PRODUCTION OF SINGLE CELL ANODE-SUPPORTED SOFC USING NiO/YSZ-YSZ-LSM/YSZ POWDER MATERIALS

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A thesis submitted in fulfillment of the requirement for award the Degree of Doctor of Philosophy

Faculty of Mechanical and Manufacturing Engineering

Universiti Tun Hussein Onn Malaysia

AUGUST, 2015

For my parents, wife, son and daughter:

Sri Asmini, Sri Sulistyowati, Nurin Asyiah Listyasari,

Akbar Fitra Listyono, Yuniar Lutfia Listyadevi

ACKNOWLEDGEMENT

In the name of Allah, Most Gracious, Most Merciful

Praise be to Allah SWT. The Cherisher ans Sustainer of the world for without His permission, this thesis cannot be completed as requested. The period I have spent as a PhD student until graduated at the Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia was a very interesting and rewarding time. So I would like to thank all those involved in completion of this thesis.

Firstly, I would like express my sincere appreciation to my supervisors, Prof Ir. Dr. Saparuddin bin Ariffin and Assoc. Prof. Dr. Shahruddin bin Mahzan for the guidance, support, continual encouragement, discussion, contribution to ideas and advice given through-out the duration for this research. I gratefully acknowledged the financial support throught my candidature from Diponegoro University Semarang, Indonesia, and on going International Postgraduate Student Scholarship sponsored by the Centre of Graduate Studies (CGS) Universiti Tun Hussein Onn Malaysia.

I would like to dedicate this thesis to my parents Barilah binti Karyo Sentono (Alm), Sri Asmini binti Achmad and my colleagues at Diponegoro University, Dr Ir. Berkah Fajar Tantowi Kiyono, Ir. Bambang Pujianto, and my friend Suparmo in Ragil ceramic company, for their care and wishes for the best in career.

I owe very special thanks to my beloved wife, Sri Sulistyowati, my beloved son, Akbar Fitra Listyono, and my daughters Nurin Aisyiah Listyasari and Yuniar Lutvia Listyadevi, for their tremendeous supports on my study. Sri Sulistyowati, your patience, encourage and thought to keep up the spirit finishing the research. You make everything mild and pleasant.

I wish to thank to my close friends, Arhami, Nurdin Ali, Tutut Herawan, Agus Dwi Anggono, Pratama Jujur Wibawa, Bana Handaka and others in Persatuan Pelajar Indonesia-UTHM for many hours of pleasant conversation and research discussion.

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ABSTRACT

Solid oxide fuel cell (SOFC) is an energy conversion device that converts gas into electricity directly. The components consist of anode, electrolyte and cathode which have different properties and operate at high temperatures up to 1000 °C. SOFC requires a thin, robust, porous anode, dense electrolyte and porous cathode. Manufacturing of single cell using low compaction value and high diameter to thickness ratio is yet to be developed. The challenge of the higher diameter to thickness ratio is inhomogeneous density distribution which causes cracks during sintering. This research investigates the manufacturing of single cell using low compaction and high diameter to thickness ratio. The performance of single cell was evaluated using hydrogen and oxygen that are supplied to the anode and cathode respectively. Initially the anode was produced using ultrasonic (U/S) process and ball mill (BM) process. The materials for single cell are NiO/YSZ, YSZ, LSM/YSZ as anode, electrolyte and cathode, respectively. The cornstarch is used to create anode porosity while the material binder of the powder is polyvinyl alcohol (PVA) to increase green compact strength. The consolidation of anode was done using a low compaction load of 16 MPa with a diameter of 40 mm. The electrolyte and cathode layer were coated using wet powder spraying (WPS) technique. The sintering for single cell used a three step air sintering. The characterizations of the anode include porosity, permeability, bending strength, microstructure and these were tested to evaluate the performance of the single cell SOFC. The results demonstrated that the thin SOFC single cell was successfully obtained. The single cell SOFC has a thickness of 600 µm where the distribution of thickness for the anode, electrolyte, and cathode were 557.5 µm, 26.1 µm and 16.4 µm, respectively. The cell diameter obtained was 36 mm. The low compaction load and the diameter to thickness ratio were 16 MPa and 60, respectively. Performance of open circuit voltage (OCV) for U/S and BM process is 0.8 V and 0.66 V, respectively. Power density performance for U/S and BM process is 200.41mA/cm^2 and 151.63mA/cm^2 respectively. The results indicated that the performance of OCV and power density for U/S were 33.34% and 32.17 % higher than BM process.

ABSTRAK

Sel bahan api oksida pejal (SOFC) adalah suatu alat penukaran tenaga yang menukarkan tenaga gas kepada tenaga elektrik secara langsung. Komponen ini terdiri daripada anod, katod dan elektrolit yang mempunyai ciri-ciri yang berbeza dan mampu beroperasi pada suhu yang tinggi mencecah 1000^{o}C. Keperluan ciri-ciri sel SOFC adalah ianya nipis, tahan lasak, mempunyai anod berliang, elektrolit padat dan katod berliang. Penghasilan sel tunggal menggunakan nilai pemadatan yang rendah dan nisbah diameter kepada ketebalan yang tinggi masih belum dikembangkan sepenuhnya. Cabaran dalam penghasilan nisbah diameter kepada ketebalan yang tinggi adalah taburan kepadatan yang tidak homogen, yang menjadi punca retak semasa proses pensinteran. Kajian ini mengkaji penghasilan sel tunggal menggunakan nilai pemadatan yang rendah serta nisbah diameter kepada ketebalan yang tinggi. Prestasi sel tunggal telah dinilai menggunakan hidrogen dan oksigen yang dibekalkan masing-masing kepada anod dan katod. Pada awalnya, anod telah diproses menggunakan teknik ultrasonik (U/S) dan pengisar bebola (BM). Bahan untuk sel tunggal adalah NiO/YSZ – YSZ – LSM/YSZ, masing-masing sebagai anod, elektrolit dan katod. Tepung jagung digunakan untuk membuat keliangan anod manakala pengikat bahan serbuk adalah polyvinyl alkohol (PVA) untuk meningkatkan kekuatan padat hijau. Penggabungan anod telah dilakukan menggunakan beban pemadatan rendah sebanyak 16 MPa dan diameter 40 mm. Manakala elektrolit dan lapisan katod telah disalut menggunakan teknik semburan serbuk basah (WPS). Pensinteran untuk sel tunggal menggunakan tiga langkah pensinteran dalam pensinteran udara. Ciri-ciri anod yang diuji adalah keliangan, kebolehtelapan, kekuatan lenturan, mikrostruktur dan ujian prestasi bagi SOFC sel tunggal. Keputusan menunjukkan bahawa sel SOFC nipis telah berjaya dihasilkan. Sel tunggal SOFC mempunyai ketebalan 600µm dengan taburan ketebalan untuk anod, elektrolit dan katod adalah masing-masing 557.5µm, 26.1µm, 16.4µm. Diameter sel yang diperolehi adalah 36mm. Nilai beban pemadatan rendah dan nisbah diameter kepada ketebalan adalah masing-masing 16 MPa dan 60. Prestasi litar voltan terbuka (OCV) untuk U/S dan BM adalah 0.8 V dan 0.66 V. Prestasi ketumpatan kuasa pula untuk U/S dan BM adalah 200.41mA/cm^{2} dan 151.63mA/cm^{2}. Keputusan menunjukkan bahawa prestasi OCV dan ketumpatan kuasa untuk U/S adalah 33.34% and 32.17 % lebih tinggi daripada BM.

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LIST OF SIMBOLS AND ABBREVIATIONS

AES	Air Electrode Supported
AFC	Alkaline Fuel Cell
AFL	Anode Functional Layer
APS	Atmospheric Plasma Spraying
ASR	Area Specific Resistance
BCNO	$BaCe_{0.9}Nd_{0.1}O_{3-\delta}$
BCY	$BaCe_{0.8}Y_{0.2}O_{3-\delta}$
BCZY	$Ba_{0.98}Ce_{0.6}Zr_{0.2}Y_{0.2}O_{3-\delta}$
BM	Ball mill
BZCY7	$Ba(Zr_{0.1}Ce_{0.7})Y_{0.2}O_{3-\delta}$
CaO	Calcium Oxide
CaSZ	Calcium Stabilized Zirconia
CCS	CO_2 Capture and Storage
CSP	Concentrated Solar Power
CFCL	Ceramic Fuel Cells Limited, Australian SOFC company
CFL	Cathode Functional Layer
CHP	Combine Heat and Power
CO_2	Carbon dioxide
CTE	Coefficient of Thermal Expansion
CVD	Chemical Vapor Deposition
DC	Direct Current
ECN	Energy research Centre of Nederland
EVD	Electrochemical Vapour Deposition
EDS	Energy Dispersive X-Ray Spectroscopy

Er_2O_3	erbium oxide
FWHM	Full Width of the peak at Half of the Maximum intensity
GDC	Gadolina Doped Ceria
GT	Gigatons
HTSOFC	High Temperature Solid Oxide Fuel Cell
IEA	International Energy Agency
ICE	Internal Combustion Engine
ITSOFC	Intermediate Temperature Solid Oxide Fuel Cell
$LaCoO_3$	Lanthanum cobalt oxide
L/A	Length to the cross-sectional ratio
LSCF	Lanthanum Strontium Cobalt Ferrum Oxide
LSCF/SDCC	Lanthanum Strontium Cobalt Ferrum Oxide- Samarium Doped Ceria Carbonate
LSM/YSZ	Lanthanum Strontium Manganite-Yttria Stabilized Zirconia
LTSOFC	Low Temperature Solid Oxide Fuel Cell
MA	Mechanical Alloying
MCFC	Molten Carbonate Fuel Cell
MEA	Membrane Electrolyte Assembly
MHI	Mitsubishi Heavy Industry
MnO_2	mangan oxide
MPa	Mega pascal
MW	Megawatts
NASA	National Aeronautics and Space Administration
NO_x	Nitrogen mono oxide
NiO/SDCC	Nickel Oxide-Samarium Doped Ceria Carbonate
NiO/YSZ	Nickel Oxide – Yttria Stabilized Zirconia
NiO/YSZ8	Nickel Oxide-Yttria Stabilized Zirconia 8 mole %
$NiO/BCIO_3$	Nickel Oxide-Barium Cerium Indium Oxide
NO_x	Nitrogen mono oxide
OCV	Open Circuit Voltage
PAFC	Phosphoric Acid Fuel Cell
PEM	Polymeric Electrolyte Membrane
PEMFC	Polymeric Electrolyte Membrane Fuel Cell
PSA	Particle Size Analyzer

PV	Photovoltaic
PVA	Polyvinyl Alcohol
PVD	Phycical Vapor Deposition
RADAR	Radio Detection And Ranging systems
SEM	Scanning Electron Microscopy
SDC	Samarium Doped Ceria
ScSZ	Scandia Stabilized Zirconia
SDCC	Samarium Doped Ceria Carbonate
SOFC	Solid Oxide Fuel Cell
SONAR	Sound Navigation and Ranging
SO_x	Sulfur mono oxide
SWPG	Siemens Westinghouse Power Generation
TEM	Transmission Electron Microscopy
TGA	Thermal Gravimetric Analyzer
TPB	Triple Phase Boundary
TPBL	Triple Phase Boundary Length
UK	United Kingdom
U/S	Ultrasonic
Vol	Volume
VO_2	Vanadium Oxide
wt	Weight
WPS	Wet Powder Spraying
WTI	West Texas Intermediate
XRD	X-Ray Diffraction
Y_2O_3	Yttrium Oxide
YSZ	Yttria Stabilized Zirconia
YSZ8	Yttria Stabilized Zirconia 8 mole %
ZrO_2	Zirconium dioxide
µm	Micro meter, unit of length
µCT	Micro Computer Topography
A	The area of the layer
C_s	Crystallite size
C_o	Cosntant
D	Diffusion coefficient

E	The electrical potential difference
E^o	The standard-state reversible voltage
F	Faraday’s constant
G	Gibbs free energy
Δg^o	The standard-state free energy change for reaction
Δp	The pressure drop over the membrane
k	Scherrer’s constant
m	meter, unit of length
n	Number of moles of electron transfer
P	Maximum load
S/cm	Siemens/ centimeter, unit of electric conductivity
T	Temperature, K
t	Thickness of specimen
V	Bulk Volume
V	Voltage, unit of electric voltage
V_s	Volume of solid
w	Width of specimen

Greek letters

λ	The wavelength of CuKα radiation (1.5406 Å)
β	The fullwidth of the peak at half of the maximum intensity (FWHM)
κ	Permeability
θ	The diffraction angle of the corresponding reflection
η	The viscosity of the gas
Φ	Porosity
σ_B	Bending stress

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CHAPTER 1

INTRODUCTION

1.1 Research background

The energy crisis and greenhouse effect has attracted the development for alternative energy. There were several types of renewable energy studied include the geothermal, wave, wind and nuclear energies. Various researchers have worked in developing devices that converts these energies into electricity. One of the potential energy devices is fuel cells.

Fuel cells can be considered as environmental friendly with relatively high efficiency [1]. There exist several types of fuel cells, e.g. Alkaline Fuel Cell (AFC) [2], Molten Carbonate Fuel Cell (MCFC) [3], Phosphoric Acid Fuel Cell (PAFC) [4], Polymeric Electrolyte Membrane Fuel Cell (PEMFC) [5] and Solid Oxide Fuel Cell (SOFC) [6, 7]. The first three use aqueous electrolyte while the rest use dense or solid electrolyte. There are two main disadvantages when using aqueous electrolyte, i.e. unstable performance and high production cost. The usage of the aqueous electrolyte also decreases the performance because of the evaporation occurs in the electrolyte. The material on the electrode sides are both made of expensive material such as platinum, hence make it not cost effective.

The differences between the PEMFC and SOFC are in its operating temperature and material used in the process. The PEMFC operates at low temperature ranging from 80 – 150 $^{\circ}$C, whereas the SOFC operated at temperature ranging between 500° – 1000°C. The core of the material of the PEMFC uses polymeric based and both electrodes at the anode and cathode use pure material, such as platinum. The weakness of the PEMFC is the presence of water flooding in the electrodes which affect the performance. The membrane is also not stable at high temperatures. On the other hand, for the SOFC, ceramic material is used in the electrodes and electrolyte. The advantages of the ceramic material is resistant to operate at high temperature and robust. Hence, the issue of water flooding on the side of the electrode of SOFC does not occur.

SOFC operating temperatures are influenced by its material. In general, there are two types of material used for SOFC, namely the Low Temperature SOFC (LT-SOFC) and High Temperature SOFC (HT-SOFC). The Low-Temperature SOFC (LT-SOFC) operates at a temperature range 500 °C - 650 °C , whereas HT-SOFC operates within 800 °C–1000 °C. An example of LT-SOFC in terms of anode–electrolyte–cathode configuration is Nickel Oxide-Samarium Doped Ceria Carbonate (NiO/SDCC)-SDCC-Lanthanum Strontium Cobalt Ferrite-SDCC (LSCF/SDCC) [8, 9]. An example of HT-SOFC in terms of anode–electrolyte–cathode configuration is Nickel Oxide-Yttria Stabilized Zirconia (NiO/YSZ)-YSZ-Lanthanum Strontium Manganite-YSZ (LSM/YSZ)[10, 11].

The performance of LT-SOFC and HT-SOFC are affected by electrical properties of material especially the electrical conductivity. It is reported that at temperature of 550 °C, SDCC has ionic conductivity of 0.131 S/cm while the electronic conductivity of LSCF/SDCC composite is as low as 9.53 10^{-4} S/cm depending on LT-SOFC operation [8]. At 1000 °C, YSZ has an ionic conductivity of 6.62 10^{-2} S/cm while LSM/YSZ has a higher conductivity of 2.27 S/cm. Based on the previous reported data, Yang [12] considers that they can be used at high temperature operations.

In general, SOFC is developed in two types of configuration namely planar and tube. Each configuration has its own advantages. The Planar type is simpler to manufacture compared to tube type. On the other hand, tube type requires smaller seal for cell stack development.

The SOFC cell manufacturing methods can be done by either conventional or non-conventional methods. The conventional methods include tape casting, slip casting, compaction or pressing, dip coating, screen printing and spraying. Whereas, for the non-conventional methods, the processes involve chemical, physical and electrochemical vapour depositions [13, 14].

Son et. al. [15] has patented the process of manufacturing an anode-supported SOFC using the screen printing method. The process can reduce the structural defects in each layer of solid oxide fuel cell and interfacial defect between the layers during the manufacturing process. Here, the used materials for anode, electrolyte, and cathode are NiO/YSZ cermet, YSZ, LSM/YSZ, respectively. The method of fabricating of NiO/YSZ anode-supported SOFC using the NiO/YSZ slurry combined with vacuum deposition also has been patented. The anode produce pore size less than 1 micron and the electrolyte thickness using YSZ was about 2 times pore size without defect [15].

Another conventional process for consolidating ceramic powder is powder compaction. The ceramic powder and the binder are filled into the mould, and then pressed at certain pressure to form green compact. Generally the density of green compact is not homogeneous. Stupkiewicz et al. [16] show the distribution of density of the green compact, the higher density is usually located at surface which is adjacent with puch. The compaction loads for the manufacturing of NiO/YSZ anode-supported SOFC may vary depending on the size and thickness. For instance, the lowest load is 21 MPa with a diameter of 57.2 mm and 3.2 mm thick [17], the medium load using material NiO/SDCC is 400 MPa with a diameter of 13 mm and thickess of 2 mm [18] while the highest load reaches 1000 MPa with a diameter of 13 mm and thickness 0.6 mm [19]. The ratios of the diameter to the thickness at low, medium and high loads are 17.9, 6.5 and 21.7 respectively.

1.2 Problem statement

A SOFC comprised of anode, electrolyte and cathode layers. In order to obtain an effective system, the cells should be manufactured as thin as possible to promote electrical transmission and minimise the electrical resistance losses. These characteristics are possible to achieve if non-conventional approaches are used. However, the manufacturing process using conventional method such as low compaction and powder spraying is a big challenge. The disadvantages of the compaction method is inhomogeneous density of green compact which cause warpage and crack during sintering [20]. Stupkiewicz et al. [16] show the distribution of density and residual stress of ceramic material using compaction process. The higher density of compact product is located in the adjacent puch surface. Randal [21] and Rahaman [22] suggest that the ratio of the diameter to thickness is no more than one to avoid crack and warpage during sintering. Several researchers have produced sintered compact with ratio of diameter to thickness is more than one successfully. The anode-supported SOFC of NiO/SDCC was made by using load compaction of 400 MPa with diameter of 13 mm and thickness of 2 mm. The ratio of diameter to thickness is 6.5 [18]. The ratio of diameter to thickness of 35.7 has been achieved by load compaction of 94 MPa with diameter 25 mm and thickness 0.7 mm [23]. Furthermore, Kongfa [19] has produced anode-supported SOFC using load compaction of 1000 MPa with diameter of 13 mm and thickness of 0.6 mm. The ratio diameter to thickness of anode-supported SOFC is 21.7.

The issue of uniformity is of concern. The effect of non-uniform density is that the product is susceptible to cracking or warpage during the sintering process [24]. The high compaction load increase the frictional forces between powder particles and mould wall [25] resulted in the green compact is easily to crack during the sintering process, especially when the powder composition is not homogeneous in terms of its hardness.

SOFC performance is measured for its capability to generate power. The higher electricity is generated, the better the SOFC is. However, SOFC performance is influenced by several key factors. These factors include the manufacturing process, ionic conductivity material, porous electrode, thin cell and large cross-sectional areas [26, 27].

The ultrasonic process improves the homogenization of powder and powder size. The process subsequently affects the microstructure of the SOFC cell component during sintering process [28]. For instance, higher sintering process improves the density of the electrolyte that affect the performance of SOFC. Next important factor is ionic conductivity material. In order to increase the performance, the ionic conductivity should achieve the optimum value for a given operating temperature. At present, the most suitable or available materials for electrolyte were SDCC and YSZ, for LT-SOFC [8] and HT-SOFC respectively [29].

Other SOFC performance parameters are the porosity and thickness of the anode. The anode requires sufficient porosity and certain thickness to reduce electrical resistance and capable to support electrolyte and cathode, especially for

REFERENCES

1. Haroune Aouzellag, Kaci Ghedamsi, Djamel Aouzellag, Review, Energy Management and Fault Tolerant Control Strategies for Fuel Cell/Ultra-Capacitor Hybrid Electric Vehicles to Enhance Autonomy, Efficiency and Life Time of the Fuel Cell System. *International Journal of Hydrogen Energy*, 2015. 40: p. 7204-7213.
2. Puqing Yang, Ying Zhu, Pei Zhang, Houcheng Zhang, Ziyang Hu, Jinjie Zhang Performance Evaluation of an Alkaline Fuel Cell/Thermoelectric Generator Hybrid System. *International Journal of Hydrogen Energy* 2014. **39**: p. 11756-11762.
3. Xiuqin Zhang, Huiying Liu, Meng Ni, Jincan Chen, Performance Evaluation and Parametric Optimum Design of a Syngas Molten Carbonate Fuel Cell and Gas Turbine Hybrid System. *Renewable Energy* 2015. 80: p. 407-414.
4. Younes Ansari, Telpriore G. Tucker, C. Austen Angell, Short communication, A novel, Easily Synthesized, Anhydrous Derivative of Phosphoric Acid for Use in Electrolyte with Phosphoric Acid-Based Fuel Cells. *Journal of Power Sources*, 2013. 237: p. 47-51.
5. Behzad Najafi, Alireza Haghighat Mamaghani, Fabio Rinaldi, Andrea Casalegno, Long-Term Performance Analysis of an HT-PEM Fuel Cell Based Micro-CHP System: Operational Strategies. *Applied Energy*, 2015. 147: p. 582-592.
6. Tan Zhongfu, Zhang Chen, Liu Pingkuo, Brent Reed, Zhao Jiayao, Focus on Fuel Cell Systems in China. *Renewable and Sustainable Energy Reviews* 2015. 47: p. 912-923.
7. Hasan Ozcan, Ibrahim Dincer, Performance Evaluation of an SOFC Based Trigeneration System Using Various Gaseous Fuels From Biomass Gasification. *International Journal of Hydrogen Energy*, 2015. 40: p. 7798-7807.

8. Hamimah Abd. Rahman, Andanastuti Muchtar, Norhamidi Muhamad, Huda Abdullah LSCF6428-SDC carbonate composite cathodes for low-temperature solid oxide fuel cells. *Materials Chemistry and Physics*, 2013. 141: p. 752-757.
9. Muhammed Ali S.A, Andanastuti Muchtar, Abu Bakar Sulonga, Norhamidi Muhamada, Edy Herianto Majlan, Influence of Sintering Temperature on the Power Density of Samarium-Doped-Ceria Carbonate Electrolyte Composites for Low-Temperature Solid Oxide Fuel Cells. *Ceramics International* 2013. 39: p. 5813-5820.
10. Lan Zhang, San Ping Jiang, Wei Wang, Yujun Zhang, Short Communication NiO/YSZ, Anode-Supported, Thin-Electrolyte, Solid Oxide Fuel Cells Fabricated by Gel Casting. *Journal of Power Sources* 2007. 170: p. 55-60.
11. Jianbing Huang, Fucheng Xie, Cheng Wang, Zongqiang Mao, Development of Solid Oxide Fuel Cell Materials for Intermediate-to-Low Temperature Operation. *International Journal of Hydrogen Energy*, 2012. 37: p. 877-883.
12. Chih-Chung T. Yang, Wen-Cheng J. Wei, Andreas Roosen, Electrical Conductivity and Microstructures of $La_{0.65}Sr_{0.3}MnO_{3-\delta}$ mol%-Yttria-Stabilized Zirconia. *Materials Chemistry and Physics* 2003. 81: p. 134-142.
13. Xiuxia Meng, Xun Gong, Naitao Yang, Xiaoyao Tan, Yimei Yin, Zi-Feng Ma, Fabrication of Y_2O_3-Stabilized-ZrO_2(YSZ)/$La_{0.8}Sr_{0.2}MnO_{3-\delta}$/YSZ Dual-Layer Hollow Fibers for the Cathode-Supported Micro-Tubular Solid Oxide Fuel Cells by a Cospinning/co-Sintering Technique. *Journal of Power Sources*, 2013. 237: p. 277-284.
14. Keegan C. Wincewicz, Joyce S. Cooper, Taxonomies of SOFC material and manufacturing alternatives. *Journal of Power Sources*, 2005. 140: p. 280-296.
15. Ji-Won Son, Ho-Sung Noh, Hae-Weon Lee, Jong Ho Lee, Hae-Ryoung Kim, Jong Cheol Kim, Anode-Supported Solid Oxide Fuel Cell Comprising a Nanoporous layer Having a Pore Gradient Structure, and a Production Methode Therefor, *in US Patent* 2012, 2012/0003565A1: USA. p. 1-10.
16. Stupkiewicz S., A. Piccolroaz, D. Bigoni, Elastoplastic Coupling to Model Cold Ceramic Powder Compaction. *Journal of the European Ceramic Society*, 2014. 34: p. 2839–2848.
17. Daniel Storjohann, James Daggett, Neal P. Sullivan, Huayang Zhu, Robert J. Kee, Sophie Menzer, Dustin Beeaff, Fabrication and evaluation of solid-

oxide fuel cell anodes employing reaction-sintered yttria-stabilized zirconia. *Journal of Power Sources* 2009. 193: p. 706–712.

18. Mohadeseh Seyednezhad, Armin Rajabi, Andanastuti Muchtar, Mahendra Rao Somalu, Characterization of IT-SOFC Non-Symmetrical Anode Sintered through Conventional Furnace and Microwave. *Ceramics International*, 2015. 41: p. 5663–5669.
19. Kongfa Chen, Zhe L¨u, Na Ai, Xiangjun Chen, Xiqiang Huang, Wenhui Su, Experimental study on effect of compaction pressure on performance of SOFC anodes. *Journal of Power Sources* 2008. 180: p. 301–308.
20. Peng Chen, Gap-Yong Kim, Jun Ni, Investigations in the Compaction and Sintering of Large Ceramic Parts. *Journal of Materials Processing Technology* 2007. 190: p. 243-250.
21. German, R.M., Powder Metallurgy of Iron and Steel 1998, New York, USA: *John Wiley & Sons, Inc.*
22. Rahaman, M.N., Ceramic Processing 2007, Boca Raton, Florida, USA: *CRC Press Taylor & Francis Group*.
23. Zhenwei Wang, Mojie Cheng, Yonglai Dong, Min Zhang, Huamin Zhang, Anode-supported SOFC with 1Ce10ScZr modified cathode/electrolyte interface. *Journal of Power Sources*, 2006. 156: p. 306-310.
24. Barsoum, M., Materials Science and Engineering Series, Fundamentals of Ceramics1997, United States of America: *McGraw-Hill Companies.*
25. Pizette P., C.L. Martin, G. Delette, P. Sornay, F. Sans, Compaction of Aggregated Ceramic Powders: From Contact Laws to Fracture and Yield Surfaces. *Powder Technology* 2010. 198: p. 240-250.
26. Shiqiang (Rob) Hui, Justin Roller, Sing Yick, Xinge Zhang, Cyrille Deces-Petit, Yongsong Xie, Radenka Maric, Dave Ghosh, Review, A brief Review of the Ionic Conductivity Enhancement for Selected Oxide Electrolytes. *Journal of Power Sources*, 2007. 172: p. 493-502.
27. Ryan P. O'Hayre, Suk-Won Cha, Whitney Colella, Fritz B. Prinz, Fuel Cell Fundamentals, 2006, United State of America: *John Wiley & Sons, Inc*.
28. Shinagawa, K., Simulation of Grain Growth and Sintering Process by Combined Phase-Field/Discrete-Element Method. *Acta Materialia* 2014. 66: p. 360-369.

29. Chunwen Sun, U.S., Review Recent Anode Advances in Solid Oxide Fuel Cells. *Journal of Power Sources*, 2007. 171: p. 247-260.

30. Claire Ferchaud, Jean-Claude Grenier, Ye Zhang-Steenwinkel, Marc M. A. van Tuel, Frans P. F. van Berkel, Jean-Marc Bassat, High performance praseodymium nickelate oxide cathode for low temperature solid oxide fuel cell. *Journal of Power Sources*, 2011. 196(4): p. 1872-1879.

31. Daniel C. Andersson, Per-Lennart Larsson, Alessandro Cadario, Per Lindskog, On the Influence from Punch Geometry on the Stress Distribution at Powder Compaction. *Powder Technology* 2010. 202: p. 78-88.

32. IEA, Energy Technology Perspectives 2008,Scenarios and Strategies to 2050, 2008: Paris, France.

33. IEA, IEA Statistic CO2 Emission from Fuel Combustion Highlights, 2010: Paris, France.

34. Shahriar Shafiee, Erkan Topal, When will Fossil Fuel Reserves be Diminished? *Energy Policy*, 2009. 37: p. 181-189.

35. Shahriar Shafiee, Erkan Topal, A Long-term view of Worldwide Fossil Fuel Prices. *Applied Energy*, 2010. 87: p. 988 - 1000.

36. Yue-Jun Zhang, Zi-Yi Wang, Investigating the Price Discovery and Risk Transfer Functions in the Crude Oil and Gasoline Futures Markets: Some Empirical Evidence. *Applied Energy* 2013. 104: p. 220-228.

37. Zegers, P., Fuel cell commercialization : The key to a Hydrogen Economy. *Journal of Power Sources*, 2006. 154: p. 497-502.

38. Hanne Lerche Raadal, Bjørn Ivar Vold, Anders Myhr, Tor Anders Nygaard, GHG (Green Hous Gases) Emissions and Energy Performance of Offshore Wind Power. *Renewable Energy* 2014. 66: p. 314-324.

39. Juergen H. Peterseim, Stuart White, Amir Tadros, Udo Hellwig, Review Concentrated Solar Power Hybrid Plants, which Technologies are Best Suited for Hybridisation? *Renewable Energy* 2013. 57: p. 520-532.

40. Johnstone C.M., D. Pratt, J.A. Clarke, A.D. Grant, A Techno-Economic Analysis of Tidal Energy Technology. *Renewable Energy* 2013. 49: p. 101-106.

41. Kevin Huang, John B Goodenough, Solid Oxide Fuel Cell Technology Principles, Performance and Operations 2009, Great Abington, Cambridge, UK: *Woodhead Publishing Limited and CRC Press LLC*.

42. Xiongwen Zhang, S.H. Chan, Guojun Li, H.K. Ho, Jun Li, Zhenping Feng, A review of Integration Strategies for Solid Oxide Fuel Cells. *Journal of Power Sources*, 2010. 195: p. 685–702.

43. Matthew, M.M., Fuel Cell Engine 2008, Hoboken, New Jersey, USA: *John Wiley & Sons.*

44. Timothy E. Lipman, Jennifer L. Edwards, Daniel M. Kammen, Fuel Cell System Economics: Comparing the Costs of Generating Power with Stationary and Motor Vehicle PEM Fuel Cell Systems. *Energy Policy*, 2004. 32: p. 101-125.

45. Li, X., Principles of Fuel Cells 2006, Madison Avenue, New York, USA: *Taylor & Francis Group*.

46. Gasik, M., Materials for Fuel Cells 2008, Cambridge England: *Woodhead Publishing Limied.*

47. Spiegel, C., Designing and Building Fuel Cell 2007, United State of America: *McGraw-Hill Company.*

48. Society, T.A.C., Progress in Solid oxide Fuel Cells 2006, Hoboken, New Jersey, USA: *John Wiley & Sons, Inc.*

49. K. Foger, J.G. Love, Fifteen years of SOFC development in Australia. Solid State Ionic, 2004. 174: p. 119-126.

50. Hwang, J.-J., Transient Efficiency Measurement of a Combined Heat and Power Fuel Cell Generator. *Journal of Power Sources* 2013. 223: p. 325-335.

51. Shaolin Ma, Jiangfeng Wang, Zhequan Yan, Yiping Dai, Bingheng Lu, Thermodynamic Analysis of a New Combined Cooling, Heat and Power System Driven by Solid Oxide Fuel Cell Based on Ammonia–Water Mixture. *Journal of Power Sources*, 2011. 196: p. 8463– 8471.

52. Lúcia Bollini Braga, Jose Luz Silveira, Marcio Evaristo da Silva, Einara Blanco Machin, Daniel Travieso Pedroso, Celso Eduardo Tuna, Comparative Analysis Between a PEM Fuel Cell and an Internal Combustion Engine Driving an Electricity Generator: Technical, Economical and Ecological Aspects. *Applied Thermal Engineering*, 2014. 63: p. 354-361.

53. G. Cacciola, V. Antonucci, S. Freni, Technology Up Date and New Strategies on Fuel Cells. *Journal of Power Sources*, 2001. 100: p. 67-79.

54. Wolf Vielstich, Harumi Yokokawa, Hubert A Gasteiger, Handbook of Fuel Cells Fundamentals Technology and Applications 2009, Chichester, West Sussex, United Kingdom: *John Wiley & Sons.*
55. Andrzej Wieckowski, Jens K. Norskov, Fuel Cell Science Theory, Fundamentals and Biocatalysis 2010, Hoboken, New Jersey, USA: *John Wiley & Sons.*
56. Bernd Emonts, Ludger Blum, Thomas Crube, Werner Lehnert, Jurgen Mergel, Martin Muller and Ralf Peters, Technical Advancement of Fuel-Cell Research and Development in Fuel Cell Science and Engineering Materials, Processes, Systems and Technology. Vol. 1. 2012, Weinheim, Germany: *Wiley-VCH Verlag GmbH & Co. KGaA.*
57. Laguna-Bercero, M.A., Review Recent Advances in High Temperature Electrolysis Using Solid Oxide Fuel Cells: A Review. *Journal of Power Sources* 2012. 203: p. 4– 16.
58. Hoogers, G., Fuel Cell Technology Hand Book 2003, Denver, MA, USA: *CRC Press LLC.*
59. M.C. Williams, J.P. Strakey, Subhash C. Singhal, U.S Distributed Generation Fuel Cell Program. *Journal of Power Sources*, 2004. 131: p. 79-85.
60. Boudghene Stambouli A., E.Traversa, Solid oxide fuel cells (SOFCs): A Review of an Environmentally Clean and Efficient Source of Energy. *Renewable & Sustainable Energy Reviews*, 2002. 6: p. 433 - 455.
61. Gardner F.J., M.J. Day, N.P. Brandon, M.N. Pashley, M. Cassidy, SOFC Technology Development at Rolls-Royce. *Journal of Power Sources,* 2000. 86: p. 122-129.
62. Tietz F., H.-P. Buchkremer, D. Stover, Review Article Components Manufacturing for Solid Oxide Fuel Cells. *Solid State Ionic*, 2002. 152-153: p. 373-381.
63. Selmar de Souza, Steven J. Visco, Lutgard C. De Jonghe, Thin Film Solid Oxide Fuel Cell with High Performance at Low-Temperature. *Solid State Ionic*, 1997. 98: p. 57-61.
64. Singal, S.C., Advances in solid oxide fuel cell technology. *Solid State Ionic,* 2000. 135: p. 305-313.
65. Han Chen, Kui Cheng, Zhicheng Wang, Wenjian Weng , Ge Shen, Piyi Du and Gaorong Han, Preparation of Porous NiO-$Ce_{0.8}Sm_{0.2}O_{1.9}$ Ceramics for

Anode-supported Low-temperature Solid Oxide Fuel Cells. *Journal Material Science Technology* 2010. 26 (6): p. 523-528.

66. Laxmidhar Besra, Shaowu Zha, Meilin Liu, Preparation of NiO-YSZ/YSZ Bi-layers for Solid Oxide Fuel Cells by Electrophoretic Deposition. *Journal of Power Sources* 2006. ***160:*** p. 207–214.
67. Fergus, J.W., Oxide Anode Materials for Solid Oxide Fuel Cells. *Solid State Ionic*, 2006. 177: p. 1529-1541.
68. Zhe Cheng, Jeng-Han Wang, and Meilin Liu, Anodes,in Jeffrey W. Fergus (Ed.)Green Chemistry and Chemical Engineering Solid Oxide Fuel Cells Materials Properties and Performance 2009, Boca Raton, USA: *CRC Press Taylor & Francis Group*.
69. John B. Goodenough, Yun-Hui Huang, Review Alternative Anode Materials for Solid Oxide Fuel Cells. *Journal of Power Sources,* 2007. 173: p. 1-10.
70. Spacil, H.S., Electrical Device Including Nickel- Containing Stabilized Zirconia Electrode, in *United States Patent Office* 1970, 3503809: USA. p. 1-8.
71. Janine Johnson, Jianmin Qu, Effective Modulus and Coefficient of Thermal Expansion of Ni–YSZ Porous Cermets. *Journal of Power Sources* 2008. 181: p. 85-92.
72. Xia, C., Electrolyte, in Jeffrey W. Fergus (Ed.)Green Chemistry and Chemical Engineering Solid Oxide Fuel Cells Materials Properties and Performance 2009, Boca Raton, Florida, USA: *CRC Press Taylor & Francis Group*.
73. Fergus, J.W., Electrolyte for Solid Oxide Fuel Cells. *Journal of Power Sources*, 2006. 162: p. 30-40.
74. San Ping Jiang and Jian Li, Cathodes, in Jeffrey W. Fergus (Ed.)Green Chemistry and Chemical Engineering Solid Oxide Fuel Cells Materials Properties and Performance 2009, Boca Raton, Florida, USA: *CRC Press Taylor & Francis Group.*
75. Adler, S.B., Factors Governing Oxygen Reduction in Solid Oxide Fuel Cell Cathodes. Chemical Reviews, *American Chemical Society*, 2004. 104: p. 4791-4843.
76. Arata Nakajo, Jakob Kuebler, Antonin Faes, Ulrich F. Vogt, Hans Ju¨rgen Schindler, Lieh-Kwang Chiang, Stefano Modena, Jan Van herle, Thomas

Hocker, Compilation of Mechanical Properties for The Structural Analysis of Solid Oxide Fuel Cell Stacks. Constitutive Materials of Anode-Supported Cells. *Ceramics International* 2012. 38: p. 3907–3927.

77. Rym Dhouib Sahnoun, Semia Baklouti, Characterization of Flat Ceramic Membrane Supports Prepared with Kaolin-Phosphoric Acid-Starch. *Applied Clay Science* 2013. 83-84: p. 399-404.

78. Eva Gregorov´a , Willi Pabst, Ivan Bohaˇcenko, Characterization of Different Starch Types for Their Application in Ceramic Processing. *Journal of the European Ceramic Society* 2006. 26: p. 1301-1309.

79. Kategunya Rengsutthi, Sanguansri Charoenrein, Physico-Chemical Properties of Jackfruit Seed Starch (Artocarpus Heterophyllus) and Its Application as a Thickener and Stabilizer in Chilli Sauce. *LWT - Food Science and Technology*, 2011. 44: p. 1309-1313.

80. Gilles Taillades, Pierre Batocchi, Abdel Essoumhi, Mélanie Taillades, Deborah J. Jones, Jacques Rozière, Engineering of Porosity, Microstructure and Electrical Properties of Ni–BaCe$_{0.9}$Y$_{0.1}$O$_{2.9}$ Cermet Fuel Cell Electrodes by Gelled Starch Porogen Processing. *Microporous and Mesoporous Materials* 2011. 145: p. 26–31.

81. Hongsheng Liu, Fengwei Xie, Long Yu, Ling Chen, Lin Li, Thermal Processing of Starch-Based Polymers. *Progress in Polymer Science*, 2009 34: p. 1348–1368.

82. Rahaman, M.N., Sintering of Ceramics 2008, Boca raton, Florida, USA: *CRC Press Taylor & Francis Group.*

83. Olivera Kesler and Paolo Marcazzan, Processing, in Jeffrey W. Fergus (Ed.) Green Chemistry and Chemical Engineering Solid Oxide Fuel Cells Materials Properties and Performance 2009, Boca raton, Florida, USA: *CRS Press Taylor & Francis Group*.

84. C.Suryanarayana, Mechanical Alloying and Milling. *Progress in Materials Science*, 2001. 46: p. 1-184.

85. Timothy J. Mason and John P. Lorimer, Applied Sonochemistry, The Uses of Power Ultrasound in Chemistry and processing 2002, Weinheim, Germany: *Wiley-VCH Verlag GmbH.*

86. Masrom, A.K., Workshop on Mechanical Milling for Production of Nanostructured Materials from Nanoparticles to Nanotubes, December, 2009: *Amrec, Sirim Berhad, Malaysia*. p. 1-127.
87. Alain Bourdillon, Giovanni Occhipinti, Jean-Philippe Molinié, Véronique Rannou, HF Radar Detection of Infrasonic Waves Generated in the Ionosphere by the 28 March 2005 Sumatra Earthquake. *Journal of Atmospheric and Solar-Terrestrial Physics* 2014. 109: p. 75-79.
88. Yi Han, Huayan Sun, Huichao Guo, Analysis of Influential Factors on a Space Target's Laser Radar Cross-section. Optics & Laser Technology, 2014. 56: p. 151-157.
89. Rubens L.Oliveira, Beatriz S.L.P. de Lima, Nelson F.F.Ebecken, Multiway Analysis in Data SONAR Classification. *Mechanical Systems and Signal Processing* 2014: p. 531-541.
90. Bruce W. Drinkwater, Paul D. Wilcox, Ultrasonic Arrays for Non-Destructive Evaluation: A Review. *NDT&E International* 2006. 39: p. 525-541.
91. Garcia P., B Ferrari, R. Moreno, A.J. Sanches-Herencia, M.T. Colomer, YSZ/Ni–YSZ Semi-cells Shaped by Electrophoretic Deposition. *Journal of the European Ceramic Society*, 2007. 27: p. 4241-4244.
92. Shigeyuki Somiya and Tokuji Akiba, Hydrothermal Zirconia Powders: A Bibliography. *Journal of the European Ceramic Society* 1999. 19: p. 81- 87.
93. Oleg Vasylkiva, Yoshio Sakka, Yasuaki Maeda , Valeriy V. Skorokhod, Nano-engineering of Zirconia–noble Metals Composites. *Journal of the European Ceramic Society* 2004. 24: p. 469–473.
94. P´erez-Rodr´ıguez J.L., J. Pascual, F. Franco, M.C. Jim´enez de Haro, A. Duran, V. Ram´ırez del Valle, L.A. P´erez-Maqueda, The influence of Ultrasound on the Thermal Behaviour of Clay Minerals. *Journal of the European Ceramic Society* 747–753, 2006. 26: p. 747–753
95. Luis A. Pe´rez-Maqueda, Jose´ M. Blanes, Jose´ Pascual, Jose´ L. Pe´rez-Rodrı´guez, The Influence of Sonication on the Thermal Behavior of Muscovite and Biotite. *Journal of the European Ceramic Society* 2004. 24: p. 2793–2801.
96. Lars Rose, Olivera Kesler, Zhaolin Tang, Alan Burgess, Application of Sol gel Spin Coated Yttria-Stabilized Zirconia Layers for the Improvement of

Solid Oxide Fuel Cell Electrolytes Produced by Atmospheric Plasma Spraying. *Journal of Power Sources* 2007. 167: p. 340–348.

97. Schrijnemakers A., S. André, G. Lumay, N. Vandewalle, F. Boschini, R. Cloots, B. Vertruyen, Mullite Coatings on Ceramic Substrates: Stabilisation of Al_2O_3–SiO_2 Suspensions for Spray Drying of Composite Granules Suitable for Reactive Plasma Spraying. *Journal of the European Ceramic Society* 2009. 29 p. 2169–2175.
98. Maciej Wozniak, Yoram de Hazan, Thomas Graule, Dariusz Kata, Rheology of UV Curable Colloidal Silica Dispersions for Rapid Prototyping Applications. *Journal of the European Ceramic Society* 2011. 31 p. 2221–2229.
99. Ferguson, B.L., Powder Shaping and Consolidation Technologies in ,Powder Metal Technologies and Applications. Vol. 7. 1999, San Fransisco, USA: *ASM International*
100. Reed, J.S., Principles of Ceramics Processing 1995, New York, USA: *John Wiley & Sons, Inc.*
101. Kennedy T., S. Hampshire & Y. Yaginuma, A Study of the Compaction Mechanism of Granulated Materials. *Journal of the European Ceramic Society*, 1997. 17: p. 133-139.
102. Richerson W. , D., Modern Ceramic Engineering Properties, Processing, and Use in Design 1992, New York, USA: *Marcel Dekker, Inc.*
103. Al-Qureshi H.A. , M.R.F. Soares, D. Hotza, M.C. Alves, A.N. Klein, Analyses of the Fundamental Parameters of Cold Die Compaction of Powder Metallurgy. *Journal of Materials Processing Technology* 2008. 199: p. 417-424.
104. Porter, J., Tooling Clearances and Design, Powder Metallurgy Presses and Tooling, in Powder Metal Technologies and Applications, ed. P.W. Lee. Vol. 7. 1999, San Fransisco, USA: *ASM International.*
105. Dil Faraz Khan, Haiqing Yin, He Li, Zainul Abideen, Asadullah, Xuanhui Qu, Mujtaba Ellahi, Effect of Impact Force on Ti–10Mo Alloy Powder Compaction by High Velocity Compaction Technique. *Materials and Design* 2014. 54: p. 149-153.

106. Yong-Ming Tien, Po-Lin Wu, Wei-Hsing Huang, Ming-Feng Kuo, Chen-An Chu, Wall Friction Measurement and Compaction Characteristics of Bentonite Powders. *Powder Technology* 2007. 173: p. 140-151.

107. Lei Bi, Zetian Tao, Wenping Sun, Shangquan Zhang, Ranran Peng,Wei Liu Proton-Conducting Solid Oxide Fuel Cells Prepared by a Single Step co-Firing process. *Journal of Power Sources* 2009. 191: p. 428–432.

108. Zhenjun Jiao, Naoki Shikazono, Nobuhide Kasagi, Performance of an Anode Support Solid Oxide Fuel Cell Manufactured by Microwave Sintering. *Journal of Power Sources* 2010. 195: p. 151–154.

109. Bukaemskiy A.A., D. Barrier, G. Modolo, Compressibility and Sinterability of CeO_2–8YSZ Powders Synthesized by a Wet Chemical Method. *Journal of the European Ceramic Society* 2009. 29: p. 1947-1954.

110. Zhiqiao Yan, Feng Chen, Yixiang Cai, High-Velocity Compaction of Titanium Powder and Process Characterization. *Powder Technology* 2011. 208: p. 596-599.

111. Patrick Pizette, Christophe L. Martin, Gérard Delette, Florence Sans, Thomas Geneves, Green Strength of Binder-Free Ceramics. *Journal of the European Ceramic Society* 2013. 33: p. 975-984.

112. Hongxia Gu, Ran Ran, Wei Zhou, Zongping Shao, Anode-Supported ScSZ-Electrolyte SOFC with Whole Cell materials from Combined EDTA–Citrate Complexing Synthesis Process. *Journal of Power Sources,* 2007. 172: p. 704-712.

113. Vanesa Alzate-Restrepo, Josephine M. Hill, Carbon Deposition on Ni/YSZ Anodes Exposed to CO/H2 Feeds. *Journal of Power Sources* 2010. 195: p. 1344–1351.

114. Kui Xie, Ruiqiang Yan, Dehua Dong, Songlin Wang, Xiaorui Chen, Tao Jiang, Bin Lin, Ming Wei, Xingqin Liu, Guangyao Meng, A modified Suspension Spray Combined with Particle Gradation Method for Preparation of Protonic Ceramic Membrane Fuel Cells. *Journal of Power Sources* 2008. 179: p. 576–583.

115. Ralf Hansch, Mohammad Rahul Reza Chowdhury, Norbert H. Menzler, Screen Printing of Sol–gel-Derived Electrolytes for Solid Oxide Fuel Cell (SOFC) Application. *Ceramics International* 2009. 35: p. 803–811.

116. Jeffrey W. Fergus, Rob Hui, Xianguo Li, David P. Wilkinson, Jiujun Zhang, Green Chemistry and Chemical Engineering Solid Oxide Fuel Cells Materials Properties and Performance 2009, Boca Raton, FL, USA *CRC Press Taylor & Francis Group*.

117. Liu Q.L., K.A. Khor, S.H. Chan, X.J. Chen, Anode-Supported Solid Oxide Fuel Cell with Yttria-Stabilized Zirconia/Gadolinia-Doped Ceria Bilalyer Electrolyte Prepared by Wet Ceramic co-Sintering Process. *Journal of Power Sources* 2006. 162: p. 1036–1042.

118. Masters, K., Spray Drying Handbook1985, New York, USA: *John Wiley & Sons.*

119. Wei Zhou, Huangang Shi, Ran Ran, Rui Cai, Zongping Shao ,Wanqin Jin, Fabrication of an Anode-Supported Yttria-Stabilized Zirconia Thin Film for Solid-Oxide Fuel Cells via Wet Powder Spraying. *Journal of Power Sources* 2008. 184: p. 229–237.

120. Kui Xie, Qianli Ma, Bin Lin, Yinzhu Jiang, Jianfeng Gao, Xingqin Liu, Guangyao Meng, An Ammonia Fuelled SOFC with a $BaCe_{0.9}Nd_{0.1}O_{3-\delta}$ Thin Electrolyte Prepared with a Suspension Spray. *Journal of Power Sources* 2007. 170: p. 38–41.

121. Rajendra N. Basu, Günter Blass, Hans Peter Buchkremer, Detlev Stöver, Frank Tietz, Egbert Wessel, Izaak C. Vinke, Simplified Processing of Anode-Supported Thin Film Planar Solid Oxide Fuel Cells. *Journal of the European Ceramic Society* 2005. 25: p. 463–471.

122. Yihong Li, Randall Gemmen, Xingbo Liu, Review Oxygen Reduction and Transportation Mechanisms in Solid Oxide Fuel Cell Cathodes. *Journal of Power Sources* 2010. 195: p. 3345–3358.

123. Jingwang Yan, Xianghui Hou, Kwang-Leong Choy, The Electrochemical Properties of LSM-Based Cathodes Fabricated by Electrostatic Spray Assisted Vapour Deposition. *Journal of Power Sources* 2008. 180: p. 373–379.

124. Minfang Han, Xiuling Tang, Huiyan Yin, Suping Peng, Fabrication, Microstructure and Properties of a YSZ Electrolyte for SOFCs. *Journal of Power Sources* 2007. 165: p. 757–763.

125. R.M.C. Clemmer, S.F. Corbin, Influence of Porous Composite Microstructure on the Processing and Properties of Solid Oxide Fuel Cell Anodes. *Solid State Ionics* 2004. 166: p. 251–259.

126. Ben Kenney, Mikelis Valdmanis, Craig Baker, J.G. Pharoah, Kunal Karan, Computation of TPB Length, Surface Area and Pore Size from Numerical Reconstruction of Composite Solid Oxide Fuel Cell Electrodes. *Journal of Power Sources* 2009. 189: p. 1051–1059.

127. Bidrawn F., G. Kim, N. Aramrueang, J.M. Vohs, R.J. Gorte, Dopants to Enhance SOFC Cathodes Based on Sr-doped $LaFeO_3$ and $LaMnO_3$. *Journal of Power Sources* 2010. 195: p. 720–728.

128. Jiang, S.P., Issues on Development of $(La,Sr)MnO_3$ Cathode for Solid Oxide Fuel Cells. *Journal of Power Sources* 2003. 124: p. 390–402.

129. Toshio Suzuki, Masanobu Awano, Piotr Jasinski, Vladimir Petrovsky, Harlan U. Anderson, Composite $(La, Sr)MnO_3$–YSZ Cathode for SOFC. *Solid State Ionics*, 2006. 177: p. 2071 – 2074.

130. Huangang Shi, Wei Zhou, Ran Ran, Zongping Shao, Comparative Study of Doped Ceria Thin-Film Electrolytes Prepared by Wet Powder Spraying with Powder Synthesized via Two Techniques. *Journal of Power Sources* 2010. 195: p. 393–401.

131. Kongfa Chen, Z.L.u., Xiangjun Chen, Na Ai, Xiqiang Huang , Xiaobo Du, Wenhui Su, Development of LSM-Based Cathodes for Solid Oxide Fuel Cells Based on YSZ Films. *Journal of Power Sources*, 2007. 172: p. 742–748.

132. Hwa Seob Song, Sang Hoon Hyun, Jooho Moon, Rak-Hyun Song, Short Communication Electrochemical and Microstructural Characterization of Polymeric Resin-Derived Multilayered Composite Cathode for SOFC. *Journal of Power Sources* 2005. 145: p. 272–277.

133. C.Y. Chen, G.S. Lan, W.H. Tuan, Preparation of Mullite by the Reaction Sintering of Kaolinite and Alumina. J*ournal of the European Ceramic Society* 2000. 20: p. 2519-2525.

134. Groza, J.R., Field-Activated Sintering, in Powder Metal Technologies and Application, Alton D. Romic, Jr. Vol. 7. 1999, San Fransisco, USA: *ASM International.*

135. Nahm C.-W., Sintering Effect on Electrical Properties and Pulse Aging Behavior of (V_2O_5-Mn_3O_4-Er_2O_3)-Doped Zinc Oxide Varistor Ceramics. *Journal of Rare Earths* 2014. 32: p. 29-36.

136. Lecomte-Nana G.L., J.P. Bonnet, P. Blanchart, Research Paper, Investigation of the Sintering Mechanisms of Kaolin–Muscovite. *Applied Clay Science*, 2011. 51: p. 445-451.

137. Peter Tatarkoa, Salvatore Grasso, Zdenˇek Chlup, Harshit Porwal, Monika Kaˇsiarová, Ivo Dlouh´y, Michael J. Reece, Toughening Effect of Multi-Walled Boron Nitride Nanotubes and Their Influence on the Sintering Behaviour of 3Y-TZP Zirconia Ceramics. *Journal of the European Ceramic Society* 2014. 34: p. 1829-1843.

138. Ferguson, H., Heat Treatment of Ferrous Powder Metallurgy Parts, in Powder Metal Technology and Applications. Vol. 7. 1999, San Fransisco, USA: *ASM International*.

139. Thomaz Augusto Guisard Restivo, Sonia Regina Homem Mello-Castanho, Sintering Studies on Ni–Cu–YSZ SOFC Anode Cermet Processed by Mechanical Alloying. *Journal of Thermal Analysis and Calorimetry*, Springer, 2009. 97: p. 775–780.

140. Marjan Marinsˇek, Klementina Zupan, Jadran Mae`ek, Ni–YSZ Cermet Anodes Prepared by Citrate/Nitrate Combustion Synthesis. *Journal of Power Sources* 2002. 106: p. 178–188.

141. Marjan Marinˇsek, Klementina Zupan, Jadran Macˇek, Preparation of Ni–YSZ Composite Materials for Solid Oxide Fuel Cell Anodes by the Gel-Precipitation Method. *Journal of Power Sources* 2000. 86: p. 383–389.

142. Chung Min An, Jung-Hoon Song, Inyong Kang, Nigel Sammes, The effect of Porosity Gradient in a Nickel/Yttria Stabilized Zirconia Anode for an Anode-Supported Planar Solid Oxide Fuel Cell. *Journal of Power Sources* 2010. 195: p. 821–824.

143. Lan Zhang, San Ping Jiang, Wei Wang, Yujun Zhang, NiO/YSZ, Short Communication Anode-Supported, Thin-Electrolyte, Solid Oxide Fuel Cells Fabricated by Gel Casting. *Journal of Power Sources* 2007. 170: p. 55–60.

144. Xinge Zhang, Mark Robertson, Cyrille Dec`es-Petit, Yongsong Xie, Rob Hui, Sing Yick, Edward Styles, Justin Roller, Olivera Kesler, Radenka Maric,

Dave Ghosh, NiO–YSZ Cermets Supported Low Temperature Solid Oxide Fuel Cells. *Journal of Power Sources* 2006. 161: p. 301–307.

145. Jiangrong Kong, Kening Sun, Derui Zhou, Naiqing Zhang, Ju Mu, Jinshuo Qiao, Ni–YSZ Gradient Anodes for Anode-Supported SOFCs. *Journal of Power Sources* 2007. 166: p. 166 (2007) 337–342.

146. Lee K.-R., Y.S. Pyo, B.S. So, S.M. Kim, B.K. Lee, J.H. Hwang, J. Kim, J.-H. Lee, H.-W. Lee, Interpretation of the Interconnected Microstructure of an NiO-YSZ Anode Composite for Solid Oxide Fuel Cells via Impedance Spectroscopy. *Journal of Power Sources* 2006. 158: p. 45–51.

147. Monteiro R.C.C., M.M.R.A. Lima, Effect of Compaction on the Sintering of Borosilicate Glass/Alumina Composites. *Journal of the European Ceramic Society*, 2003. 23: p. 1813–1818.

148. William F. Smith, Javad Hashemi,, Ph.D, Foundation of Materials Science and Engineering. Fourth Edition ed 2006, Singapore: *McGraw-Hill International Edition.*

149. Yeong Yoo, Nguon Lim, Performance and Stability of Proton Conducting Solid Oxide Fuel Cells Based on Yttrium-Doped Barium Cerate-Zirconate Thin-Film Electrolyte. *Journal of Power Sources* 2013. 229**:** p. 48-57.

150. Capdevila X.G., J. Folch, A. Calleja, J. Llorens, M. Segarra, F. Espiell, J.R. Morante, High-Density YSZ Tapes Fabricated via the Multi-Folding Lamination Process. *Ceramics International* 2009. 35: p. 1219–1226.

151. Jinhua Piao, Kening Suna, Naiqing Zhang, Shen Xu, A study of Process Parameters of LSM and LSM–YSZ Composite Cathode Films Prepared by Screen-Printing. *Journal of Power Sources* 2008. 175: p. 288–295.

152. Guo-jun Li, Zhan-ru Sun, Hong Zhao, Chun-huan Chen, Rui-ming Ren, Effect of Temperature on the Porosity, Microstructure, and Properties of Porous $La_{0.8}Sr_{0.2}MnO_3$ Cathode Materials. *Ceramics International* 2007. 33: p. 1503–1507.

153. Yu Konyashin I. , T.V. Chukalovskaya, A Technique for Measurement of Porosity in Protective Coatings. *Surface and Coatings Technology*, 1996. 88: p. 5-11.

154. Galmarini, S., Cermics : Sintering and Microstructure, in Work practices "Ceramics Process" : TP3 Sintering 2011: *MXC 210,EPFL*, Lausanne, Switzerland. p. 1-15.

155. Bruckschen B., H. Seitz, T. M. Buzug, C. Tille, B. Leukers, S. Irsen Comparing Different Porosity Measurement Methods for Characterisation of 3D Printed Bone Replacement Scaffolds. *Biomedizinische Technik volume* 50 2005 (supplementary vol.1 - part 2): p. 1609-1610.

156. Lohse B.H., A. Calka, D. Wexler, Effect of Starting Composition on the Synthesis of Nanocrystalline TiC During Milling of Titanium and Carbon. *Journal of Alloys and Compounds*, 2005. 394: p. 148-151.

157. Chau-Hsiang Wang, Moo-ChinWang, Je-Kang Du , Yu-YouSie, Chi-Shiung Hsi , Huey-ErLee, Phase Transformation and Nanocrystallite Growth Behavior of 2 mol % Yttria-Partially Stabilized Zirconia (2Y-PSZ) Powders. *Ceramics International* 5165–5174, 2013. 39: p. 5165–5174.

158. Rajkumar M., K. Kavitha, M. Prabhu, N. Meenakshisundaram, V. Rajendran, Nanohydroxyapatite–Chitosan–Gelatin Polyelectrolyte Complex with Enhanced Mechanical and Bioactivity. *Materials Science and Engineering C*, 2013. 33: p. 3237–3244.

159. Toshihiro Isobe, Yoshikazu Kameshima, Akira Nakajima, Kiyoshi Okadaa, Yuji Hotta, Gas Permeability and Mechanical Properties of Porous Alumina Ceramics with Unidirectionally Aligned Pores. *Journal of the European Ceramic Society* 2007. 27: p. 53–59.

160. Simwonis D., H. ThuÈlen, F.J. Dias, A. Naoumidis, D. StoÈver, Properties of Ni/YSZ Porous Cermets for SOFC Anode Substrates Prepared by Tape Casting and Coat-Mix Process. *Journal of Materials Processing Technology*, 1999 92-93: p. 107 -111.

161. Weckmann H., A. Syed, Z. Ilhan, and J. Arnold, Development of Porous Anode Layers for the Solid Oxide Fuel Cell by Plasma Spraying. *Journal of Thermal Spray Technology*, 2006. 15(4): p. 604-609.

162. Ji Haeng Yu, Gun Woo Park, Shiwoo Lee, Sang Kuk Woo, Microstructural Effects on the Electrical and Mechanical Properties of Ni–YSZ Cermet for SOFC Anode. *Journal of Power Sources* 2007. 163: p. 926–932.

163. Nobuhisa Suzuki, Takao Uchida, Kenichi Suzuki, Test Method and Strength Characteristics of Alumina Ceramics at Cryogenic Temperatures. *Cryogenics* 38 1998. 38: p. 363-366.

164. Ik-Hyun Oh, Naoyuki Nomura, Naoya Masahashi, Shuji Hanada, Mechanical Properties of Porous Titanium Compacts Prepared by Powder Sintering. *Scripta Materialia* 2003. 49: p. 1197-1202.

165. Voort, G.F.V., Metallography Principle and Practice 1984, United State of America: *McGraw-Hill Book Company.*

166. Zheng R., X.M. Zhou, S.R. Wang, T.-L. Wen, C.X. Ding, A study of Ni + 8YSZ/8YSZ/$La_{0.6}Sr_{0.4}CoO_3$− ITSOFC Fabricated by Atmospheric Plasma Spraying. *Journal of Power Sources* 2005. 140: p. 217–225.

167. Han Minfang, Tang Xiuling, Peng Suping, Research on Sintering Process of YSZ Electrolyte. *Rare Metals*, 2006. 25 (special issue): p. 209.

168. Malinee Meepho, Darunee Wattanasiriwech, Suthee Wattanasiriwech, Pavadee Aungkavattana, 10th Eco-Energy and Materials Science and Engineering (EMSES2012), Preparation of NiO-YSZ Substrate for Electrophoretic Deposition of Thin YSZ Film. *Energy Procedia*, 2013. **34:** p. 714-720.

169. GmbH, F., Operating Manual Ultrasonic cleaner "laborette 17", in Fritsch GmbH, Fritsch, Editor 2002, *Fritsch GmbH*: Germany. p. 1-12.

170. Michele Casarin, Vincenzo M.Sglavo, Influence of Processing Conditions on the Microstructure of NiO-YSZ Supporting Anode for Solid Oxide Fuel Cells. *Ceramics International*, 2015. 41: p. 2543-2557.

171. Huangang Shi, Ran Ran, Zongping Shao, Wet Powder Spraying Fabrication and Performance Optimization of IT-SOFCs with Thin-Film ScSZ Electrolyte. *International Journal of Hydrogen Energy*, 2012. 37: p. 1125-1132.

172. Eva Gregorov´a, Willi Pabst, Porosity and Pore Size Control in Starch Consolidation Casting of Oxide Ceramics—Achievements and Problems. *Journal of the European Ceramic Society* 2007. 27: p. 669–672.

173. Mohammad Taghi Taghizadeh, Narges Sabouri, Thermal Degradation Behavior of Polyvinyl Alcohol/Starch/Carboxymethyl Cellulose/ Clay Nanocomposites. *Universal Journal of Chemistry* 2013. 1(2): p. 21-29.

174. Sandrine Cottrino, Yves Jorand, Eric Maire, Jérôme Adrien, Characterization by X-ray Tomography of Granulated Alumina Powder During in Situ Die *Compaction Materials Characterization* 2013. 81: p. 111-123.

175. Fasaki I., A. Koutoulak, M. Kompitsas, C. Charitidis, Structural, Electrical and Mechanical Properties of NiO Thin Films Grown by Pulsed Laser Deposition. *Applied Surface Science* 2010. 257: p. 429-433.

176. Jeffrey J. Swab, Andrew A. Wereszczak, Jason Tice, Russ Caspe, Reuben H. Kraft, and Jane W. Adams, Mechanical and Thermal Properties of Advanced Ceramics for Gun Barrel Applications, 2005, *US Army Research Laboratory*: Maryland, USA. p. 1-77.

177. Horng-Yi Changa, Yao-Ming Wang, Chia-Hsin Lin, Syh-Yuh Cheng, Effects of Rapid Process on the Conductivity of Multiple Elements Doped Ceria-Based Electrolyte. *Journal of Power Sources*, 2011. 196(4): p. 1704-1711.

178. Xiaoming Hao, Yajie Liu, Zhenhua Wang, Jinshuo Qiao, Kening Sun, A Novel Sintering Method to Obtain Fully Dense Gadolinia Doped Ceria by Applying a Direct current. *Journal of Power Sources* 2012. 210: p. 86– 91.

179. Wang J.Z., H.Q. Yin, X.H. Qu, J.L. Johnson, Effect of Multiple Impacts on High Velocity Pressed Iron Powder. *Powder Technology*, 2009. 195: p. 184-189.

180. Gori, F., Remarks on the Paper “Mass and Energy-Capital Conservation Equations to Forecast Monthly Oil Price”. *Applied Thermal Engineering* 2014. 68: p. 59-61.

181. Harold Burrier, J., High-Strength Structural and High-Strength Low-Alloy Steels in Properties and Selection: Irons, Steels, and High Performance Alloys Section: Carbon and Low-Alloy Steels. Vol. 1. 2005, USA: *ASM.*

182. Lee D.-S., J.-H. Le, J. Kim, H.-W. Lee, H.S. Song, Tuning of the Microstructure and Electrical Properties of SOFC Anode via Compaction Pressure Control During Forming. *Solid State Ionics* 2004. 166: p. 13-17.

183. Sophie Giraud, J´erˆome Canel, Young’s Modulus of Some SOFCs Materials as a Function of Temperature. *Journal of the European Ceramic Society* 2008. 28: p. 77-83.

184. Bahman Amini Horri, Cordelia Selomulya, Huanting Wang, Characteristics of Ni/YSZ Ceramic Anode Prepared Using Carbon Microspheres as a Pore Former. *International Journal of Hydrogen Energy*, 2012. 37: p. 15311-15319.

185. Mikko Pihlatie, Andreas Kaiser, Mogens Mogensen, Mechanical Properties of NiO/Ni–YSZ Composites Depending on Temperature, Porosity and Redox Cycling. *Journal of the European Ceramic Society* 2009. **29:** p. 1657–1664.

186. Anhai Li, Jun Zhao, Dong Wang, Xinliang Gao, Hongwei Tang, Three-point Bending Fatigue Behavior of WC–Co Cemented Carbides. *Materials and Design* 45 (2013) 271–278, 2013. 45: p. 271-278.

187. Byung-Koog Jang, Hideaki Matsubara, Influence of Porosity on Hardness and Young’s Modulus of Nanoporous EB-PVD TBCs by Nanoindentation. *Materials Letters* 2005. 59: p. 3462 – 3466.

188. Balakrishnan S., K.Ananthasivan, K.C.HariKumar, Studies on the Synthesis of Nanocrystalline Yttria Powder by Oxalate Deagglomeration and its Sintering Behaviour. *Ceramics International* 2015. 41: p. 5270-5280.

189. Kharton V.V, F.M.B. Marques, A. Atkinson, Review Transport Properties of Solid Oxide Electrolyte Ceramics: A Brief Review. *Solid State Ionic,* 2004. 174: p. 135-149.

190. Gang Yu, Xinghua Huang, Chao Zou, Li Chen, Bonian Hu, Liyuan Ye, Preparation of Graphite@Cu Powders from Ultrasonic Powdering Technique. *Advanced Powder Technology* 2012. 23: p. 16-21.

191. Guthrie R.I.L. and J.J. Jonas, Steel Processing Technology, in Klaus M. Zwilsky, ASM Handbook, Volume 1, Properties and Selection: Irons, Steels, and High Performance Alloys Section: Carbon and Low-Alloy Steels. Vol. 1. 2005, Ohio, USA: *American Society for Metals*.

192. Kilo M. , G. Borchardt, B. Lesage, O. KaõÈtasov, S. Weber, S. Scherrer, Cation Transport in Yttria Stabilized Cubic Zirconia: ^{96}Zr Tracer Diffusion in $(Zr_xY_{1-x})O_{2-x/2}$ Single Crystals with $0.154<x<0.48$. *Journal of the European Ceramic Society* 2000. 20: p. 2069-2077.

193. Robert L. González-Romero, Juan J. Meléndez, Diego Gómez-García, Francisco L. Cumbrera, Arturo Domínguez-Rodríguez, A Molecular Dynamics Study of Grain Boundaries in YSZ: Structure, Energetics and Diffusion of Oxygen. *Solid State Ionics* 2012. 219: p. 1-10.

194. Nash P., C.S.Jayanth, Binary Alloy Phase Diagrams, in Huke Baker, Introduction to Alloys Phase Diagrams. Vol. 3. 1991, Ohio, USA: *American Society for Metals.*

195. Chih-Jen Wang, Chi-Yuen Huang, Yu-Chun Wu, Two-step Sintering of Fine Alumina–Zirconia Ceramics. *Ceramics International* 2009. 35: p. 1467–1472.

196. Hana Ursic, Janes Holc, Marija Kosec, Influence of Sintering Condition on the Properties of 0.57PSN-0.43PT Ceramics Prepared from Mechanochemically Activated Powder. *Journal of the European Ceramic Society* 2013. 33: p. 795-803.

197. Mercera P.D.L., J.G. van Ommen, E.B.M. Doesburg, A.J. Burggraaf, J.R.H. Ross, Stabilized Tetragonal Zirconium Oxide as a Support for Catalysts Evolution of the Texture and Structure on Calcination in Static Air Applied Catalysis, *Elsevier Science Publishers B.V.*, Amsterdam, 1991. 78: p. 79-96.

198. Lasocka, M., Binary Alloy Phase Diagrams, in Huke Baker, Introduction to Alloys Phase Diagrams. Vol. 3. 1991, Ohio, USA: *American Society for Metals.*

199. Kyung Joong Yoon, Jeffrey W. Stevenson, Olga A. Marina, High Performance Ceramic Interconnect Material for Solid Oxide Fuel Cells (SOFCs): Ca- and Transition Metal-Doped Yttrium Chromite. *Journal of Power Sources,* 2011. 196(20): p. 8531-8538.

200. Jiang, S.P., Sintering Behavior of Ni/Y_2O_3-ZrO_2 Cermet Electrodes of Solid Oxide Fuel Cells. *Journal of Materials Science,* Kluwer Academic Publishers 2003. 38: p. 3775-3782.

201. Li Jia, Xiqiang Huang, Xiqiang Huang , Zhiguo Liu , Zhu Zhi , Xueqing Sha, Guoqing Li , Wenhui Su, Preparation of YSZ Film by Gravity-Electrophoretic Deposition and Its Application in SOFC. *Ceramics International* 2007. 33: p. 631–635.

202. Jiang Liu, Wei Liu, Zhe Lu, Li Pei, Li Jia, Lanying He, Wenhui Su, Study on the Properties of YSZ Electrolyte Made by Plaster Casting Method and the Applications in Solid Oxide Fuel Cells. *Solid State Ionics*, 1999. 118: p. 67-72.