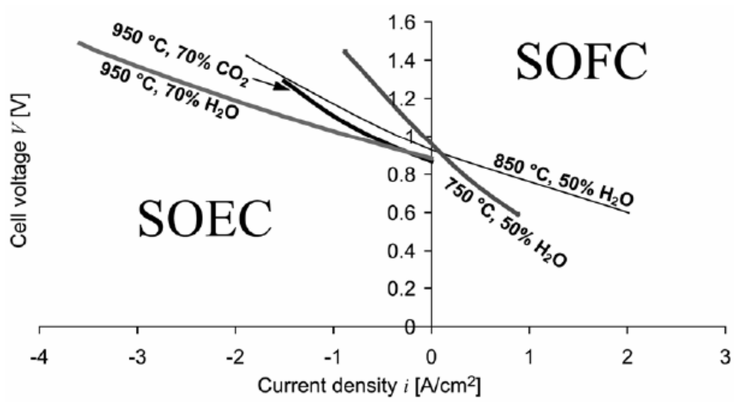

圖 16　SOC 操作於 SOFC 及 SOEC 模式例圖。(參考自：A. Hauch et al., "Durability of Solid Oxide Electrolysis Cells for Hydrogen Production," Risø-R-1608 (EN))

Oxide Electrolysis Cell, SOEC)可視為 SOFC 之逆向反應操作，SOFC 之反應為供給氧化劑及燃料(通常為 H_2 或 CO)而產生電子和水；而 SOEC 則為其逆反應，藉由供給電流及高溫水汽，而產出純 H_2，如圖 15、16。相較於傳統之水電解產氫方式，於相同之輸入電能條件，SOEC 可多產出 40%之 H_2。氫可做為能量之載子，因此儲氫即為儲能，此外，SOEC 亦可產出 CO，H_2 與 CO 結合之合成氣(Syngas)，又可供 SOFC 燃料之用或做為製作化學品之原料。本屆研討會亦有相當篇數之論文探討 SOC (Solid Oxide Cell)之學理，實驗上藉由現有之 SOFC 技術或成品，施以逆反應探討 SOEC 效能及變化機制，關鍵在於其陰極

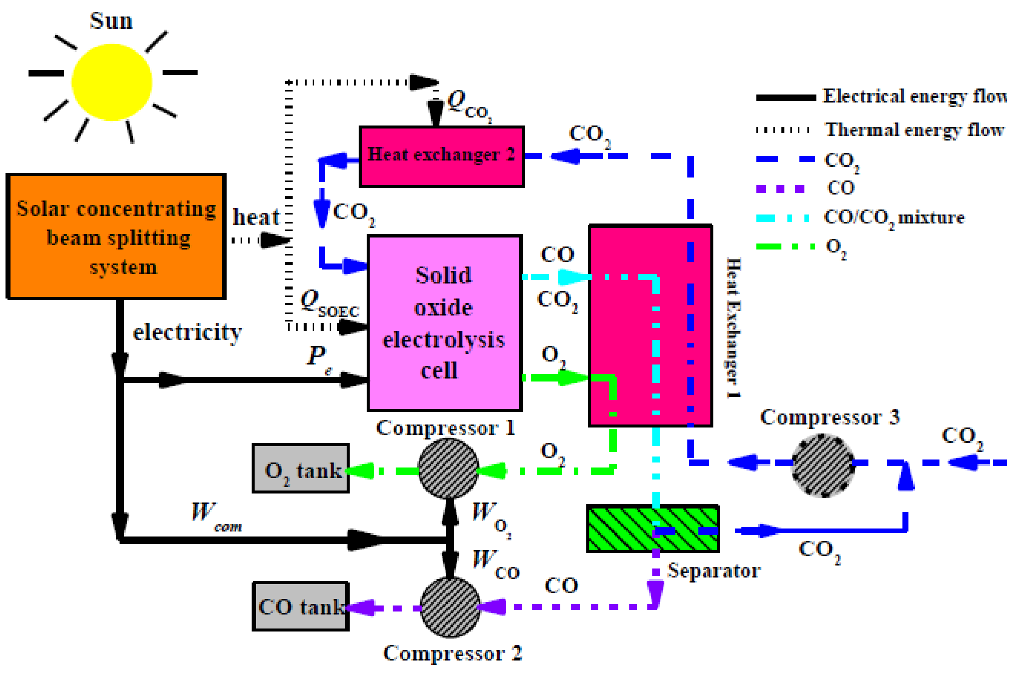

圖 17 太陽能結合 SOEC 達成 CO_2 減量示意圖。(參考自：*Int. J. Electrochem. Sci.*, 9, 1146-1162 (2014))

材料需在高溫氧化和還原氣氛條件下之穩定性，同時亦必須具有相當良好的電子和離子傳導特性。如能結合 SOFC 及 SOEC，製成可逆式固態氧化物燃料電池(Reversible Solid Oxide Fuel Cell, RSOFC)系統，則不但可做為發電，亦可結合其他再生能源做為儲能之應用，可更進一步達到全功能及抑低碳排放之效果(圖 17、18)。

（四） 美國國家技術能源實驗室(National Energy Technology Laboratory, NETL)計畫經理 B. White 在本屆會議中報告了固態能源轉換聯盟(SECA)計畫之現況。NETL 結合了產業界、學術界及國家實驗室共同研發 SOFC，部分核心技術諸如金屬連接板之開發，選用具經濟性、量產性及熱膨脹係數匹配之 ss441 為金屬基板，保護膜則選用 MCO 及 Co 鍍膜，實證方面則已於 2013 年完成以電池堆為設施之 6,000 小時測試。然而因 ss441 組成並無稀土元素，因此其本質上之氧化層附著力不足，改善之措施包括嘗試以 Ce 元素進行表面改質，以及探討基板表面粗糙度對於氧化層附著力的影響，其目的在於延後氧化層剝落以增長連接板之使用壽命。此外，在陰極材料之開發，則選用 LSCF，藉由觸媒顆

粒滲透鍍附 LSCF 的方式，改善陰極本質上對於鉻、二氧化碳及水之穩定性及耐受度，目標為由目前之 1~2%/kh 劣化率降低至 0.2%/kh。

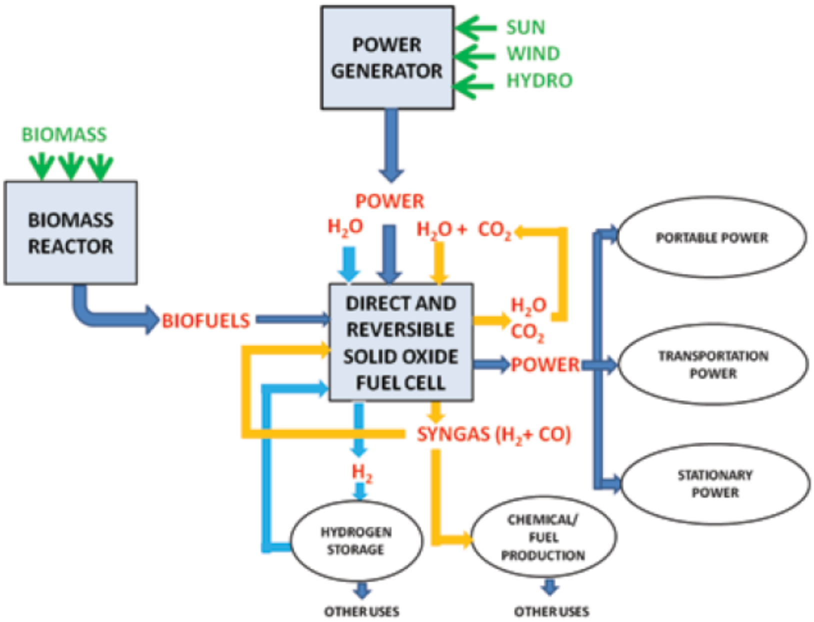

圖 18 可再生能源能結合 RSOFC 之可續能源系統示意圖。(參考自：The Electrochemical Society *Interface*, Winter 2013, pp.55-62)

（五） 奧地利 AVL 公司之 J. Rechberger 於本屆會議報告 AVL 發展 SOFC 系統於定置型與移動型之應用。其報告指出 AVL 發展之定置型 SOFC CCHP(冷熱電聯產)系統，結合發電、製冷及熱利用等功能，功率容量範圍為 5~100 kW。AVL 同時並與 IKTS、Plansee 等合作開發 5~10 kW 之 SOFC CHP(熱電聯產)系統，其發電效率大於 50%，總能源轉換效率可近 90%。此外，AVL 於 2002 開始研發可攜式 SOFC 發電機，此項產品預計可應用軍事、海事、休閒或車輛等，相較於小型柴油發電機，較小容量之 SOFC 系統具有顯著優勢，AVL 並於 2013 年展出第 2 代之 3 kW SOFC，據其指出此一系統發電效率大於 30%，並已安裝於行動車輛展示。

（六） 美國太平洋西北國家實驗室(Pacific Northwest National Laboratory, PNNL)之 J. Stevenson 於本屆會議報告 PNNL 於 SOFC 材料之研發。Jeff 指出 SECA 的任務為開發適當的材料，如連接板材料、封裝材料、陰/陽極材料等，達成電池片或電池堆具可靠性、耐受性及耐久性的目標。例如在連接板材料選用 ss441，以

鍍覆 MCO 作為保護層，或以反應空氣鋁化(Reactive Air Aluminization, RAA)處理增強其抗氧化性。據指出其 ss441/MCO 連接板鍍膜系統試樣於 800°C 測試，已超過 35,000 小時，仍維持穩定及低 ASR 值。此外，以摻雜 Ce 改質之 ss441/Ce-MCO 連接板鍍膜系統試樣亦經 6,300 小時及 10 次之升降溫循環測試，未發現氧化層剝落之跡象。封裝材料則選用柔性玻璃封裝材料(Compliant glass seals)，以改善抗熱循環特性，另外尚包含結合玻璃與二氧化鋯纖維的複合材料，藉由摻加短纖之二氧化鋯於玻璃中，可有效降低封裝玻璃之孔洞粗化現象。

（七） 美國西北大學之 S. Barnett 於本屆會議報告利用可逆式 SOC 做為高效率之電能儲存裝置。圖 19 顯示一典型之 PEMC (Proton Exchange Membrane Cell)與 SOC (Solid Oxide Cell)的電位-電流密度關係圖，取正負 0.5 A/cm^2 電流密度對應之電位，可計算 Round-trip efficiency。例如 PEMC 之效率為 0.7 V/1.8 V=39%，而 SOC 之效率則為 0.87 V/1.07 V=81%。據其指出應用 LSGM 為電解質之 SOC，可應用於中溫型 SOFC，其面積比電阻值可小於 0.2 Ω·cm^2 (at 600~650°C)。渠等研究並指出，操作在小於 0.9 A/cm^2 之電流密度條件，可維持長效壽命且幾乎無劣化率(0.5%/kh over 50,000 h)。

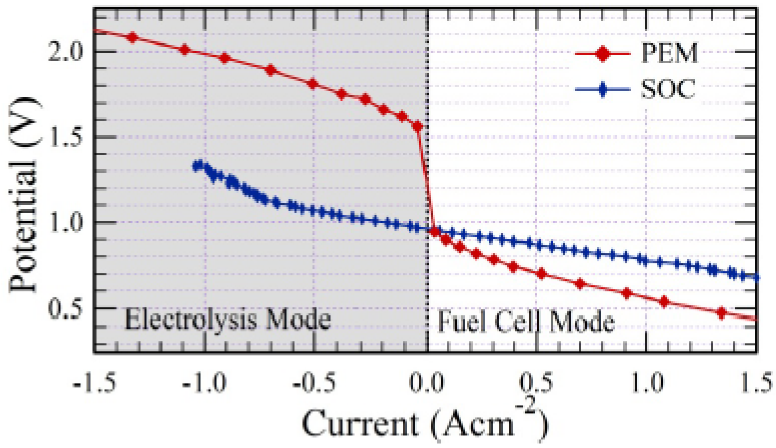

圖 19　PEMC 與 SOC 之電位-電流密度關係圖。(參考自：*ECT Trans*, 35(1), 2969-2978 (2011))

（八） 德國 Fraunhofer Institute for Ceramic Technologies and Systems (IKTS)之 M. Kusnezoff，亦為本屆 SOFC 會議籌組委員會之主委，在本次會議報告 CFY-Stack

操作在燃料電池及電解電池模式之效能及劣化率。其研究使用 10Sc1CeSz 作為電解質之電解質支撐型電池片，分別比較其在單片電池單元測試及電池堆測試之劣化率，結果顯示在 SOEC 模式之劣化率甚至比在 SOFC 模式為低。然而在 30 片裝之 CFY-satck，裝置容量 850 W，在 SOEC 模式及溫度 800°C 時，劣化率為 1%/kh；在 SOFC 模式及溫度 790°C 時，劣化率則為 0.5%/kh，電流-電壓曲線如圖 20。

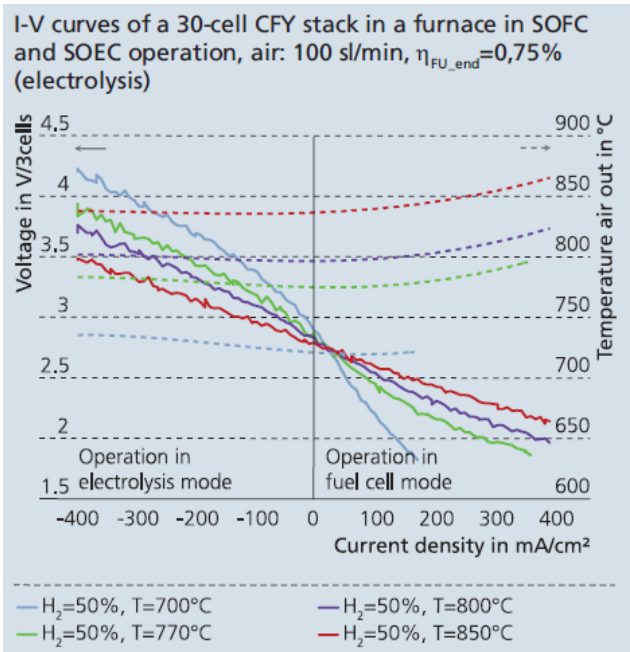

圖 20　30 片裝 CFY 電池堆操作於 SOFC 及 SOEC 模式之電流-電壓曲線。(參考自：http://www.ikts.fraunhofer.de/content/dam/ikts/en/images/publications/jahresberichte1/jb2013/13_3_CFY_stack_technology_for_high-temperature_electrolysis.pdf)

（九）　本屆會議國內清華大學材料系葉安洲教授團隊，亦以先進金屬合金設計應用於 SOFC 連接板為題進行報告。金屬連接板占 SOFC 電池堆成本比重之大部分，因此連接板之選用及開發是重要的研發課題之一，葉教授團隊之研究選定鎳基、鐵基及鎳鐵基等三種合金組成，先藉由 Jmatpro 及 Thermo calc 進行合金設計及相組成之模擬，再進行真空熔煉，針對所製成合金(CMH-1, CMH-2, CMH-3)依據設定目標進行特性量測及驗證，如圖 21。研究結果顯示以 CMH-3 之抗氧

化能力與商用金屬連接板相比擬，於 800°C 持溫 500 小時之面積比電阻(Area Specific Resistance, ASR)值為 6 mΩ·cm^2，室溫至 800°C 之平均熱膨脹係數為 11 ppm/°C，具有應用潛力。

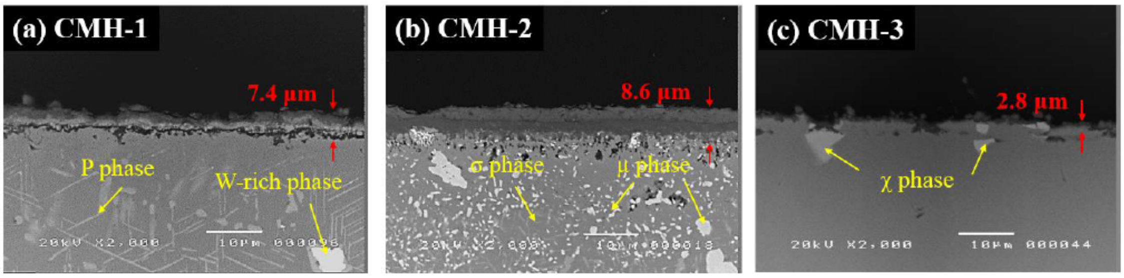

圖 21　CMH-1, CMH-2, CMH-3 合金試樣經 800°C 持溫 500 小時後之橫截面微觀結構圖。(參考自：許銘哲等人，ICACC2015 口頭論文報告)

（十）　本所研發金屬支撐型電池單元之黃振興博士團隊，由張鈞量博士主撰 1 篇海報論文於本屆會議發表，主題為利用大氣電漿噴塗製程於含鉻不銹鋼基板鍍覆 LSM 及其特性。其研究對象為商用合金，如 ss441、Crofer22APU 及 Crofer22H，並探討預氧化對於鍍膜試樣高溫 ASR 值變化之影響，由其研究結果顯示，預氧化所形成之氧化層雖然造成起始 ASR 值較高，然長期之測試結果，經預氧化處理試樣之 ASR 值增加率較低，表示預氧化層減緩了氧化速率，而 LSM 鍍膜又進一步提供了雙重抗氧化之保護效果。本次會議論文發表過程，亦與與會者討論金屬連接板於高溫之 ASR 曲線演變機制，假設連接板試樣在高溫時效過程量測電性，倘合金相是穩定的，電阻應是定值，唯一可能改變電阻的是表面氧化層的厚度，(如果是鍍膜試樣，且組成相穩定，則亦同)，因為氧化層的增長受反應及擴散機制控制，短時間(反應控制)為線性，但長時間(擴散控制)應符合拋物線定律，另方面倘長時間的數據為線性，則隱含試樣之氧化並非擴散控制(一種可能的情形是氧化層已剝離，造成氧化層厚度增長為線性)。然而試樣實際量測時，可能影響之因素尚包括量測接觸方式及鍍膜是否穩定等等，其演變之機制應可能受多重變數影響。

四、建議事項

參加第 39 屆國際先進陶瓷與複合材料會議及展覽會，無論就參與國際會議主持及論文發表，以及汲取國際第一手研究內容或與國際一流專家學者討論互動，深感頗有收穫。幾點淺見建議如下：

（一）本次參與之國際先進陶瓷與複合材料會議及展覽會以及國際固態氧化物燃料電池材料、科學與技術研討會，其研討內容雖然偏重學術性討論，並未見電池堆組裝或系統之論文發表及廠商參展。然而與會者對於材料特性之研究與實驗設計，進行了相當精細的發表及討論，對於提升材料研發之知識累積及瞭解國際研究之最新發展成果，具有相當正面之助益。下屆會議將於 2016 年 01/24~29 日在相同地點舉行，適逢 40 周年，必有盛大氣象，建議本所持續關注並派員參加會議及發表論文，除可藉由國際重要會議展現本所研發成果，亦可維繫國際學術研究人脈關係，有效提升本所於國際之能見度。

（二）本次參與會議期間向與會專家學者請益，多對於本所於 SOFC 研發之進展均十分肯定，並表示希望來訪或歡迎派員交流實習。建議於會議結束後，對於可能互訪或合作之事宜，仍需持續關注或追蹤。

（三）部分可再生能源(如風力、太陽能等)所產生的電力因具間歇性，固態氧化物電解電池(Solid Oxide Electrolysis Cell, SOEC)可成為具有潛力及效率之儲能關鍵技術。由於 SOEC 實為 SOFC 之逆反應，建議所內可以開發 SOFC 之完整能量作為基礎，積極投入 SOEC 相關材料及系統之研發及測試。

（四）本次會議共同籌組委員之一日本九州大學石原達已教授應邀於大會進行邀請演講，本所計畫同仁與九州大學與石原教授於 103 年度有參訪與合作實習活動，藉此次出國發表之機會進一步與石原教授確認後續合作意願，順利於回國後 2 月 26 日完成本所與九州大學在 SOFC 研發上的合作意向書簽訂事項(MOU)，期能透過緊密的國際交流與合作提升本所研發實力以及未來產業平台的建構。

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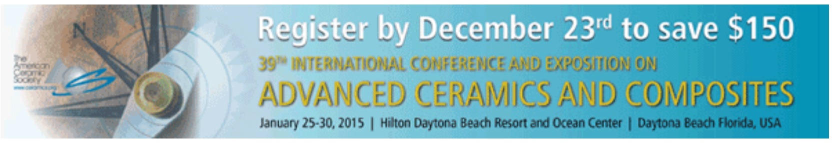
S3-12th International Symposium on Solid Oxide Fuel Cells (SOFC): Materials, Science and Technology



Solid oxide fuel cells (SOFC) offer potential for clean and efficient power generation from a wide variety of fuels ranging from hydrocarbons to renewables and coal derived fuels. Advanced systems configurations are currently being developed for applications in centralized and distributed stationary generation using SOFCs. Considerable progress has been made in automotive auxiliary power generation as well as in man portable and unmanned operation. With demonstrated advantages of high electrical efficiency, lower emissions (greenhouse gas, SOx, NOx, VOC and particulate matters) and ease of products configurability, major focus of interest continues to be on systems research and development, products engineering and cost effective manufacturing under the sponsorship of government agencies and private industries. Although significant progress has been made in the areas of cell and stack materials, component fabrication, stack and systems simulation and design, fuel processing and systems operation on a wide variety of liquid and gaseous hydrocarbons, technology development continues towards the identification of bulk and interfacial modifications for performance enhancement, understanding of ageing phenomena, accelerated testing and minimization of degradation as well as cost reduction at both materials and process levels. Significant challenges still exist in the areas of stacking cells, fracture mechanics of ceramic components, thermal management, and BOP component development at both sub-kWe and large multi-kWe levels. Future energy systems should cope with randomly distributed renewable energy sources (wind, sun) under certain circumstances, as power generation cannot be planned or predicted and the storage of any excess energy is only possible to a limited extent. High-temperature electrolysis can solve this problem providing highest efficiency for generation of chemicals and products from excessive power. In electrolysis, the regenerative energy is directly converted into hydrogen or/and into a synthesis gas which can be further processed into any fuel. The production of methane, synthetic oils or diesel, in particular, provides promising synergies. So, it will be possible to couple electricity grid, natural gas grid and chemicals production. For this reason the research on Solid Oxide Electrolysis is important task which helps to understand the opportunities and limitations of this new technology for future energy systems. The primary purpose of this symposium is to provide an international forum for scientists and engineers to present recent technical progress, and to exchange ideas and technical information on various aspects of solid oxide fuel cells.

Proposed Session Topics

- Electrolytes; oxygen ion, proton and mixed conductors; conduction mechanisms
- Electrode materials and microstructural engineering; electrode processes, defect chemistry, analytical techniques
- Ceramic and metallic interconnects; degradation mechanisms, coatings, accelerated testing and life prediction
- Sealing materials, designs and approaches; compatibility and interactions
- Novel processing and design of cell and stack materials
- Mechanical and thermal properties, electrochemical performance and stability
- Electrical and structural reliability
- Surface and interfacial reactions; materials transport and electrode poisoning; catalytic degradation, carbon formation
- Degradation modeling and computational simulation of cells and stacks
- High temperature electrolysis: steam, steam and CO2, chemical process engineering utilizing SOEC
- Fuel processing; reforming using supported/unsupported catalysts; carbon and sulfur contaminations, gas separation membranes

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- Ruey-Yi Lee, Institute of Nuclear Energy Research, Taiwan
- Nguyen Q. Minh, Consultant, USA
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- Prabhakar Singh, Univ. of Connecticut, USA
- Federico Smeacetto, Politecnico di Torino, Italy
- Jeffrey W. Stevenson, Pacific Northwest National Lab, USA
- Toshio Suzuki, National Institute of Advanced Industrial Science and Technology (AIST), Japan
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CURRENT CATEGORY: SYMPOSIUM 3: 11th International Symposium on Solid Oxide Fuel Cells (SOFC): Materials, Science and Technology

CURRENT SUB-CATEGORY: Ceramic and metallic interconnects

PRESENTATION TYPE: Contributed (Oral)

TITLE: Electrical and Microstructural Evolutions of La0.67Sr0.33MnO3 Coated Ferritic Stainless Steels after Long-term Aging at 800°C

AUTHORS (LAST NAME, FIRST NAME): Liu, Chien-Kuo[1]; Yang, Peng[1]; Shong, Wei-Ja[1]; Lee, Ruey-yi[1]; Wu, Jin-Yu[1]

INSTITUTIONS (ALL): 1. Physics Division, Institute of Nuclear Energy Research, Taoyuan County, Taiwan.

ABSTRACT BODY: Sr-doped LaMnO3 (LSM) coated ferritic stainless steels are commonly used as metallic interconnect for planar solid oxide fuel cells (pSOFCs). Four kinds of specimens of LSM coated ferritic stainless steels designated as C1, Z1, Z2, and I1 were employed in this study. The La0.67Sr0.33MnO3 protective films with a thickness of ~3.5 μm were successfully deposited on the surfaces of the four commercial ferritic stainless steels by pulsed DC magnetron sputtering. The evolutions of electrical and microstructural properties of the four LSM coated ferritic stainless steels aged in an air atmosphere at 800°C for 10,103 hours have been investigated. Area specific resistance (ASR) measurement showed that the initial values of the specimens of C1, Z1, Z2, and I1 aged at 800°C were 3.51, 1.15, 1.25, and 1.38 mΩcm2, respectively. The corresponding ASR values became 49.9, 16.4, 19.4, and 4.6 mΩcm2 respectively after aging at 800°C for 10,103 hours in an air atmosphere. In addition, a two-step coating process was conducted for depositing a LSM protective film on the substrate C1 using pulsed DC magnetron sputtering. The preliminary results of microstructural observation revealed that the crevices in the film resulted from LSM shrinkage at elevated temperatures could be mitigated effectively by applying the two-step coating process.

KEYWORDS: Sr-doped LaMnO3, Interconnect, Planar solid oxide fuel cells, Pulsed DC magnetron sputtering, Area specific resistance.

附錄(三)

Two-stage performance and durability evaluation of anode-supported solid oxide fuel cell with 15,000 hours operation

Tai-Nan Lin*, Wei-Xin Kao, Hong-Yi Kuo,

Ruey-Yi Lee, Shih-Wei Cheng

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Abstract

An anode-supported solid oxide fuel cell consisting of a NiO-YSZ anode, YSZ electrolyte, and YSZ-LSM || LSM composite cathodes has been investigated. The cell is fabricated with a 10 × 10 cm^{-2} commercially available size and has been electrochemically tested. The open circuit voltage is greater than 1.1 V at 800 °C, suggesting a firm cell structure. The power densities are 173, 257, and 364 mW cm^{-2} at 700, 750, and 800 °C, respectively. The durability evaluation is conducted for 15,000 hours with 14 thermal cycles. During the first stage test with fixed current density of 300 mA cm^{-2}, the degradation rate is 0.4 %/Khr for 6761 hours operation. At the second stage, operation with 400 mA cm^{-2} was executed for 8241 hours to further investigate the electrochemical property and the degradation rate is 1.07 %/Khr. The cell shows consistent power output, indicating the stable cell structure as well as the compatible performance behavior. Some expected thermal cycling operations were conducted. However, the open circuit voltage exceeded 1.0 V whenever the cell was operated again. It is evidenced that the operational conditions with lower current density or higher cell voltage can prolong the cell lifetime but somehow decrease the output power of the cell.

Keywords: anode-supported solid oxide fuel cell, open circuit voltage, durability evaluation, degradation rate

附錄(四)

The American Ceramic Society
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26 August 2014

Dr. Chien-Kuo Liu
Institute of Nuclear Energy Research
Physics Division
No. 1000, Wenhua Rd., Jiaan Village, Longtan Township
Taoyuan County, Taiwan 32546
Taiwan

Dear Dr. Liu,

We are pleased to invite you to present your topic entitled ***Electrical and Microstructural Evolutions of La0.67Sr0.33MnO3 Coated Ferritic Stainless Steels after Long-term Aging at 800°C***, abstract **#2058424**, accepted for presentation at the 39th International Conference & Exposition on Advanced Ceramics and Composites. The conference dates: January 25 - 30, 2015 at the Hilton Daytona Beach Resort & Ocean Center in Daytona Beach, Florida.

Please inform any co-authors of the acceptance of this abstract. The specific details of the day, time and location of your presentation will be communicated by email in October:

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All attendees must register for the meeting and pay the appropriate registration fee. Registration and hotel information for the conference is available at http://www.ceramics.org/daytona2015. We encourage you to make your hotel reservation early to take advantage of the special conference rates, available only until December 14, 2014. You must mention that you are participating in The American Ceramic Society conference to qualify for the special conference rate.

If it is necessary for you to obtain a travel visa to attend the conference, you may use this letter as an invitation. Please refer to the U.S. government website http://travel.state.gov for official guidelines to obtain a B-1 nonimmigrant travel visa for entry into the U.S. Early application (14 weeks prior to conference) is suggested to allow for the required processing. Information on obtaining a travel visa also appears on the meeting webpage. Individuals from Visa Waiver Countries must have registered with the U.S. Department of Homeland Security's Electronic System for Travel Authorization (ESTA) program.

Thank you for your interest in participating in the 39th International Conference & Exposition on Advanced Ceramics and Composites. We look forward to seeing you in Daytona Beach!

Sincerely,

Marilyn Stoltz

Marilyn Stoltz
Technical Content Administrator
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附錄(五)

The American Ceramic Society
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26 August 2014

Dr. Tai-Nan Lin
Institute of Nuclear Energy Research
Chemical Engineering Division
No. 1000, Wenhua Rd., Jiaan Village, Longtan Township
Taoyuan County, 32546
Taiwan

Dear Dr. Lin,

We are pleased to invite you to present your topic entitled ***Two-stage performance and durability evaluation of anode-supported solid oxide fuel cell with 15,000 hours operation***, abstract **#2037986**, accepted for presentation at the 39th International Conference & Exposition on Advanced Ceramics and Composites. The conference dates: January 25 - 30, 2015 at the Hilton Daytona Beach Resort & Ocean Center in Daytona Beach, Florida.

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Sincerely,

Marilyn Stoltz

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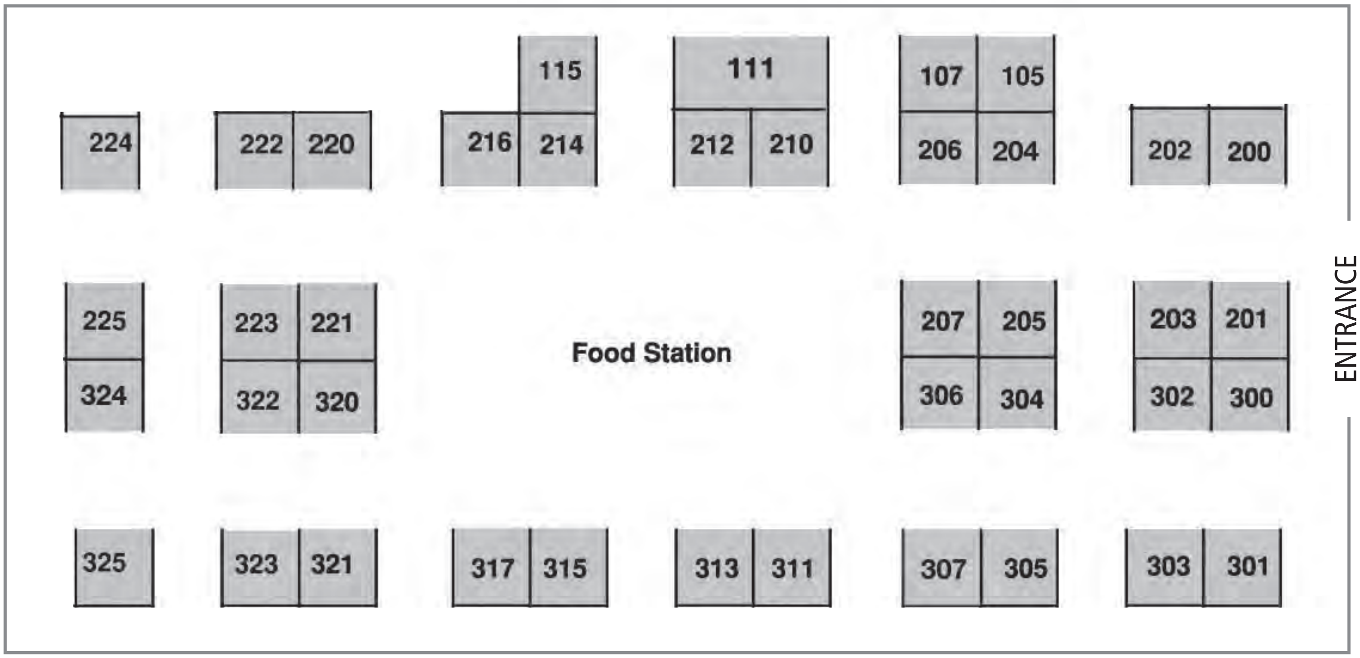

Exhibitor	Booth #
Alfred University	315
AVS, Inc.	107
BTU International	307
C-Therm Technologies Ltd.	222
Carbolite, Inc.	206
Centorr Vacuum Industries, Inc.	200
Ceramics Expo	115
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Electrical and Microstructural Evolutions of $La_{0.67}Sr_{0.33}MnO_3$ Coated Ferritic Stainless Steels after Long-term Aging at 800°C

Chien-Kuo Liu*, Yang Peng, Wei-Ja Shong, Ruey-Yi Lee, Jin-Yu Wu
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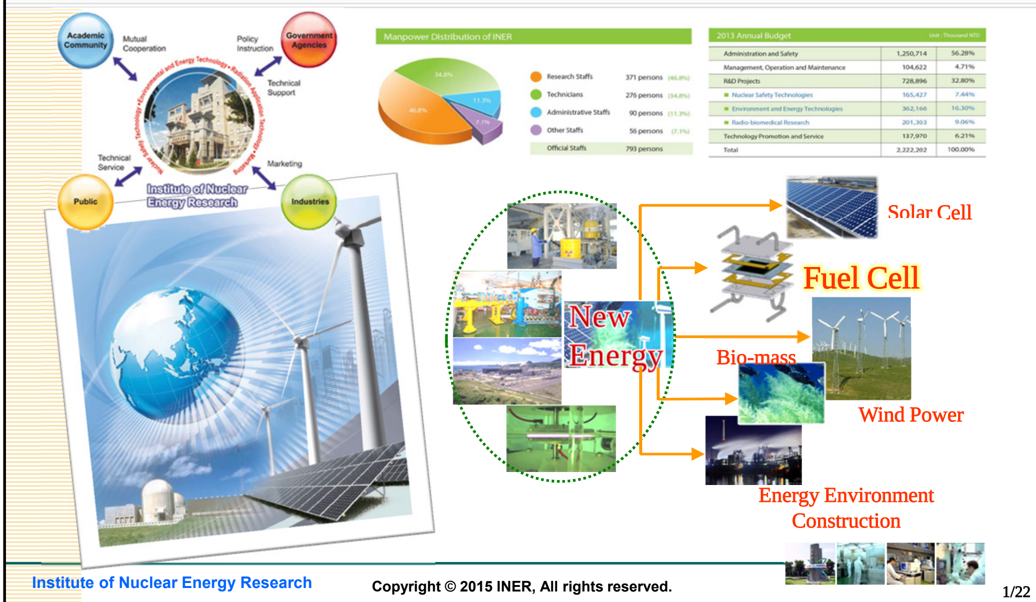
Physics Division,
Institute of Nuclear Energy Research

39th International Conference and Expo
on Advanced Ceramics and Composites
S3: 12th IS-SOFC-MST
Daytona Beach, FL
Jan. 25-30, 2015

Visiting www.iner.gov.tw for more information

IC&Seals
R&D Group



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1/22

IC&Seals R&D Group

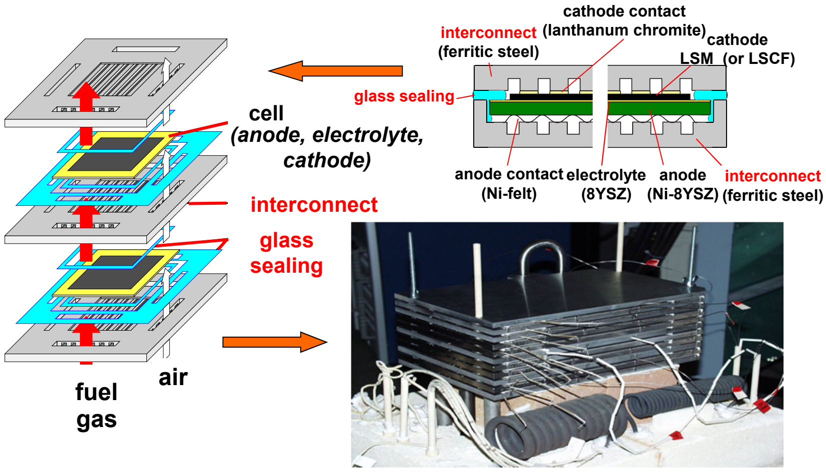
SOFC in Brief and Current Status of SOFC R&D at INER

IC&Seals R&D Group

Outline:

- Introduction
- Interconnect & Coatings Selection
- Protective Layer (LSM) Coating
- SEM/EDS Microstructure Observation
- XRD Analysis
- Area Specific Resistance (ASR) Measurement
- Pre-oxidation & Two-step Coating
- Summaries

INTRODUCTION



Ref: H. Nabielek et al., "Fabrication of Solid Oxide Fuel Cells", 2006 Taiwan SOFC workshop.

INTRODUCTION (cont'd)

Requirements for Interconnect

- Physical properties stable at high temperature
- Chemical properties stable at high temperature
- High Electrical Conductivity
- Compatible CTE
- Easy Manufacture
- Low cost

INER's 1 kW SOFC Stack

INTERCONNECT SELECTION

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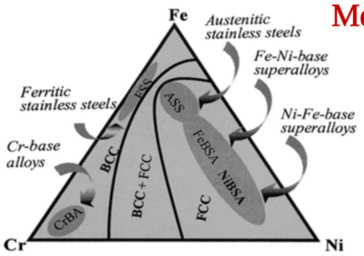

Metallic Interconnect System & Examples

Fe-Cr base：Crofer22APU (ThyssenKrupp)

Cr base ：Ducrolloy (Plansee)

Ni-Cr base：HAYNES 230 (PNNL)

Alloys	Matrix structure	TEC $\times 10^{-6}$ K^{-1}	Oxidation resistance	Mechanical strengths	Manufacturability	Cost
CrBA	bcc	11.0-12.5 (RT-800°C)	Good	High	Difficult	Very expensive
FSS	bcc	11.5-14.0 (RT-800°C)	Good	Low	Fairly readily	Inexpensive
ASS	fcc	18.0-20.0 (RT-800°C)	Good	Fairly high	Readily	Inexpensive
FeBSA	fcc	15.0-20.0 (RT-800°C)	Good	High	Readily	Fairly expensive
NiBSA	fcc	14.0-19.0 (RT-800°C)	Good	High	Readily	Expensive

Ref.: Z. Yang et al., J. Electrochem. Soc., 150(9), A1188-A1201 (2003)

INTERCONNECT SELECTION (cont'd)

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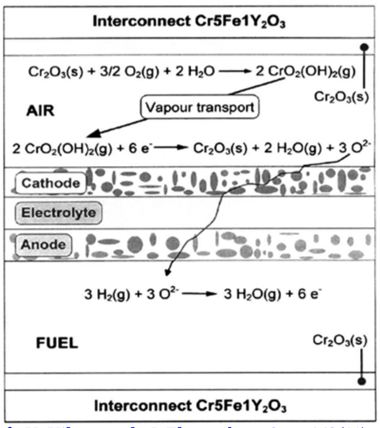
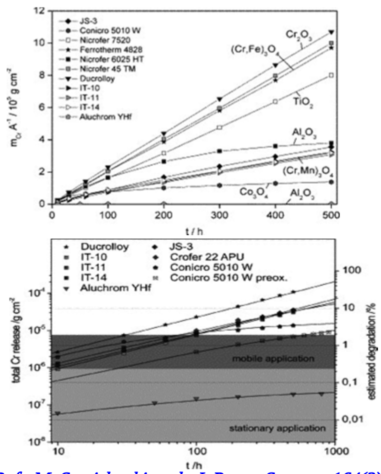
Cr Poisoning



Ref.: K. Hilpert et al., J. Electrochem. Soc., 143(11), 3642-3647 (1996)



Ref.: M. Stanislowski et al., J. Power Sources, 164(2), 578-589 (2007)

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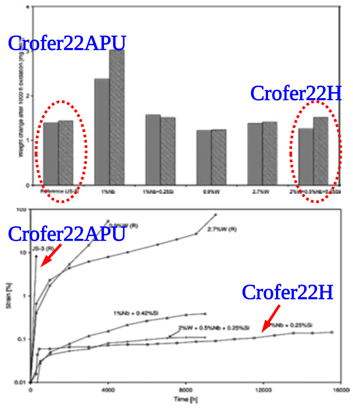
INTERCONNECT SELECTION (cont'd)

Strategies: Alloy Design, Surface Modification, Protective Layer Coating

Additions	Functions
Cr	Improve oxidation resistance, Low CTE
Mn	Low Cr evaporation, Improve conductivity (oxide scale)
La	Improve adherence (oxide scale), Improve oxidation resistance
Ce	Improve adherence (oxide scale)
Al	High oxidation rate, Low conductivity (oxide scale)
Si	High oxidation rate, Low conductivity (oxide scale)
W	Improve mechanical strength (high Temp.)
Nb, Si	Improve mechanical strength (high Temp.)



Ref.: J. Froitzheim et al., J. Power Sources, 178(1), 163-173 (2008)

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INTERCONNECT SELECTION (cont'd)

Protection layer: Perovskite – LSM, LSC, LSF, LCC… Spinel – MnCo, MnCr, NiCr, CoCr…

Name	$\alpha/10^{-6}$ K^{-1}(ΔT, °C)	σ(S cm^{-1}) T (°C)	Function
8YSZ	10.8(20–800) [47]	(5.3–4.5) × 10^{-2}(800) [48]	Electrolyte
Crofer22 APU	12.0(20–800) [49]	8.70 × 10^{3}(800) [49]	Interconnect
Cr_2O_3	9.6(20–1400) [50]	1.28(750) [50] 2.50(1000) [50]	Oxide scale
$MnCr_2O_4$	7.2(25–900) [43]	0.22(750) [43] 0.05(800) [43]	Oxide scale
Mn_2CrO_4	–	12.8–30.3(750) [43]	Oxide scale
Co	14.0(20–400) [51]	1.71 × 10^{4}(800) [51]	Coating
Co_3O_4	–	35.5(800) [52]	Coating
$CoCr_2O_4$	7.4(25–900) [43]	1.92(750) [43]	Coating
Ni	16.3(20–900) [51]	2.20 × 10^{4}(900) [51]	Coating
NiO	12.6(100–800) [50]	14.9(590 [50] 71.4(1000) [50]	Coating
$NiCr_2O_4$	7.6(25–900) [43]	62.5(750) [43]	Coating
Cu	20.3(20–1000) [51]	1.23 × 10^{5}(977) [51]	Coating
CuO	–	2 × 10^{3}(700) [50] 10^{5}(1000) [50]	Coating
LSC-80	9.8–11.2(20–1000) [53]	10–40(1000) [53]	Coating/interconnect
LMAC-DLR	–	–	Coating/interconnect
LSM-80	11.4(50–1000) [54]	175(1000) [55]	Coating/cathode
LSM-65	12.3(25–800) [47]	3.39(800) [56]	Coating/cathode

Ref.: M. Stanislowki et al., J. Power Sources, 164(2),578-589 (2007)

INTERCONNECT SELECTION (cont'd)

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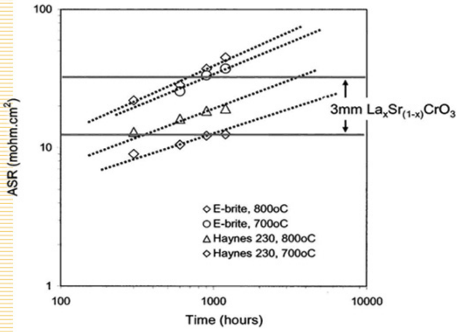
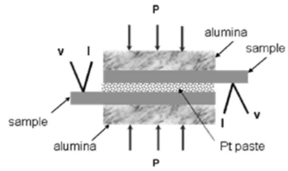
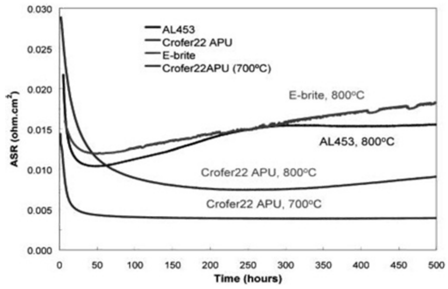
Area Specific Resistance (ASR)

Acceptable ASR For SOFC: < 0.1 $\Omega\cdot cm^2$







Ref.: Z. Yang et al., J. Electrochem. Soc., 150(9), A1188 -A1201 (2003)

Ref.: Z. Yang et al., Int. Mater. Rev., 53(1), 39-54 (2008)

PROTECTIVE LAYER (LSM) COATING

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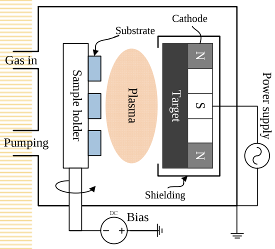
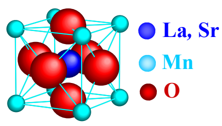
Alloy	Fe	Cr	Mn	Si	Cu	Al	Ti	La	Nb	W	Ni	Zr
C1	Bal.	20-24	0.3-0.8	0.1-0.60	≤0.50	≤0.10	0.02-0.20	0.04-0.20	0.20-0.10	2.01	–	–
Z1	Bal.	21-23	≤0.10	≤0.10	–	≤0.50	–	0.03-0.10	–	–	≤0.70	0.10-0.40
Z2	Bal.	23.7	0.27	≤0..01	0.94	0.01	–	0.07	–	1.8	0.37	0.28
I1	Bal.	26	–	≤0.03	–	≤0.03	–	–	–	–	–	–

size: $10\times10\ mm^2$
surface polished

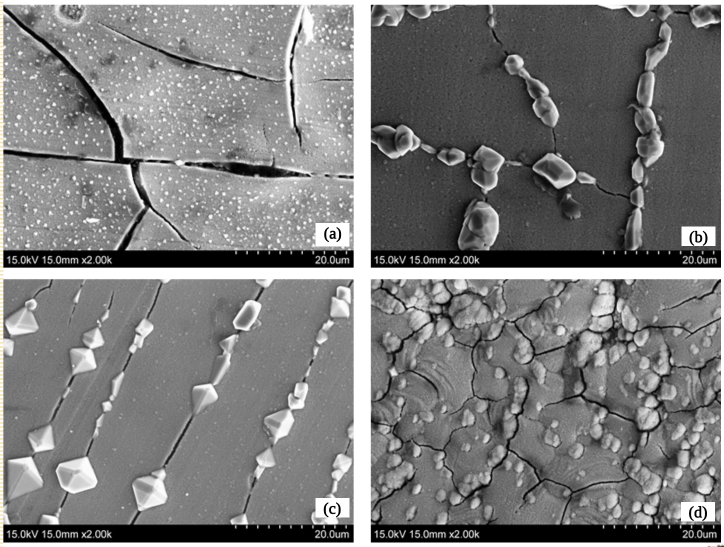




$La_{0.67}Sr_{0.33}MnO_3$

Sputtering Parameters	
Distance (cm)	5
Power (kW)	1.5
Atmosphere	Ar
Flow Rate (sccm)	130
Vaccum (torr)	$7.5\sim8.0\times10^{-3}$
Rotation (rpm)	20
Time (min)	90
Thickness (μm)	3~4

SEM/EDS MICROSTRUCTURE OBSERVATION



Surface coated with $La_{0.67}Sr_{0.33}MnO_3$ & after aging at 800ºC for 10,103 hours.

Substrate:

(a) C1

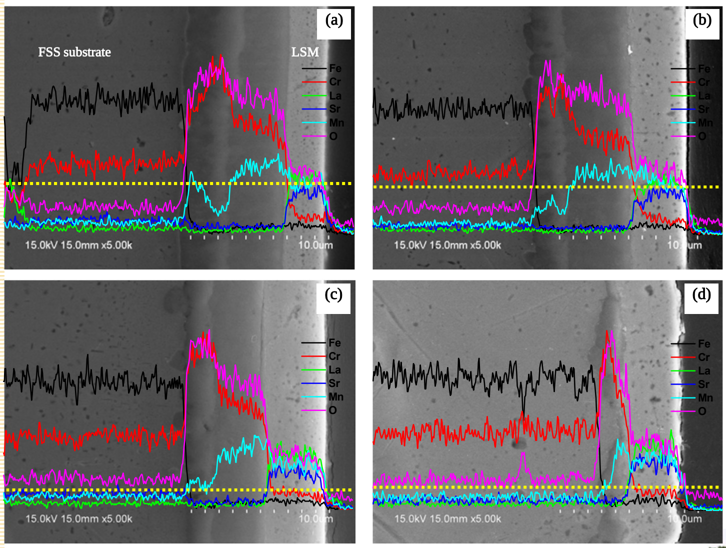
(b) Z1

(c) Z2

(d) I1

Cracks generated on LSM coatings due to volume shrinkage at elevated temper-atures, resulting in $(Mn,Cr)_3O_4$ deposi-tion.

SEM/EDS MICROSTRUCTURE OBSERVATION (cont'd)



Cross-sectional micrographs and elemental concentration profiles of LSM-coated (a)C1, (b)Z1, (c)Z2, and (d)I1 steel substrate after aging at 800 C for 10,103 hours in an air atmosphere.

Thickness of Cr_2O_3 : C1>Z1>Z2>I1

XRD ANALYSIS

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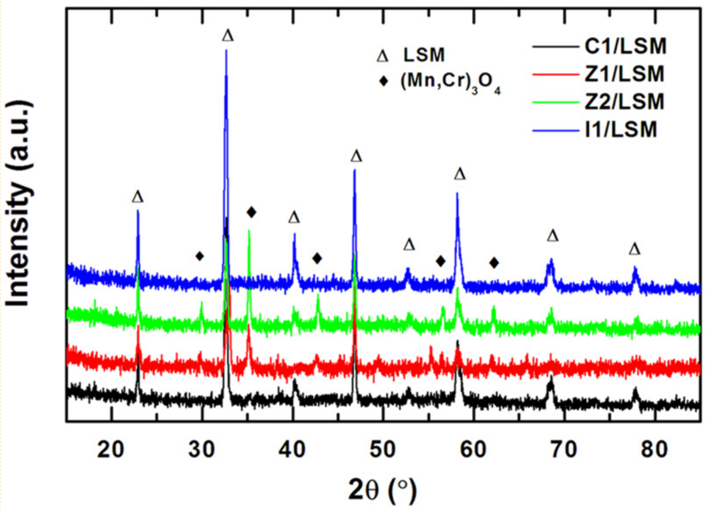

XRD patterns of LSM-coated (a)C1, (b)Z1, (c)Z2, and (d)I1 steel substrate after aging at 800°C for 10,103 hours in an air atmosphere.

characteristic peaks of the (Mn, Cr)$_3$O$_4$ spinels were detected in the aged LSM-coated Z1 and Z2 specimens.

AREA RESISTANCE MEASUREMENT

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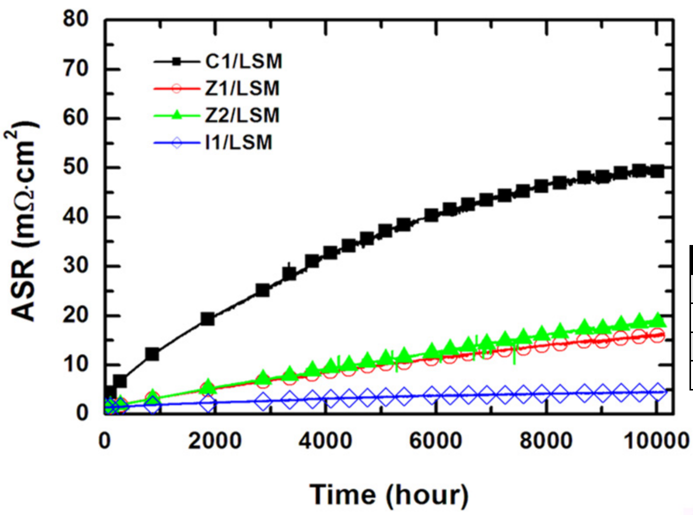

ASR values of LSM-coated (a)C1, (b)Z1, (c)Z2, and (d)I1 steel substrate aging at 800°C for 10,103 hours in an air atmosphere.

Specimen	Initial	Final
C1	3.51	49.9
Z1	1.15	16.4
Z2	1.25	19.4
I1	1.38	4.6

unit: mΩ·cm^2

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PRE-OXIDATION TREATMENT

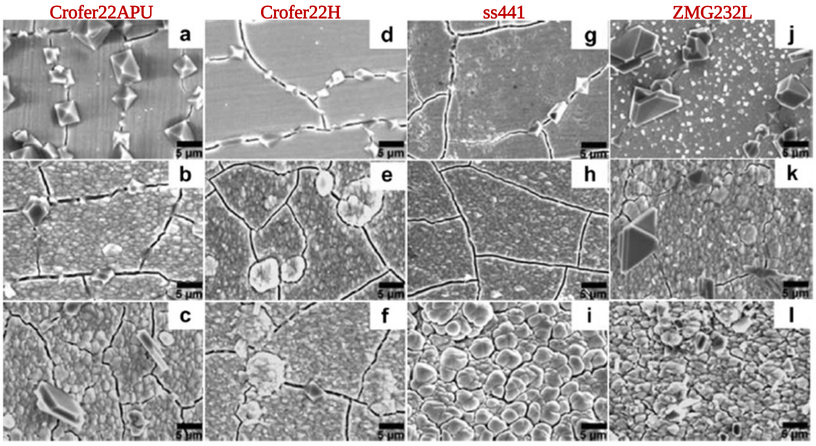

Fig. 4. SEM micrographs (surface morphologies) of LSM-coated (a)–(c) Crofer22APU; (d)–(f) Crofer22H, (g)–(i) ss441 and (j)–(l) ZMG232L after aging at 800 °C for 500 h in air. The substrate's condition was (a) without pre-oxidation; (b) pre-oxidised at 850 °C for 25 h in air; and (c) pre-oxidised at 850 °C for 50 h in air, respectively. (Note: substrate's conditions of (d)–(f), (g)–(i) and (j)–(l) are the same as (a)–(c) in sequence.)

Ref.: *Yang et al., J. Power Sources, 213, 63-68 (2012).*

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PRE-OXIDATION TREATMENT (cont'd)

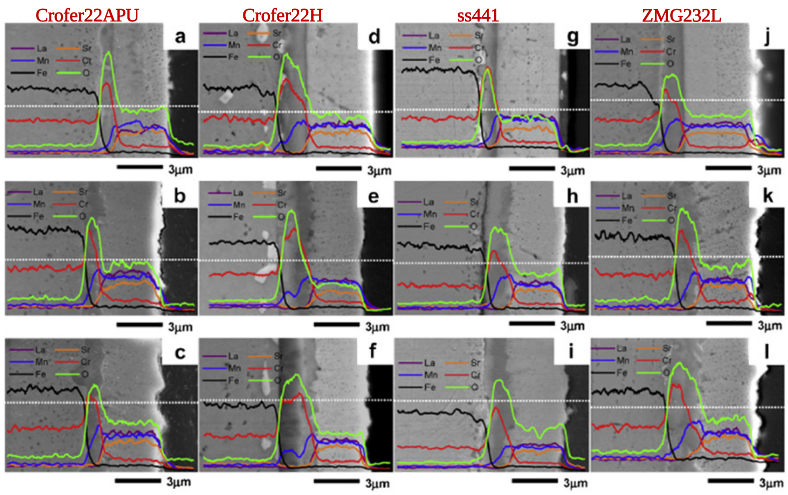

Fig. 3. Cross-section SEM micrographs of LSM-coated (a)–(c) Crofer22APU; (d)–(f) Crofer22H, (g)–(i) ss441 and (j)–(l) ZMG232L after aging at 800 °C for 500 h in air. The substrate's condition was (a) without pre-oxidation; (b) pre-oxidised at 850 °C for 25 h in air; and (c) pre-oxidised at 850 °C for 50 h in air, respectively. (Note: substrate's conditions of (d)–(f), (g)–(i) and (j)–(l) are the same as (a)–(c) in sequence.)

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PRE-OXIDATION TREATMENT (cont'd)

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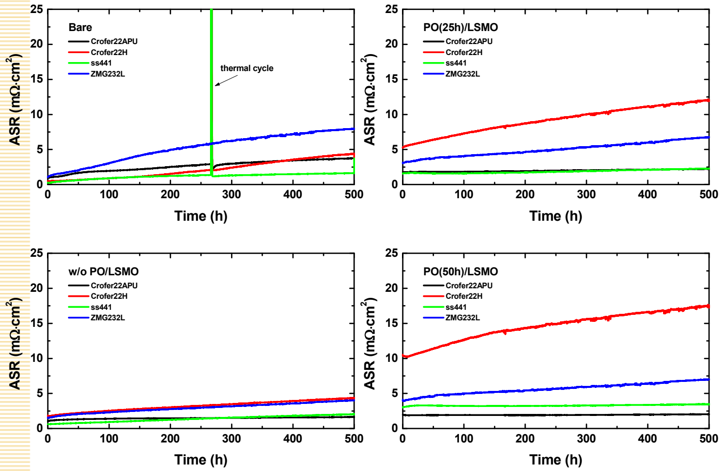
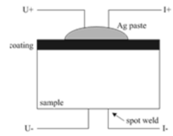


After 800°C, 500 h

1	3
2	4

1 Bare
2 w/o PO/LSM
3 PO(25h)/LSM
4 PO(50h)/LSM

Patent:US7,663,384B2



PRE-OXIDATION TREATMENT (cont'd)

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The pre-oxidation treatment is a simple and effective way to inhibit the diffusion of Cr element from the oxide scale to the surface, and it lowers the increasing rate of ASR during aging at high temperatures.

ASR (mΩ·cm²)

Sample	Crofer22APU		Crofer22H		ss441		ZMG232L	
@800°C	0 h	500 h	0 h	500 h	0 h	500 h	0 h	500 h
Bare	0.94	3.76	0.50	4.41	0.28	1.64	1.07	7.96
W/O PO/LSM	1.05	1.63	1.89	4.31	0.62	2.01	1.59	4.03
PO(25h)/LSM	1.77	2.20	5.31	11.89	1.56	2.25	3.17	6.77
PO(50h)/LSM	1.97	2.02	10.54	17.24	2.97	3.44	4.14	7.00

TWO-STEP COATING

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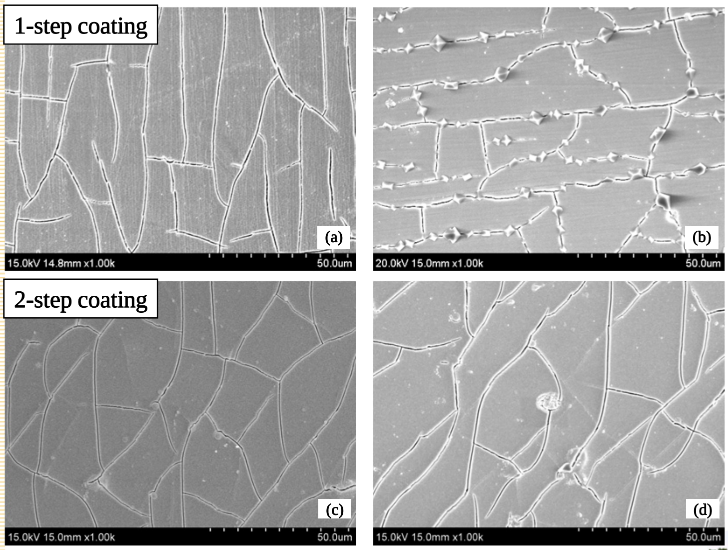

Comparison of the surface morphology of Z2/LSM coated by 1- & 2-step process after aging at 800°C for 500 hours.

There were no penetrate-through cracks generated in the LSM layer for the LSM-coated specimen by introducing two-step coating process.

Thickness of LSM film: 4 μm

SUMMARY

IC&Seals R&D Group

- ✓ A dense and continuous of $La_{0.67}Sr_{0.33}MnO_3$ protective films with a thickness of about 3.5 μm were successfully deposited on the surfaces of the four commercial ferritic stainless steels by using pulsed DC magnetron sputtering.
- ✓ The initial values of ASR for the LSM-coated C1, Z1, Z2, and I1 were 3.51, 1.15, 1.25, and 1.38 mΩ•cm^2, respectively, at 800°C. The corresponding ASR values became 49.9, 16.4, 19.4, and 4.6 mΩ•cm^2 respectively after aging at 800°C for 10,103 hours in an air atmosphere.
- ✓ The thickness of Cr_2O_3 scale for the LSM-coated C1, Z1, and Z2 substrate aged at 800°C for 10,103 hours are about 3.5 μm, 2.5 μm, and 2.0 μm, respectively.
- ✓ Pre-oxidation treatment and a two-step coating process were successfully applied to mitigate the Cr diffusion outward and penetrate-through cracks generated in the LSM layer while calcination treatment.

IC&Seals R&D Group

Acknowledgement

Special thanks to INER's SOFC project P.I., Dr. Ruey-Yi Lee, and thanks all the co-workers of SOFC team at INER.

Thank You for Your Attention!

Contact: ckliu2@iner.gov.tw

Fabrication of the anode-supported solid oxide fuel cell with composite cathodes and the performance evaluation upon long-term operation

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Chemical Engineering Division, Institute of Nuclear Energy Research (INER)
Atomic Energy Council, Taiwan ROC

39th International Conference and Expo on Advanced Ceramics and Compounds
12th International Symposium on Solid Oxide Fuel Cells (SOFC): Materials, Science and Technology

January 29, 2015

INER Institute of Nuclear Energy Research

About INER

The Institute of Nuclear Energy Research (INER) was founded in 1968 and currently under the administration of Atomic Energy Council (AEC), Taiwan, ROC. INER is the sole national research institute to promote peaceful applications of nuclear science in Taiwan.

As the sole national research institute for nuclear science and technology studies, aside from the above research activities in supporting AEC's regulatory practices, INER's primary R&D objectives are maintaining nuclear safety, innovating environment and energy technologies, and promoting nuclear technologies in civilian application. INER's major research areas include nuclear energy, new/renewable energy, radiopharmaceuticals and plasma technology. All these R&D projects operate in close matrix with eleven functional divisions.

About INER

To comply with the energy policy of the government, INER has initiated an integrated energy research program using our nuclear technologies, consisting of several projects, to develop new/renewable and eco-friendly energy technologies with lower cost and high efficiency. The goal of the program is to fulfill the national requirement on CO2 reduction, to reserve energy sources, and to foster new energy technologies in the country. The projects in the program are: small/medium size wind turbine system, high concentration photovoltaic system, cellulosic ethanol technology, and fuel cells etc.

As a national research institute, INER possesses a strong research team composed of nearly 500 talented researchers with graduate degrees. In the future, INER is determined to actively meet the severe domestic challenges in energy and environmental areas. Through the use of research results, INER aims to bring welfare to the people as well as feedback to the society and the country.

About INER

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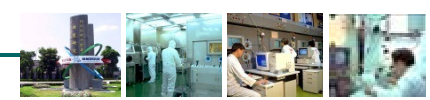
Policy Instruction
Government Agencies
Nuclear Safety Technology • Environmental and Energy Technology • Radiation Application Technology • Marketing
Technical Support
Technical Service
Marketing
Public
Institute of Nuclear Energy Research
Industries



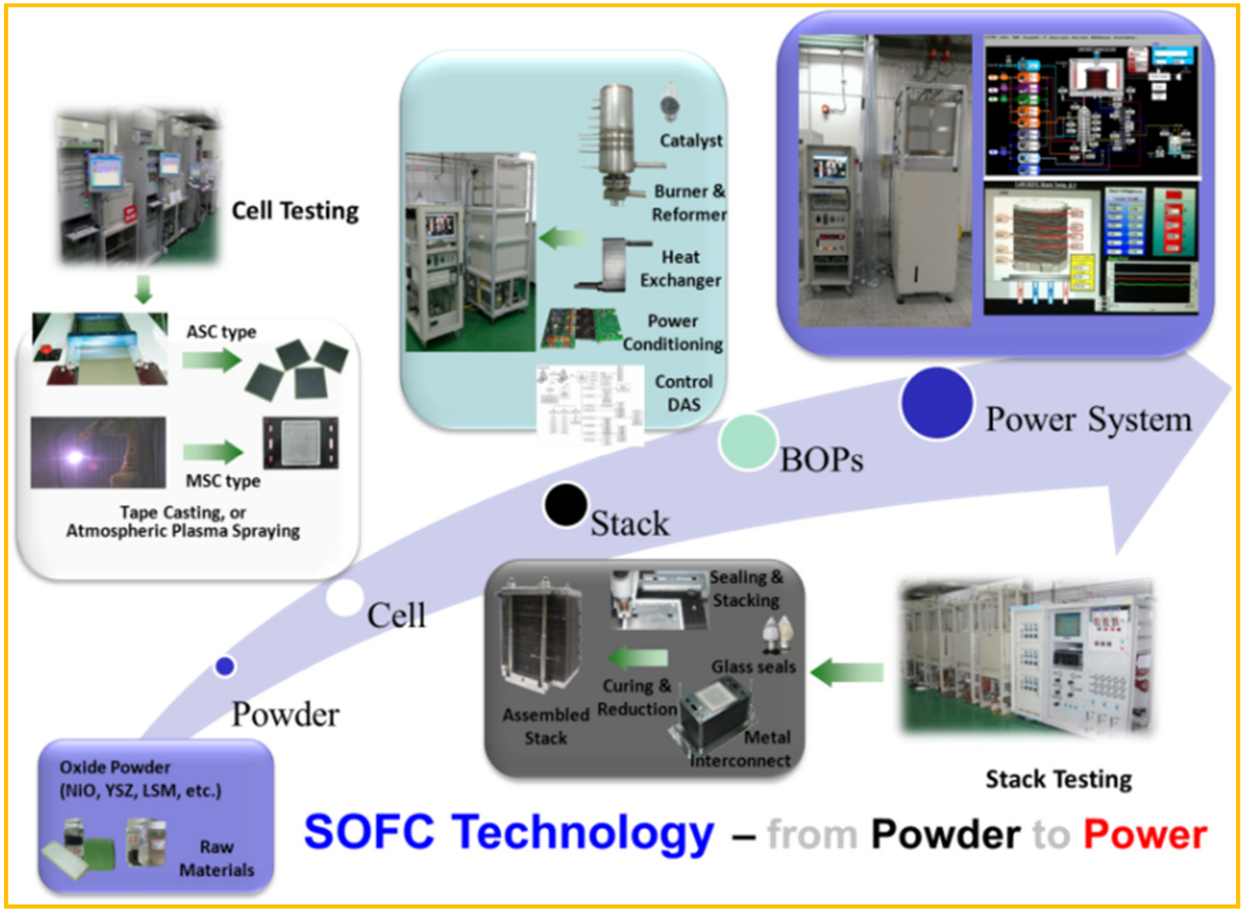
SOFC at INER

A. In compliance with the national energy policy at Taiwan, the SOFC project at the Institute of Nuclear Energy Research (INER) focuses on establishing manufacture capability of SOFC-MEA/components and integration technology of SOFC power system.

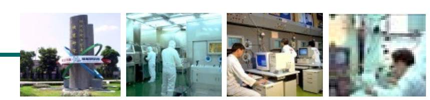
B. Since the commitment to developing the SOFC technology in 2003, this institute has set its short-term target of 1~5 kW SOFC distributed power generation systems and will then extend its long-term prospect to integration with the Integrated Gasification Combined Cycle (IGCC) technology for biomass and coal based central power generation and large demonstration systems.

C. Cooperation with universities, research institutes, local companies.

SOFC at INER



- 2012 ➔ kW SOFC power system installation contract signed with CSC
- 2013/June ➔ 500 hour SOFC system demonstration for the first time



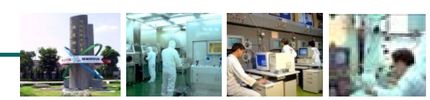
Outline

I. Introduction

II. Experimental

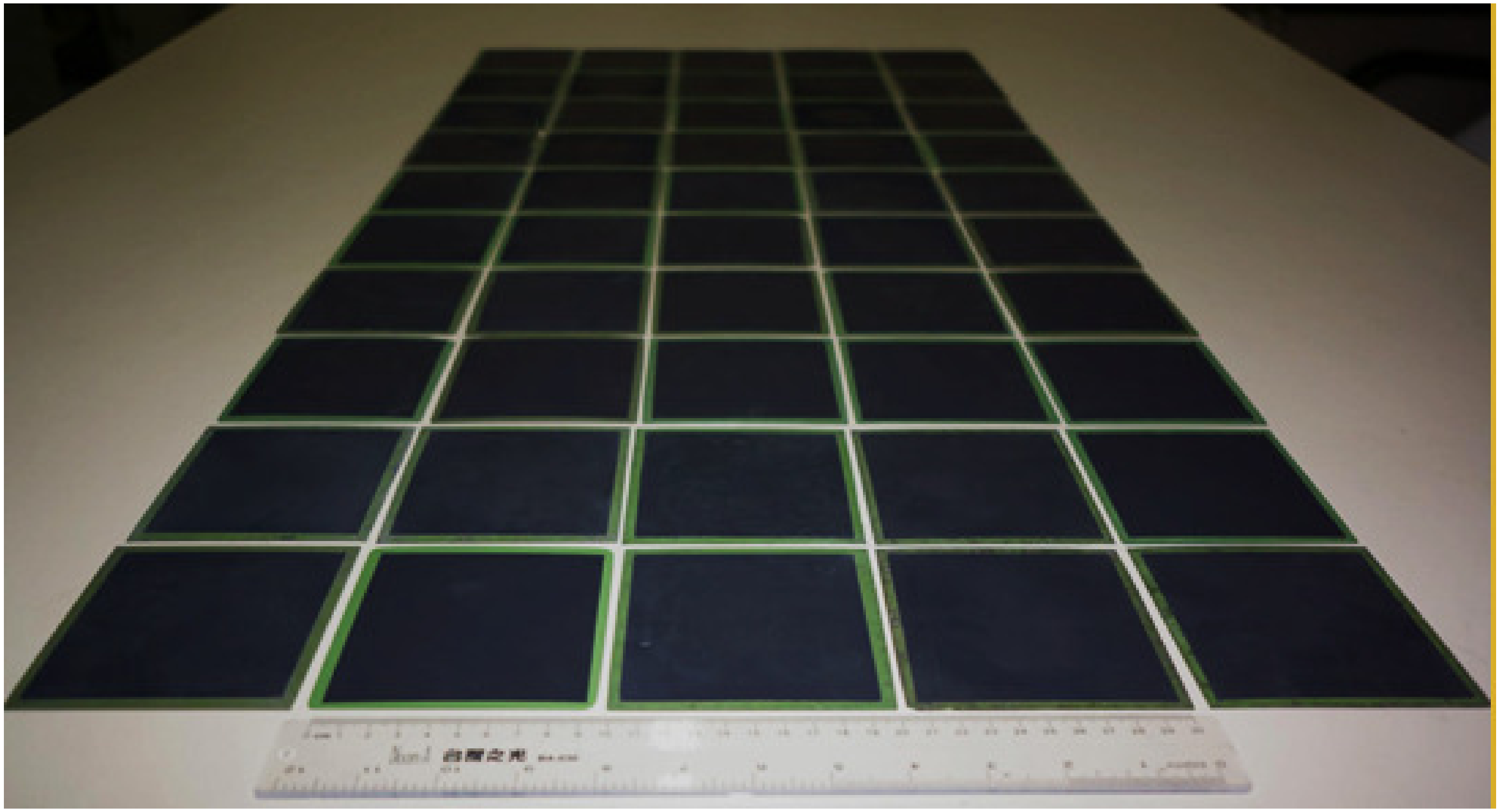
III. Experiment Results

IV. Summary



Small-scale production line

Good production yield for cells with dimensions of 10 × 10 cm^2 in size



Outline

I. Introduction

<u>II. Experimental</u>

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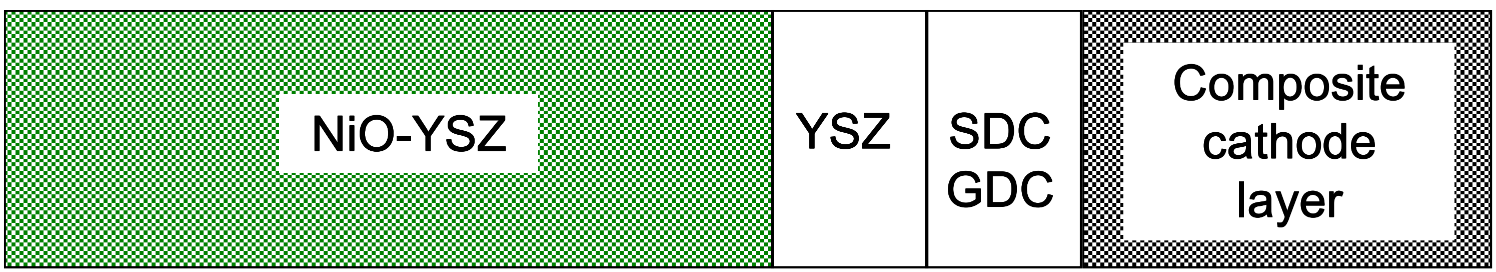
IV. Summary

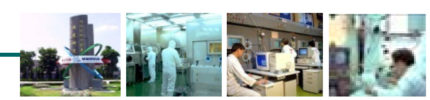
NiO-YSZ | YSZ | SDC | SDC-SBSC

- NiO-YSZ anode green substrate:
  Tape casting / mass production

- YSZ electrolyte and SDC buffer
  Thin film process / well-dispersion

- The composite cathodes
  Eliminate the mismatch of material





Outline

I. Introduction

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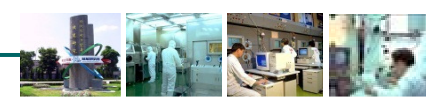
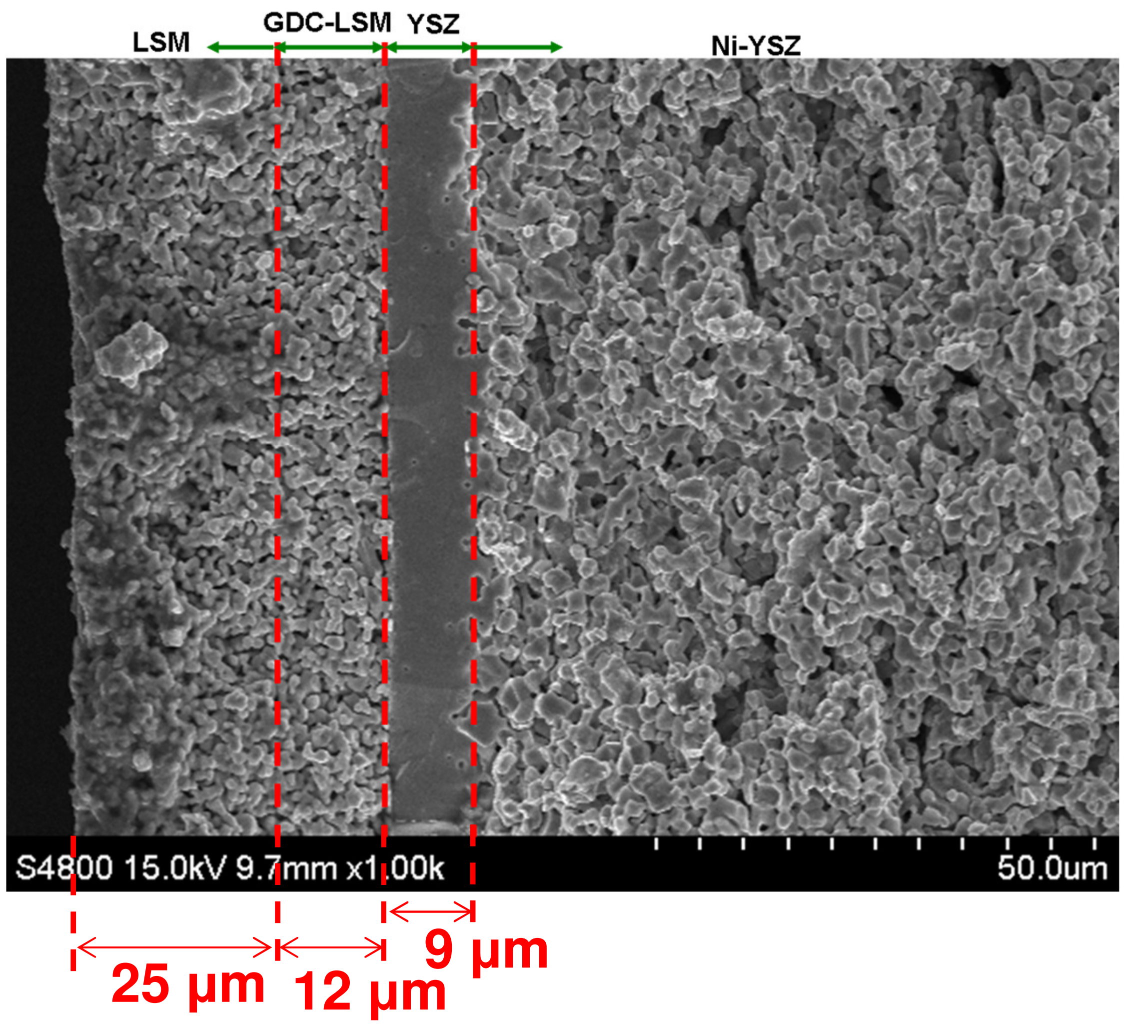
<u>III. Experiment Results</u>

IV. Summary

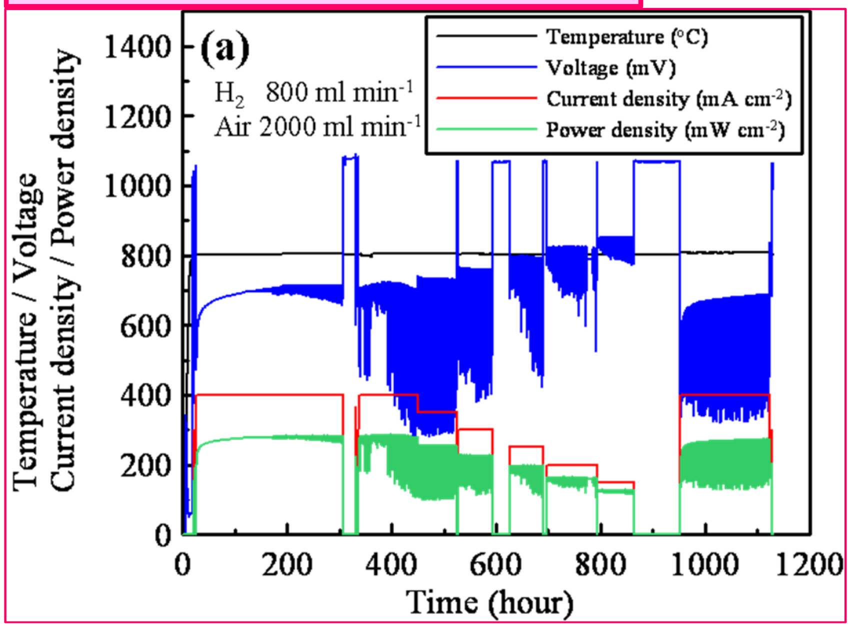


Experimental results

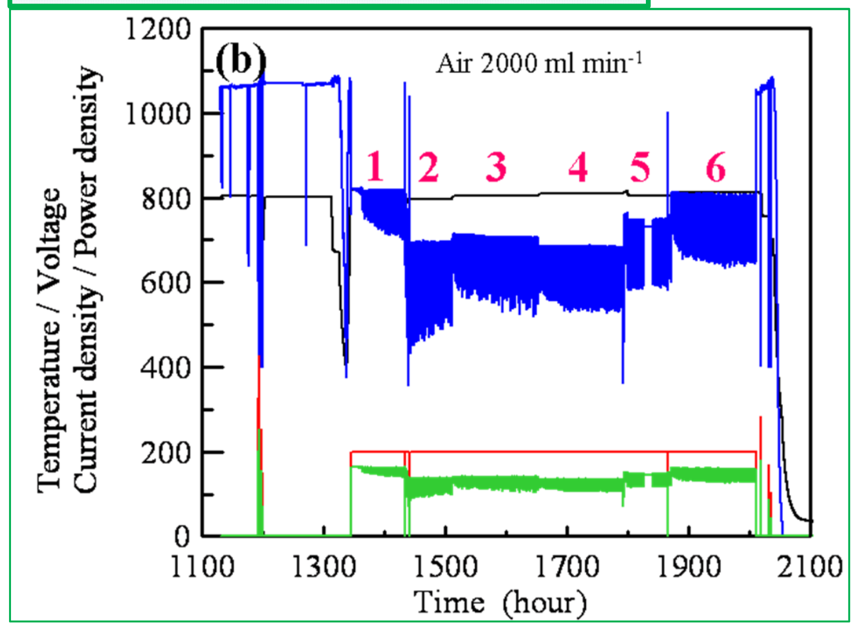


Experimental results

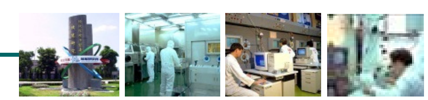
Effects of the current density



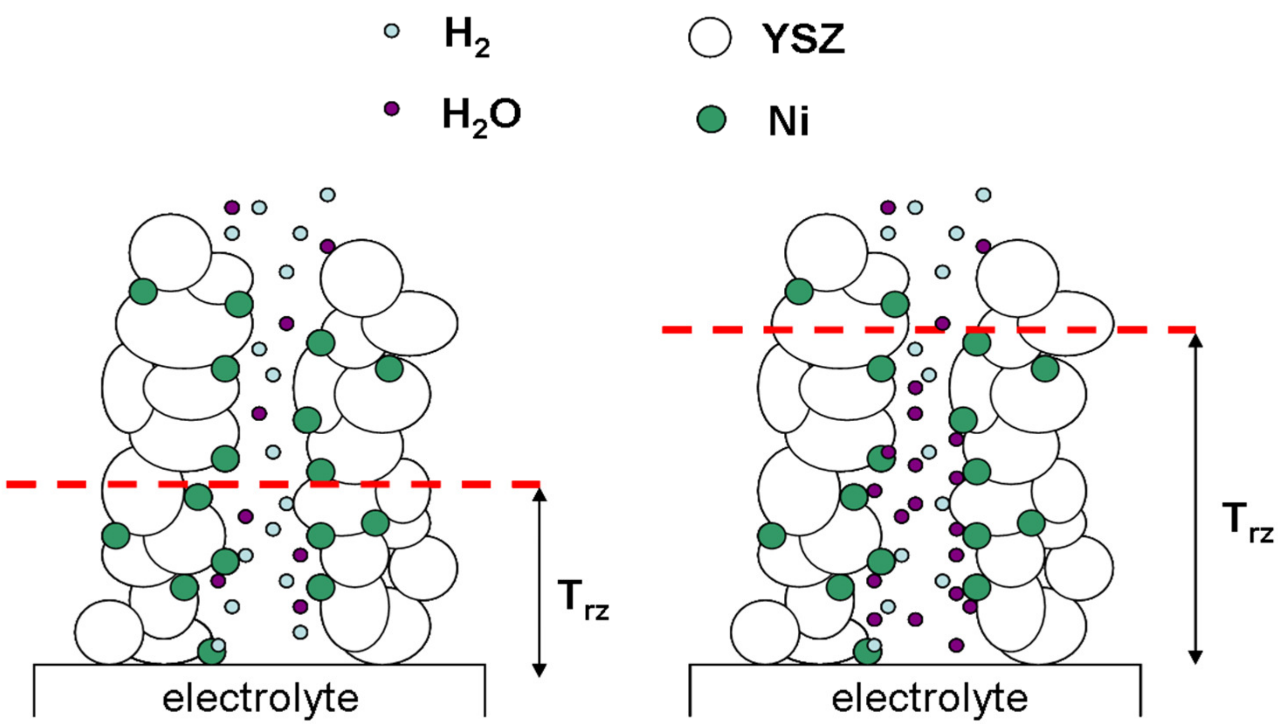
Effects of the concentration and flow rate of fuel



The operation conditions from region 1 to region 6 are: (1) 800 H_2, (2) 200 H_2/600 N_2, (3) 320 H_2/480 N_2, (4) 200 H_2, (5) 400 H_2 and (6) 800 H_2 ml min^{-1}, respectively.



Experimental results

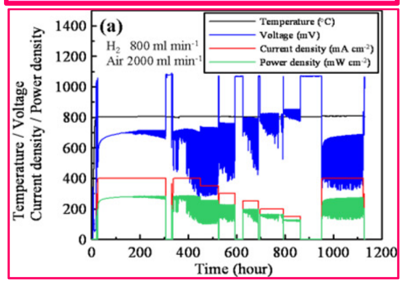


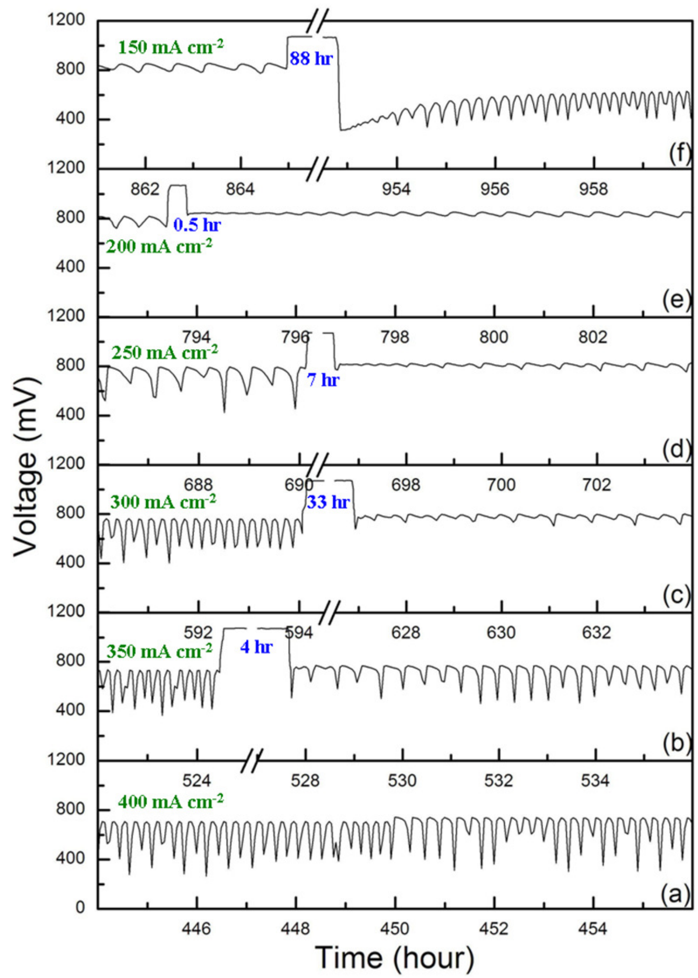
The schematic diagram of the boundary migration of the reaction zone caused by the concentration polarization in the anode side. T_{rz} : thickness of the reaction zone.

Experimental results

The cell voltage variations as the change of constant current density

Effects of the current density





Change of constant current density:

150 to 400 mA cm^{-2}

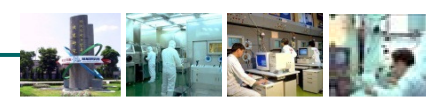
200 to 150 mA cm^{-2}

250 to 200 mA cm^{-2}

300 to 250 mA cm^{-2}

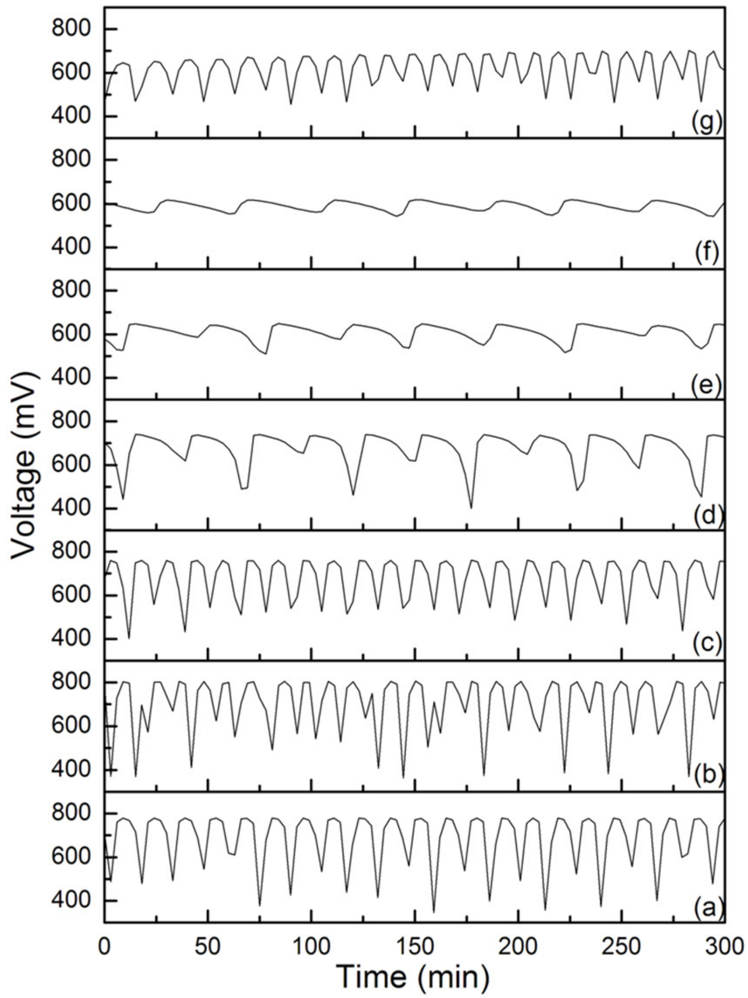
350 to 300 mA cm^{-2}

400 to 350 mA cm^{-2}



Experimental results

The cell voltage variations as the change of constant current density



400 mA cm^{-2}

150 mA cm^{-2}

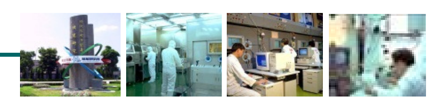
200 mA cm^{-2}

250 mA cm^{-2}

300 mA cm^{-2}

350 mA cm^{-2}

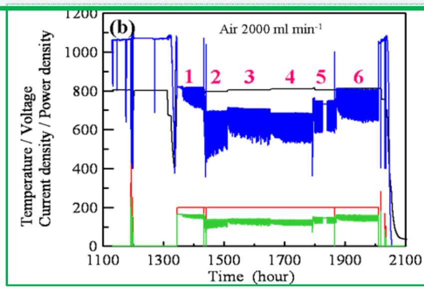
400 mA cm^{-2}



Experimental results

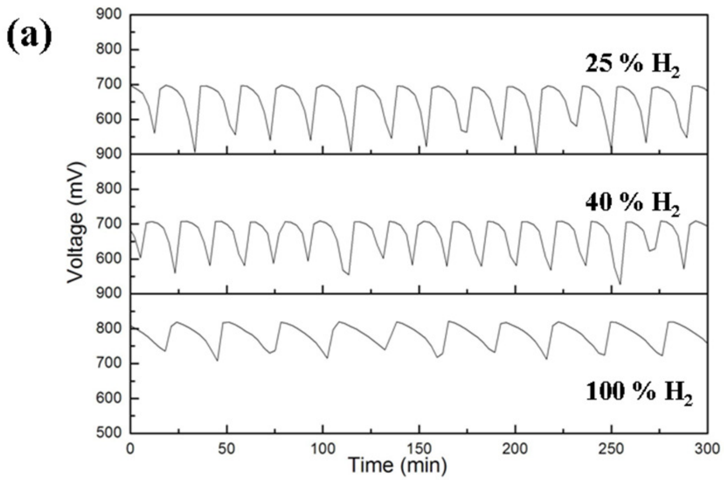
The cell voltage variations as the change of concentration / flow rates

Effects of the concentration / flow rate

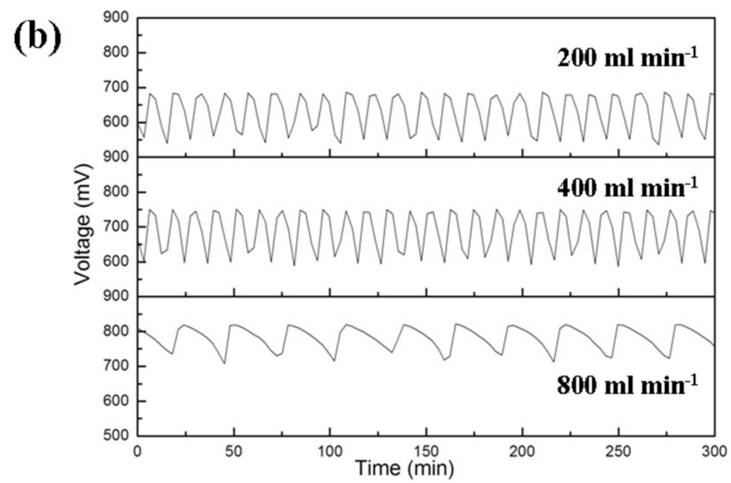


Low hydrogen concentration or flow rate

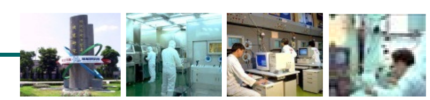
- Decrease of the hydrogen concentration inside the reaction zone
- Increase of concentration polarization
- High value of V_m and the low value of t_m.



Cell voltage vs. time under different hydrogen concentrations



Cell voltage vs. time under different hydrogen flow rates



Experimental results

High current density

↓

High concentration of water vapor in the reaction zone

Low hydrogen concentration or flow rate

↓

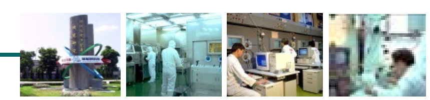
Decrease of the hydrogen concentration inside the reaction zone

↓

Increase of concentration polarization

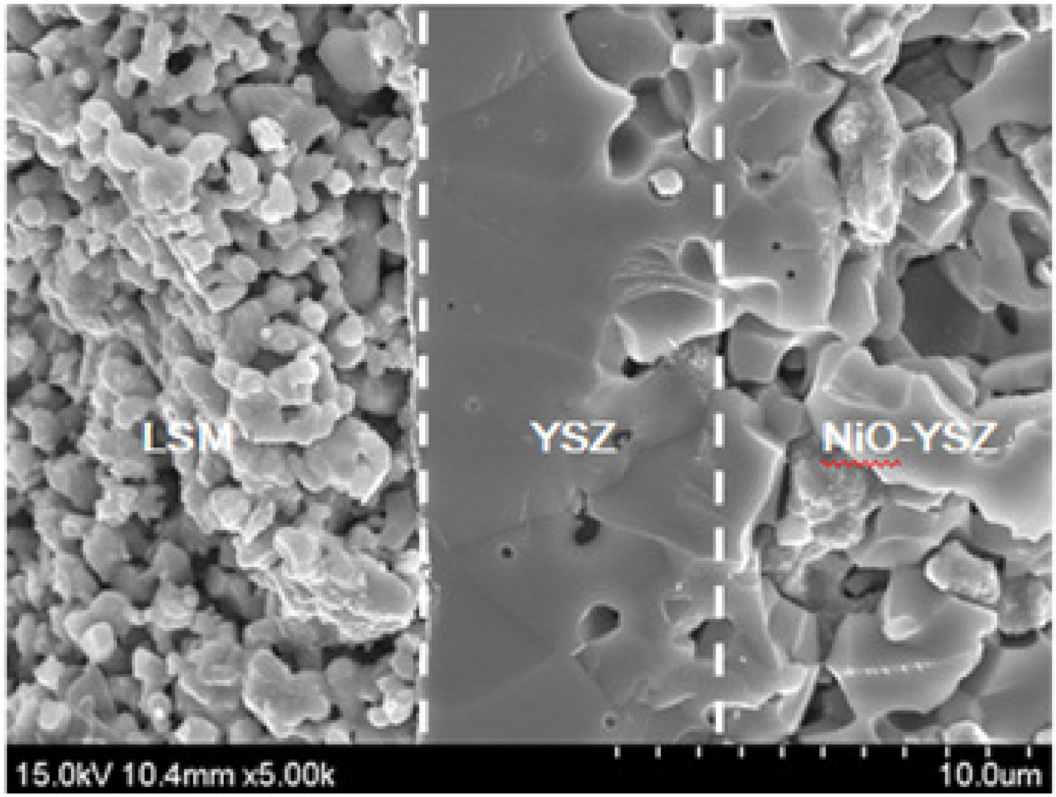
↓

V_m increase and t_m reduced
(rapid movement on boundary of the reaction zone)

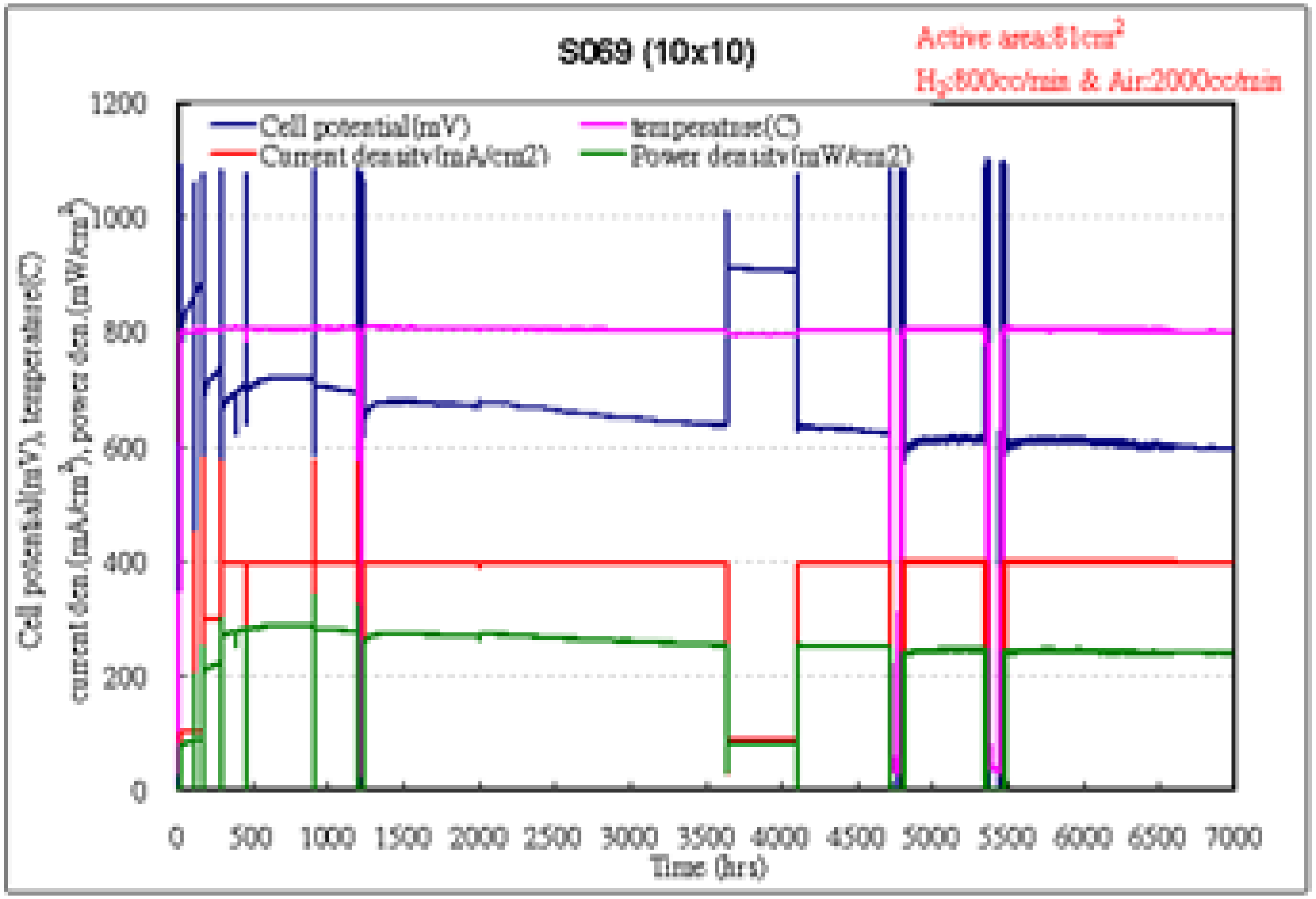


Experimental results

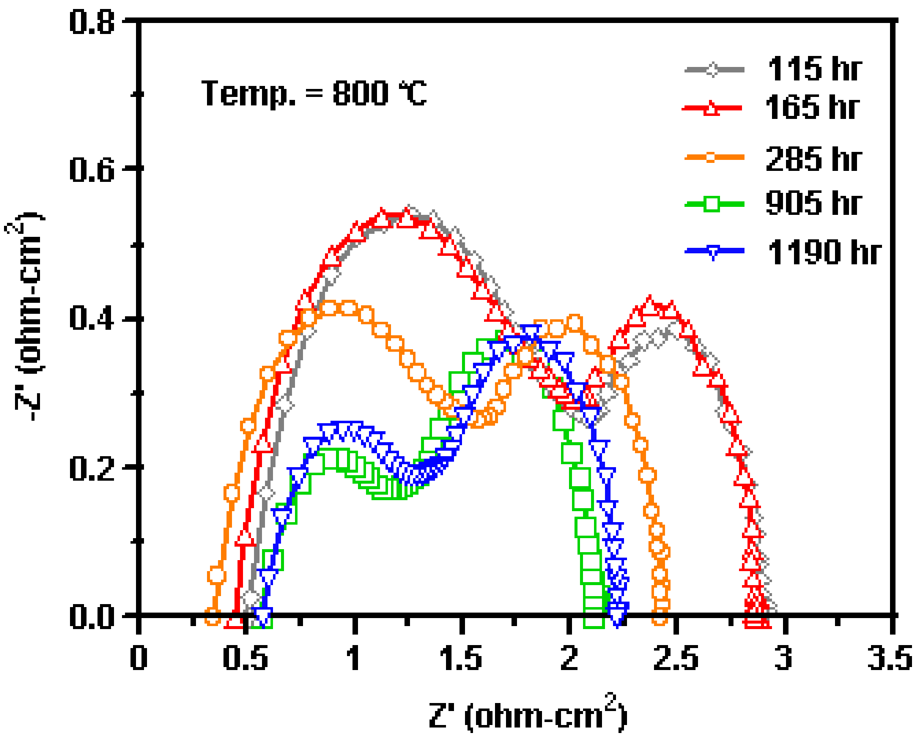
The single cell picture and the cross-section SEM microstructure

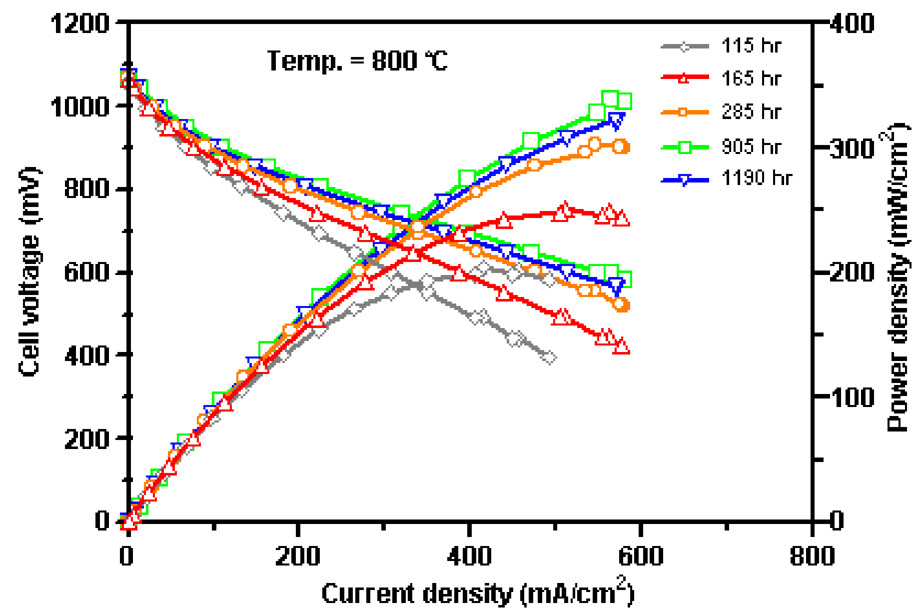


Experimental results



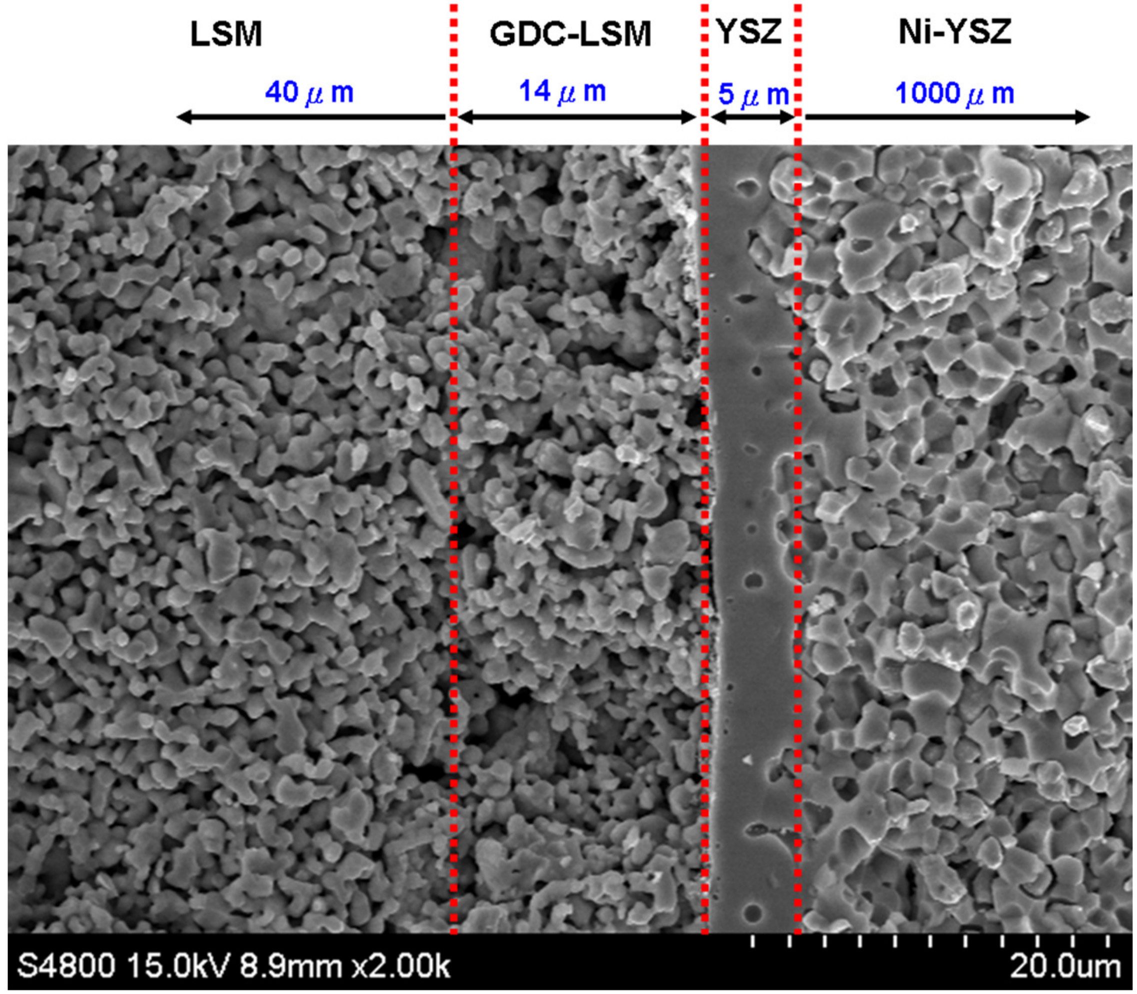
Experimental results



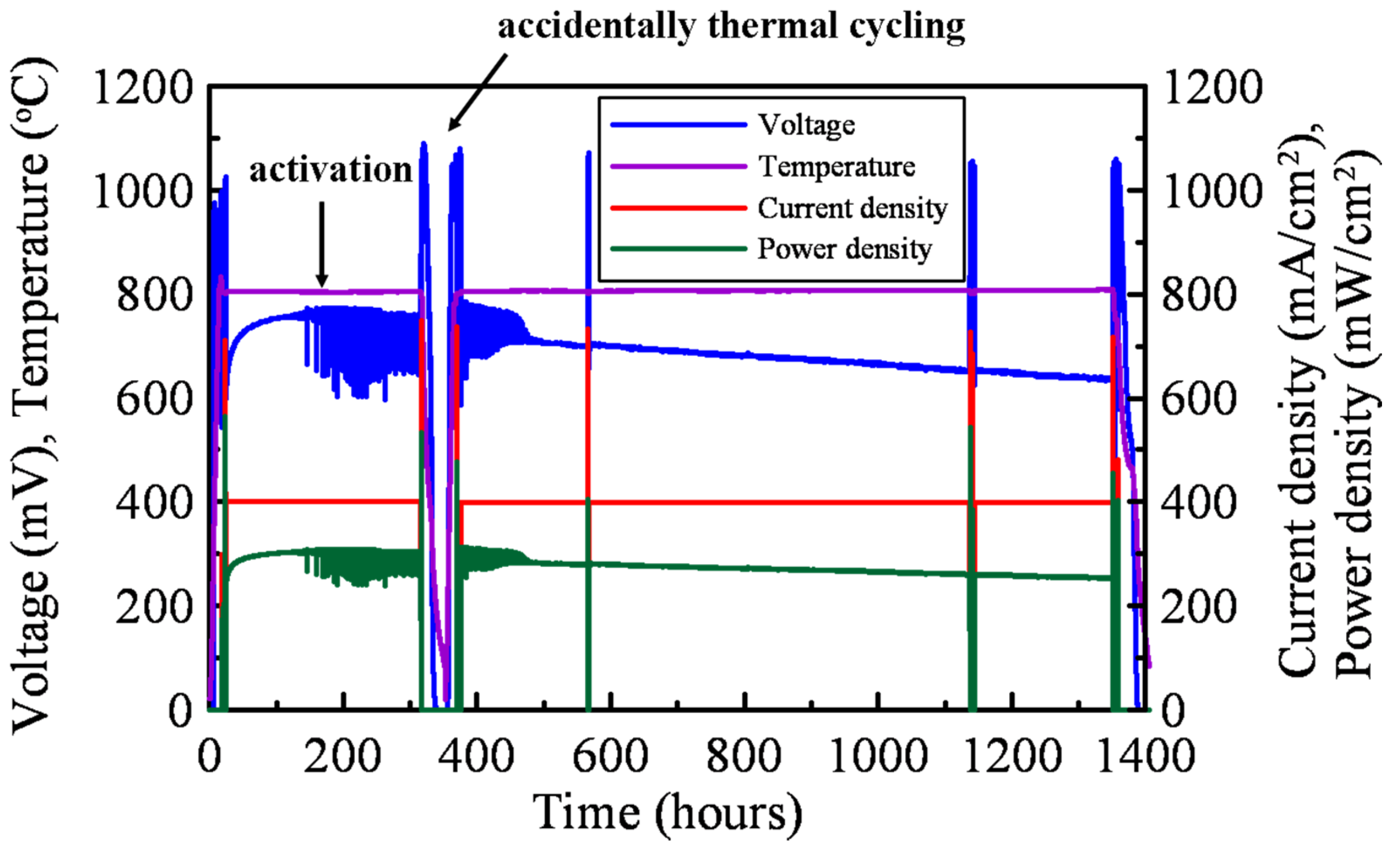


Experimental results

The single cell picture and the cross-section SEM microstructure

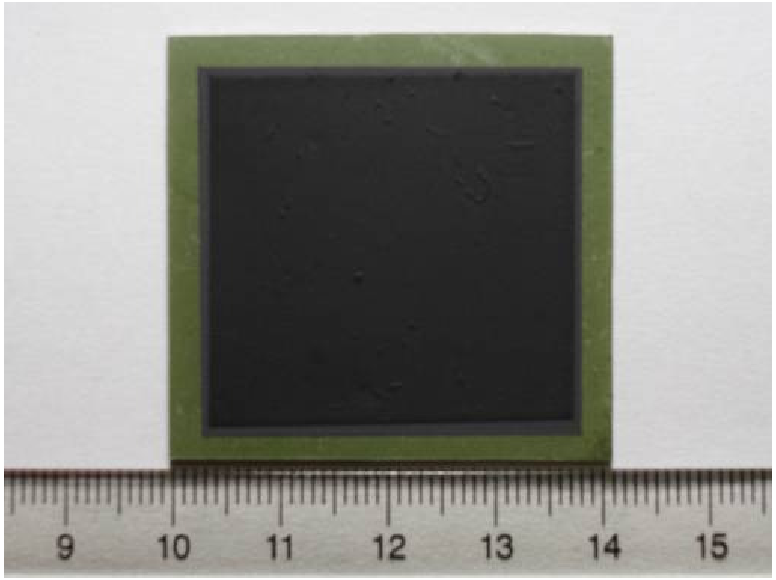


Experimental results

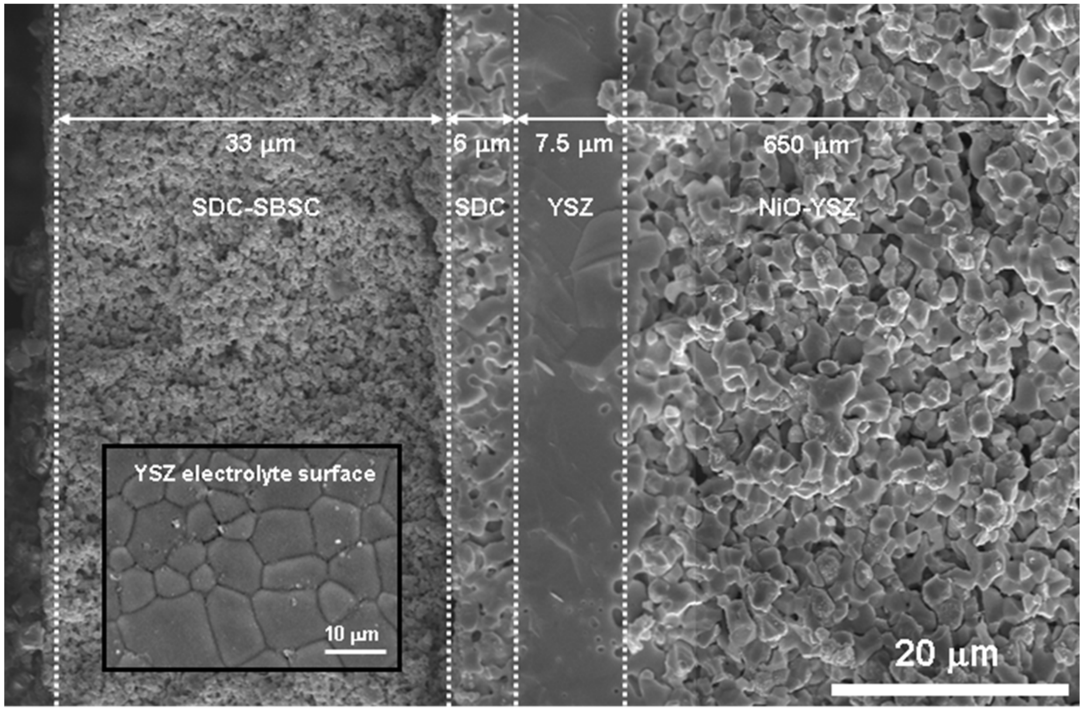


Experimental results

The single cell picture and the cross-section SEM microstructure

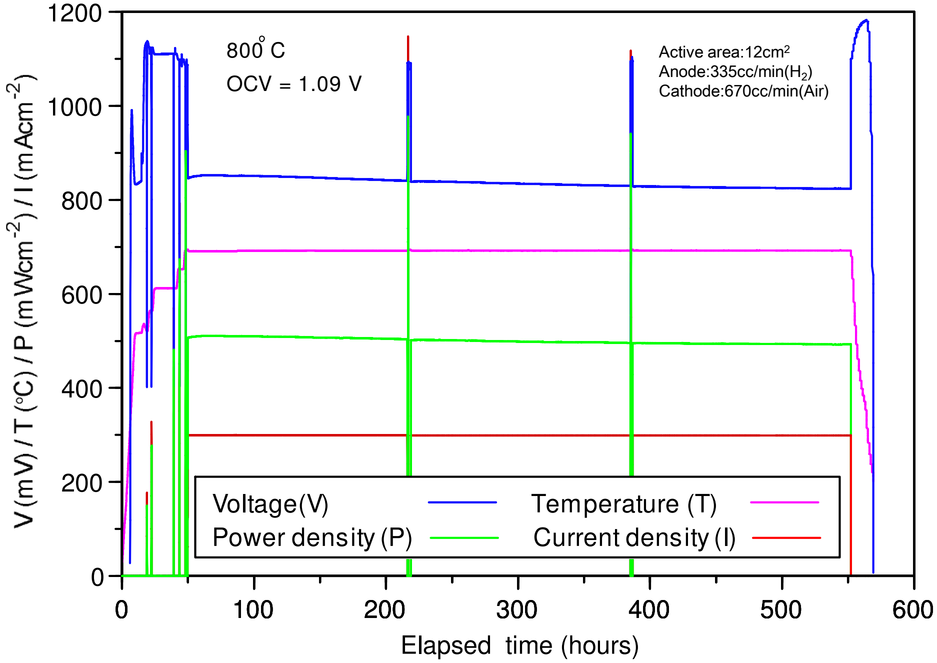


*commercial spec. 10 × 10 cm^2 is available at INER



Experimental results

The single cell performance test results



The single cell after certain activation process reaches stabilization. TPBs are generated during activation process. Impedance plots for the cell at various activation times show that the impedance arc shifts to lower resistance region and finally approaches a limited value. The shift phenomenon is contributed by the increasing activity of the cell from the bred TPBs.

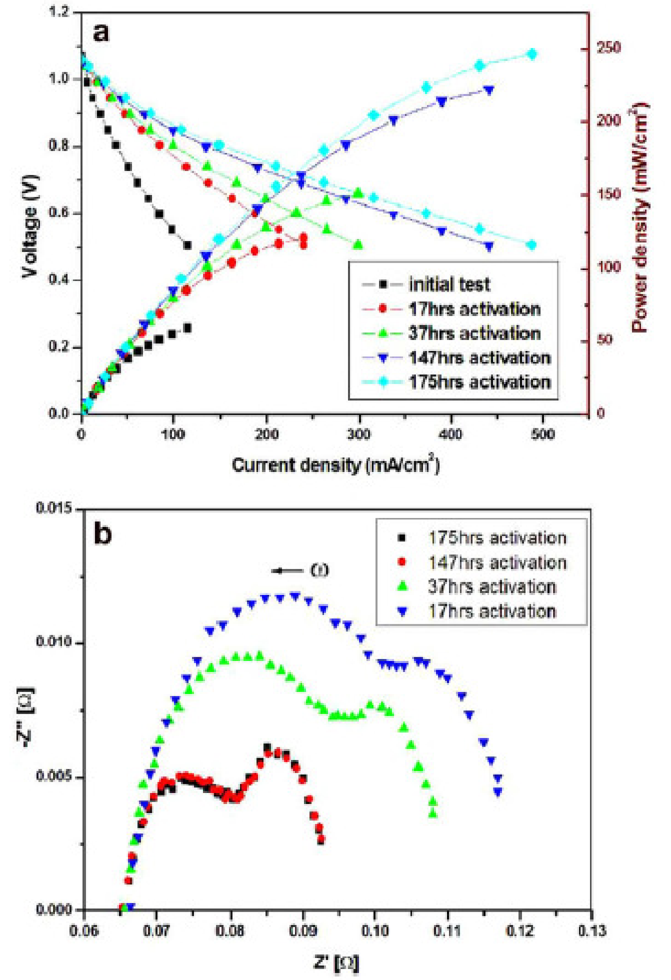
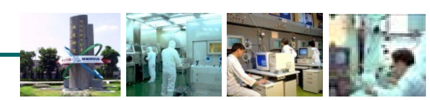
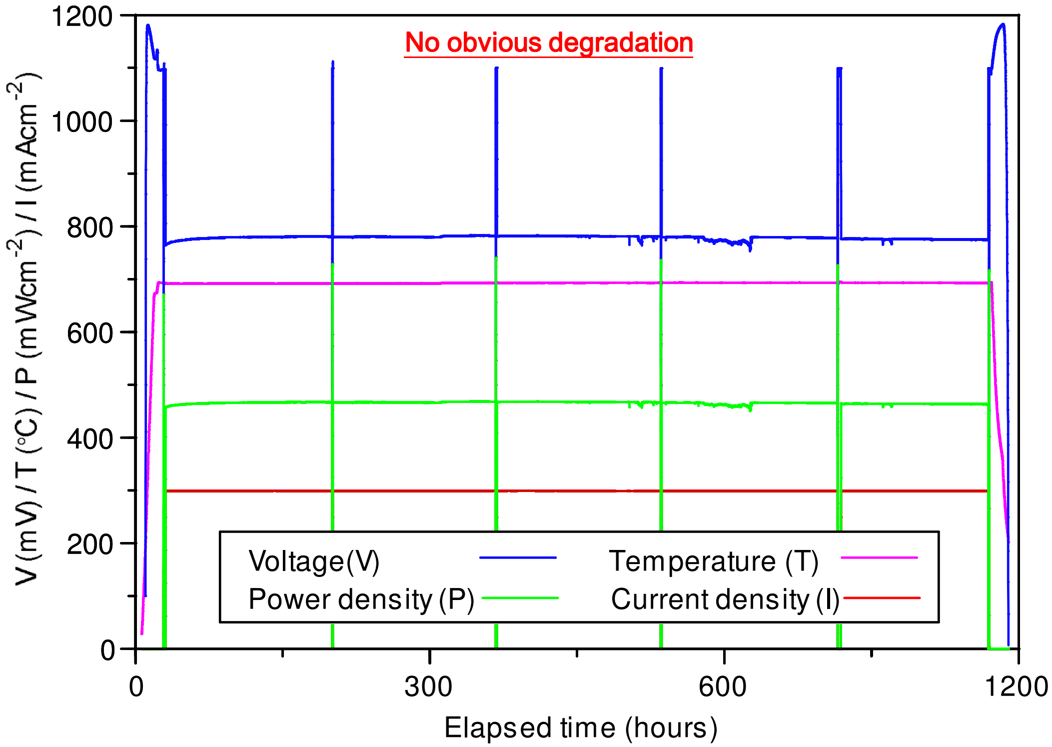


Fig. 1. (a) Performance test via various activation times; (b) A.C. impedance via various activation times.



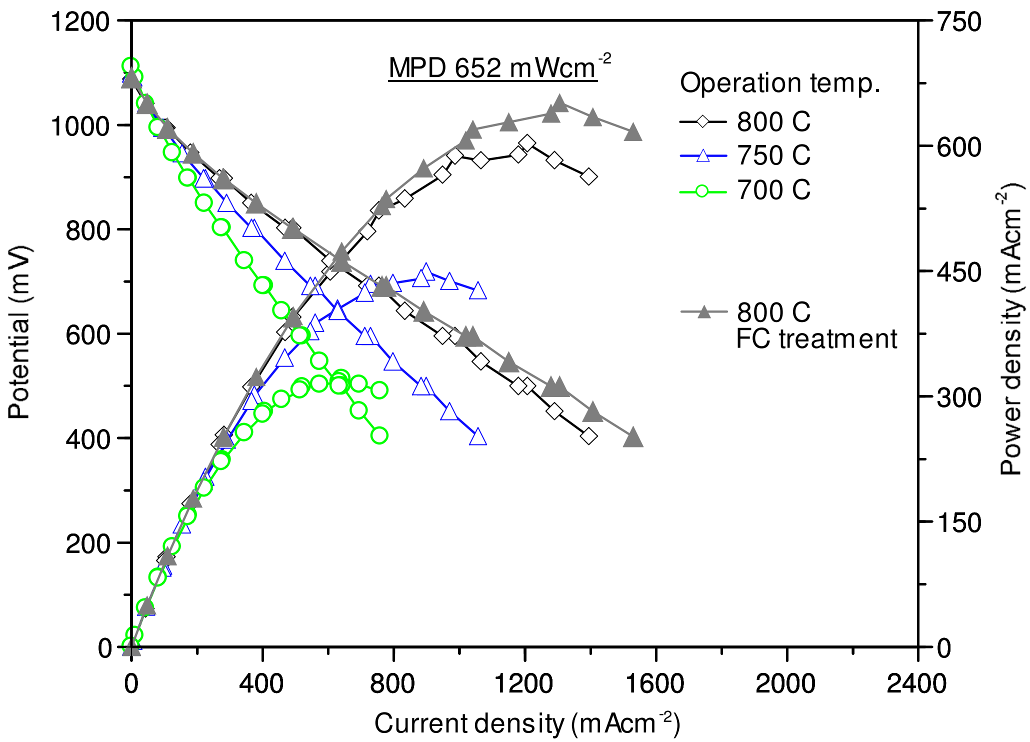
* Wang, *et al.,* Electrochemistry communications

Experimental results



Further operation exhibits stabilization.
The degradation rate is < 0.5 % / khr with 1,000 hour operation.

Experimental results



Operation temperature (˚C)	700	750	800
OCV (voltage)	1.11	1.10	1.09
Power density ($mWcm^{-2}$)	321	449	603

The electrochemical performance exceeds the general level INER-SOFC-MEA.
The MPD is 652 mW/cm^2 (at 800 °C, OCV = 1.099 V)

With SDC-SBSC composite cathode, performance behavior twice the power density than typical INER-SOFC-MEA

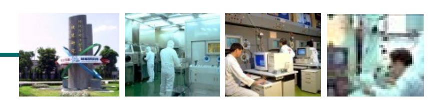
Outline

I. Introduction

II. Experimental

III. Experiment Results

IV. Summary



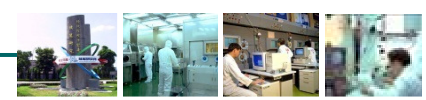
Summary

- The SBSC ($SmBa_{0.5}Sr_{0.5}Co_2O_{5+\delta}$) powders were synthesized via glycine nitrate combustion process and the layered perovskite structure can be obtained at a calcination temperature above 1000 °C.

- The TEC value of the composite cathode SBSC-SDC is ~ 22 % lower than that of pure SBSC, resulting in an excellent adhesion between the porous SBSC-SDC cathode and the SDC buffer.

- For the cell performance, the maximum power reaches 652 mW cm^{-2} after certain operation. This result identifies that the SBSC cathode material is compatible with the YSZ electrolyte via suitable structure design of SDC buffer layer and SDC-SBSC composite cathode layer.

- Reproduce the single cells with 10 × 10 cm^2 in size is necessary to confirm the feasibility and obtain a repeatable performance behavior before going to the production line.



Acknowledgement

Dr. Maw-Chwain Lee

Mr. Sang-Chih Fang

Dr. Yang-Chuang Chang

Dr. Chun-Hsiu Wang

Mr. Jen-Cheng Chang

Dr. Rung-Je Yang

Mr. Ling-Song Lee

Ms. Wang-Ting Huang

Dr. Liang-Cheng Wen

Dr. Ta-Nan Lin

Mr. Wei-Xin Kao

Mr. Hong-Yi Kuo

Mr. Jen-Yuan Kuo

Mr. Chun-Yen Yeh

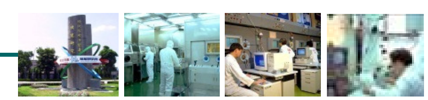
Dr. Ruey-yi Lee

Mr. Shih-Wei Cheng

Dr. Ming-Wei Liao

Mr. Yu-Ming Chen

INER-SOFC-MEA group devoted in the technical development area of SOFC in the past decade, making progress from powder to power. Efforts of the people have been acknowledged.



Thank you for your attention