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FUEL FLEXIBILITY IN SOLID OXIDE FUEL CELL - A REVIEW

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ABSTRACT

There is a need for proper conversion of fuels with high efficiency. On such is fuel cell (SOFC). In this fuel cell we can use different fuel with different composition. In this fuel cell there is an internal or external reforming of fuel takes place because of high temperature. In this we review the working principle of SOFC and different fuel we can use in SOFC is discussed. Performance characteristics of the SOFC is discussed and reviewed.

KEYWORDS: SOFC, Biodiesel, Ammonia, Biogas, Syngas

A fuel cell is a electrochemical device which convert chemical energy to electrical energy with high conversion efficiency. There are different types of fuel based on mechanism, shape, operating temperature. We are concentrated only on SOFC because of fuel flexibility in the fuel. The working principle of the SOFC is indicated in the below planar SOFC figure 1.

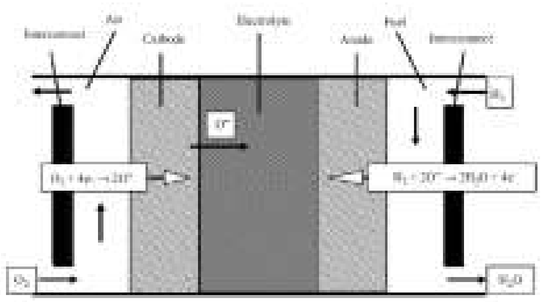

Figure 1: Planar SOFC single structure

Usually SOFC is made up Nickel electrode, non-porous ceramics YSZ electrolyte operating around 600-1000°C. There are two types based on shape planar and tubular SOFC. Different fuels can be used in SOFC are Ammonia, Biodiesel, biogas, Carbon monoxide, ethanol, kerosene, LPG, methane, syngas.

Ammonia Guangyao Meng et al (2007) studied Hydrogen and Ammonia in SOFC. A. Fuerte et al (2009) studied varying the Ammonia comparison from 0-100% in the interval 20 performance is studied and compared with hydrogen. Qianli Ma et al (2006) studied the Ammonia as fuel is studied and compared with Hydrogen shows marginal difference.

Biodiesel Yusuke Shiratori et al (2013)in the biodiesel is directly feed with water by internal reformation it produce rich syngas. Has steam and carbon ratio of 2.0-3.5 produces 1A/cm^2 at 0.7V at 800°C. G. Nahar et al (2011), Gaurav A et al (2010) also studied the Biodiesel as fuel for SOFC. Usallythe is carbon deposition on the anode surface can be removed by increasing the steam ratio.

Biogas Y. Shiratori et al (2010) and Massimo Santarelli et al (2013) studied the biogas as fuel in SOFC producing 0.8V over 800h of running at 200mA/cm^2.

Carbon monoxide Yixiang Shi et al (2011) studied the CO has fuel for SOFC.

Ethanol Bruno L. Augusto et (2014) and Amornchai Arpornwichanop et al (2009) studied the ethanol as fuel for SOFC.

Kerosene Praveen K. Cheekatamarla et al (2009) and Yohei Tanaka et al (2008) studied the kerosene as fuel for SOFC.

LPG K. Ahmed et al (2002), Katsutoshi Sato et al (2012), N. Laosiripojana et al (2011) studied LPG as fuel for SOFC.

Methane Huaiyu Zhu et al (2013), K. Kendall et al (2002), J. Laurencin et al (2008) studied Methane as fuel for SOFC.

Syngas F.P. Nagel et al (2011), Gennaro Campitelli et al (2013), Cheng-Xin Li et al (2010), He Miao et al(2010), Xiao-Feng Ye et al (2011), Ting Shuai Li et al (2014) studied the syngas as fuel for

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SOFC.

PERFORMANCE CHARACTERISTICS OF SOFC

Ammonia

A single cell SOFC cell performance with hydrogen and ammonia gas. Fueled by hydrogen has power densities were 1872, 1357, and 748mWcm^{-2}. While with ammonia as fuel, the cell showed the maximum power densities of 1190, 434, and 167mWcm^{-2} at650, 600, and 550 °C respectively.

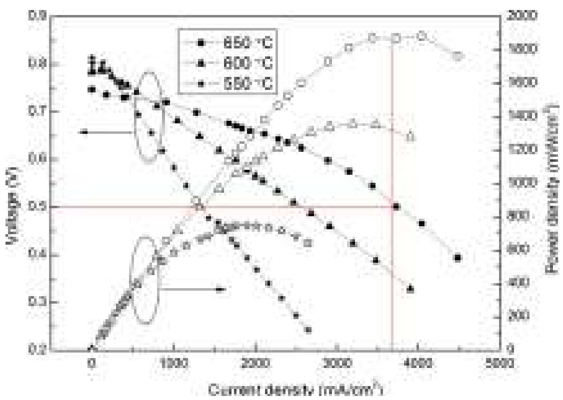

Figure 2: Cell performance with hydrogen fuel at various temperatures

The solid symbols correspond to the cell voltage and open symbols to power density Guangyao Meng et al (2007).

A Fuerte et al (2009) in this Ammonia and hydrogen flow with 40ml/min with varying composition and temperature varied at 700-900°C

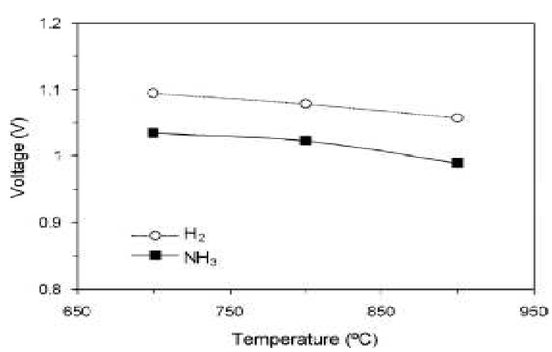

Figure 3: Open circuit voltage with different temperature

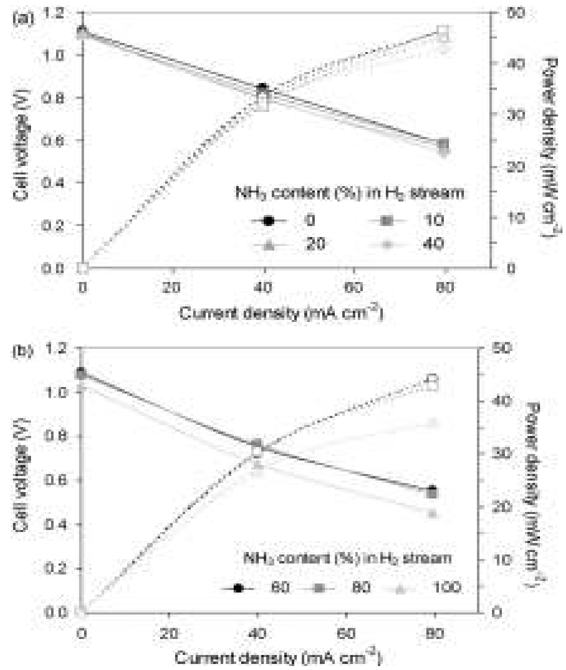

Figure 4: Power density (hollow) and voltage (solid) with different composition of Ammonia Fuerte et al (2009)

Syngas

A syngas with composition of 4% methane, 5% carbon monoxide, 13% carbon dioxide, 48% hydrogen and 30% water. Flow rate of 500 cm^3/min for hydrogen and syngas and air as flow rate of 2000 cm^3/min. Performance is studied and compared with hydrogen as shown in figure 5.

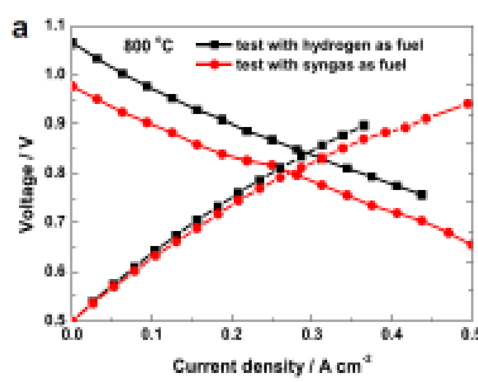

Figure 5 Cell performance with Hydrogen and syngas as fuel for SOFC at 800°C Ting Shuai Li et al (2014)

Different Fuel

M. Lo Faro et al et al (2012) studied the different fuel in SOFC namely methane, methanol, propane, Glycerol. The various composition of fuel is shown in figure 6.

The performance of the SOFC with different fuel in comparison with hydrogen is shown in figure 7 with temperature is around 800°C. In this glycerol is diluted with water with steam to carbon ratio of 0.2 because to increase proper viscosity.

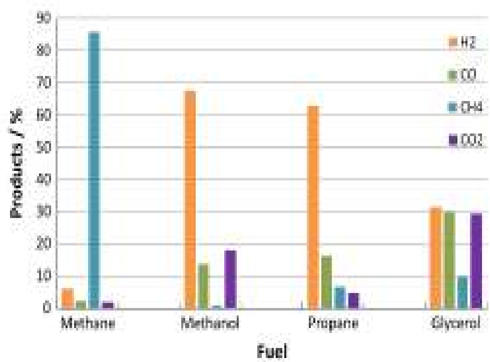

Figure 6: Fuel with different composition

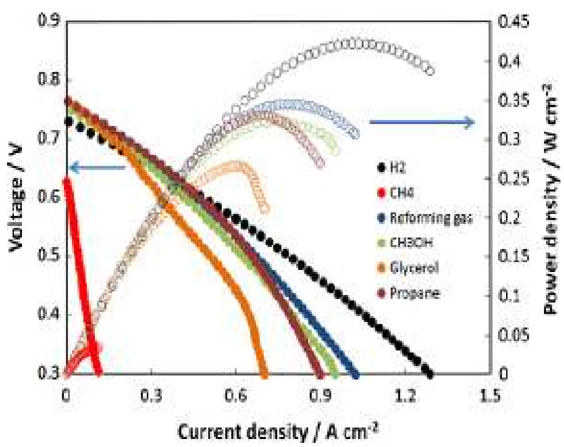

Figure 7: Performance of different fuel in comparison with hydrogen fuel at 800°C M. Lo Faro et al (2012)

CONCLUSIONS

- We can use different fuel with hydrogen or alone along with water so that due to internal reformation there is a production of hydrogen.
- Optimum temperature and composition we can produce maximum power density.
- Carbon deposition can be reduced by increasing steam and carbon ratio.
- The power density of different fuel in the decreasing order like hydrogen, reforming fuel, propane, methanol, glycerol and methane.

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REFERENCES

GuangyaoMeng, Cairong Jiang, Jianjun Ma, Qianli Ma, Xingqin Liu, 2007. Comparative study on the performance of a SDC-based SOFC fueled by ammonia and hydrogen, Journal of Power Sources 173, 189–193.

A. Fuertea, R.X. Valenzuelaa, M.J. Escuderoa, L. Dazaa, 2009 Ammonia as efficient fuel for SOFC. Journal of Power Sources 192 170–174.

Qianli Ma, RanranPeng, Yongjing Lin, JianfengGao, GuangyaoMeng 2006, A high-performance ammonia-fueled solid oxide fuel cell, Journal of Power Sources 161 95–98

Qianli Ma, RanRanPeng, Longzhang Tian, Guangyao Meng 2006, Direct utilization of ammonia in intermediate-temperature solid oxide fuel cells Electrochemistry Communications 8, 1791–1795.

Yusuke Shiratori, Tran Quang-Tuyen, Kazunari Sasaki 2013, Performance enhancement of biodiesel fueled SOFC using paper-structured catalyst international journal of hydrogen energy 38, 9856-9866.

G. Nahar, K. Kendall 2011,Biodiesel formulations as fuel for internally reforming solid oxide fuel cell, Fuel Processing Technology 92, 1345–1354.

Gaurav A. Nahar 2010, Hydrogen rich gas production by the auto thermal reforming of biodiesel (FAME) for utilization in the solid-oxide fuel cells: A thermodynamic analysis, international journal of hydrogen energy 35, 889-8911.

Y. Shiratori, T. Ijichi, T. Oshima, K. Sasaki 2010, Internal reforming SOFC running on biogas

International journal of hydrogen energy 35, 7905-7 912.

Massimo Santarelli, Francesco Quesito, Valerio Novaresio, Cosimo Guerra, Andrea Lanzini, Davide Beretta 2013 Direct reforming of biogas on Ni-based SOFC anodes: Modelling of heterogeneous reactions and validation with experiments, Journal of Power Sources 242, 405-414.

Yixiang Shi, Chen Li, Ningsheng Cai 2011, Experimental characterization and mechanistic modeling of carbon monoxide fueled solid oxide fuel cell, Journal of Power Sources 196, 5526–5537.

Bruno L. Augusto, Fabio B. Noronha, Fabio C. Fonseca ,Francisco N. Tabuti, Rita C. Colman, Lisiane V. Mattos 2014, Nickel/gadolinium-doped ceria anode for direct ethanol solid oxide fuel cell, international journal of hydrogen energy 39, 11196-11209.

Amornchai Arpornwichanopa, Nuttapong Chalerm panchaia, Yaneeporn Patcharavorachota, Suttichai Assabumrungrata, Moses Tade 2009, Performance of an anode-supported solid oxide fuel cell with direct-internal reforming of ethanol, international journal of hydrogen energy 34, 7780 – 7788.

Praveen K. Cheekatamarla, Caine M. Finnerty, Charles R. Robinson, Stanley M. Andrews, Jonathan A. Brodie, Y. Lu, Paul G. DeWald 2009, Design, integration and demonstration of a 50WJP8/kerosene fueled portable SOFC power generator, Journal of Power Sources 193, 797–803.

Yohei Tanaka, Tohru Kato 2008, Reforming of methane, ethylene, and desulfurized kerosene over Ni-8YSZ catalyst Applied Catalysis A: General 348, 229–235.

K. Ahmed, J. Gamman, K. Foger 2002, Demonstration of LPG-fueled solid oxide fuel cell systems, Solid State Ionics 152–153, 485– 492.

Katsutoshi Sato, Yohei Tanaka, Akira Negishi, Tohru Kato 2012, Dual fuel type solid oxide fuel cell using dimethyl ether and liquefied petroleum gas as fuels, Journal of Power Sources 217, 37-42.

N. Laosiripojana, W. Sutthisripok, S. Charojrochkul, S. Assabumrungrat 2011, Steam reforming of LPG over Ni and Rh supported on Gd-CeO2 and Al2O3: Effect of support and feed composition, Fuel 90, 136–141.

Huaiyu Zhu a, Wei Wanga, Ran Ran, Zongping Shao 2013, A new nickeleceria composite for direct-methane solid oxide fuel cells, international journal of hydrogen energy 38, 3741-374 9.

K. Kendall, C.M. Finnerty, G. Saunders, J.T. Chung 2002, Effects of dilution on methane entering an SOFC anode, Journal of Power Sources 106 323–327.

J. Laurencin, F. Lefebvre-Joud, G. Delette 2008, Impact of cell design and operating conditions on the performances of SOFC fuelled with methane, Journal of Power Sources 177, 355–368.

F.P. Nagel, S. Ghosh, C. Pitta, T.J. Schildhauer, S. Biollaz 2011, Biomass integrated gasification fuel cell systems Concept development and experimental results, biomass and bio energy 35, 354-362.

Gennaro Campitelli, Stefano Cordiner, Mridul Gautam, Alessandro Mariani, Vincenzo Mulone 2013, Biomass fueling of a SOFC by integrated gasifier: Study of the effect of operating conditions on system performance, international journal of hydrogen energy 38, 320-327.

Cheng-XinLia, Chang-JiuLia, Lie-Jin Guob 2010, Performance of a Ni/Al2O3 cermet-supported tubular solid oxide fuel cell operating with biomass-based syngas through supercritical water, international journal of hydrogen energy 35, 2904 – 2908.

He Miao, Wei Guo Wang, Ting Shuai Li, Tao Chen, Shan Shan Sun, Cheng Xu 2010, Effects of coal syngas major compositions on Ni/YSZ anode-supported solid oxide fuel cells, Journal of Power Sources 195, 2230–2235.

Xiao-Feng Ye, S.R. Wang, J. Zhou, F.R. Zeng, H.W. Nie, T.L. Wen 2011, Application of a Cu–CeO2/Ni–yttria-stabilized zirconia multi-layer anode for anode-supported Solid Oxide Fuel Cells operating on H2–CO syngas fuels, Journal of Power Sources 196, 5499–5502.

Sadik Kakaça, Anchasa Pramuan jaroenkijb, Xiang Yang Zhoub 2007, A review of numerical modeling of solid oxide fuel cells, International Journal of Hydrogen Energy 32, 761 – 786.

Ting Shuai Li, Min Xu, Chongxin Gao, Baoqing Wang, Xiyun Liu, BaihaiLi, WeiGuo Wang 2014, Investigation into the effects of sulfur on syngas reforming inside a solid oxide fuel cell, Journal of power sources 258,1-4.

M. Lo Faro, V. Antonucci, P.L. Antonucci, A. S. Arco 2012, Fuel flexibility: A key challenge for SOFC technology fuel 102,554-559.