

Short Communication

Direct Biomass Fuel Micro–Solid Oxide Fuel Cell

Tarkeshwar C. Patil^{1,*}, Sanjay M. Mahajani², Siddhartha P. Dutttagupta¹

¹Department of Electrical Engineering, Indian Institute of Technology Bombay, Mumbai, India

²Department of Chemical Engineering, Indian Institute of Technology Bombay, Mumbai, India

*E-mail: tarkeshwar7@gmail.com

Received: 28 May 2014 / Accepted: 2 October 2014 / Published: 28 October 2014

Direct biomass fuel were tested as fuels for operating micro–solid oxide fuel cell. In this study two types of biomass fuels were used viz., Biomethane and rice husk based syngas. Species present in these fuels were analyzed using gas chromatography. It showed that biomethane is composed of N₂ and CH₄ whereas syngas comprised of CO₂, H₂, N₂, CH₄ and CO. During the performance study of the fuel cell, it was observed that syngas when used as fuel operated the cell at lower power density than that of biomethane. Thus an optimal combination of fuel and temperature can serve as a best power source for portable applications.

Keywords: Biomass fuel, μ -SOFC, Peak Power Density, Gas Chromatography, Biomethane, Syngas.

1. INTRODUCTION

The fuel used to operate Micro–Solid Oxide Fuel Cell (μ -SOFC) is Hydrogen, Methane and/ or direct carbon [1, 2, 3, 4]. For portable applications like powering portable electronic devices such as MP3 players, mobile phones, laptops, etc. [5], powering electronic devices, including communications in remote locations where gas is easily available [6], micro-hybrid vehicle [7], the above mentioned fuels are hazardous or may not be readily available. Thus we propose to utilize the biomass fuels, which are easily generated in remote places and would enable to boost technological advancement in these areas. These fuels can be stored in small cartridges and can be replenished as and when required. The biomass fuels can be generated in various forms [8, 9, 10, 11, 12]. Biomass utilized as a fuel for SOFC stack operations [11, 12] is based on wood chips and also there are reports suggesting of microbial catalysts [10] to reform the syngas before using it as a fuel for SOFC stack. Further [13] reports that the syngas derived from rice husk gasification undergoes catalytic oxidation to produce

hydrogen using Cobalt Phyllosilicate Catalyst to serve as an input fuel. The impact of these fuels on the performance of the μ -SOFC is studied. Moreover the constituent species analysis for both the biomass fuels has also been described in this study.

2. EXPERIMENTAL

2.1 Biomass Fuels

The fuels used for studying the performance of μ -SOFC were formed using commercial technologies. As an alternative to the hydrocarbon fuels and to be eco-friendly, biofuels can be opted as fuels for powering portable devices. Since these biofuels can be easily available can serve as a prime candidate as fuels for μ -SOFC. Biofuels can be obtained from upgraded landfill establishments to extract Biomethane which can be gathered and stashed away in the canisters and/ or cartridges. Also by gasification of biomass feedstock, producer gas can be extracted.

Biomethane was supplied by MED Gas through their facility which is an upgraded biogas plant using the landfill as the biomass feedstock. Syngas was collected from the in-house gasifier setup available in IIT Bombay campus. This gasifier works with dried rice husk and is based on complete combustion using air as a medium. This gasification was carried out with an in-house gasifier using rice husk and biodiesel, which were gasified at 600°C in the presence of air. Syngas from this gasifier was collected using a simple setup comprising of a double diaphragm pump and the portable canister. The inlet of the pump is linked via a PV tubing to the vent of the rice husk gasifier which sucks the gas and is filled into the canister through its exhaust. Both of the gases were filled in portable canisters. Gases were used as received without any further purification.

2.2 Gas chromatography study

NUCON 5765 Gas Chromatograph was used to break down the biomass fuel constituents and correlated the changes observed in the performance of the μ – SOFC. 1.25ml of each gases was injected into the analyzer using a glass syringe.

2.3 μ – SOFC

Table 1. Technical specifications of the μ – SOFC

Cell Region	Material	Thickness (μ m)	Diameter (mm)
Anode	Ni-YSZ	220	20
Electrolyte	YSZ	6	20
Cathode	LSM	50	12.5

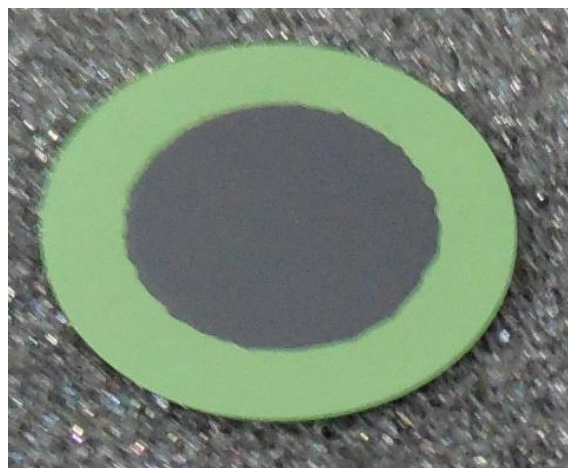


Figure 1. μ -SOFC from fuelcellmaterials.com used for the biomass fuel analysis.

The μ -SOFC used for the study was procured from fuelcellmaterials.com. The technical specifications of the μ -SOFC are tabulated in table 1. The cell is 20mm in diameter and is anode supported. Fig. 1 shows the μ -SOFC used for the study, the green region is the anode, followed by a transparent membrane of the electrolyte and the black region being the cathode.

2.4 μ -SOFC test setup

The μ -SOFC testing was performed utilizing a novel ultra-portable setup. The constructional details of the setup cannot be revealed as a patent has been filed [14]. This is a universal test setup for characterizing any μ -SOFC.

3. RESULTS AND DISCUSSION

3.1 Gas chromatographic (GC) analysis

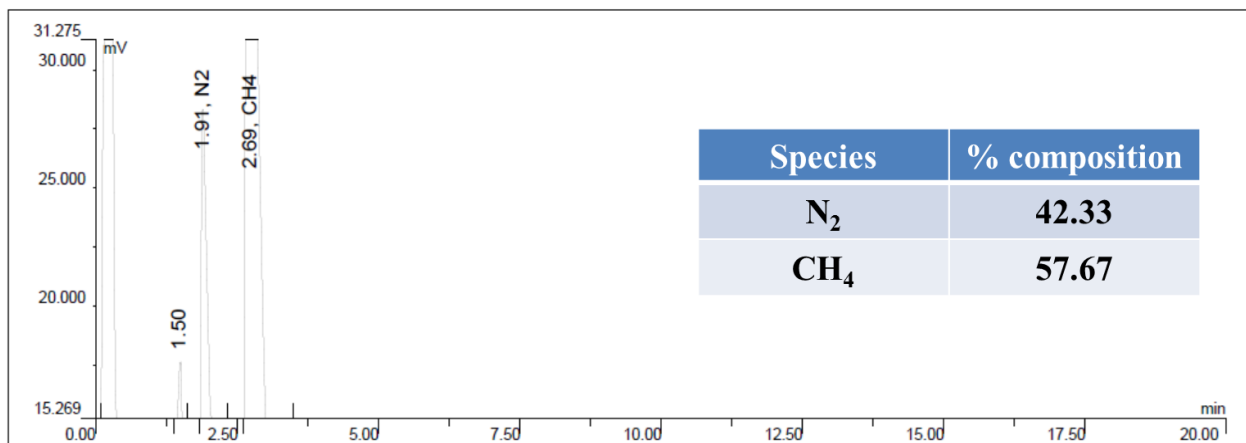


Figure 2. Chromatograph for Biomethane showing distinct peaks for N₂ and CH₄. The table in the inset shows the v/v % composition of the constituent gases.

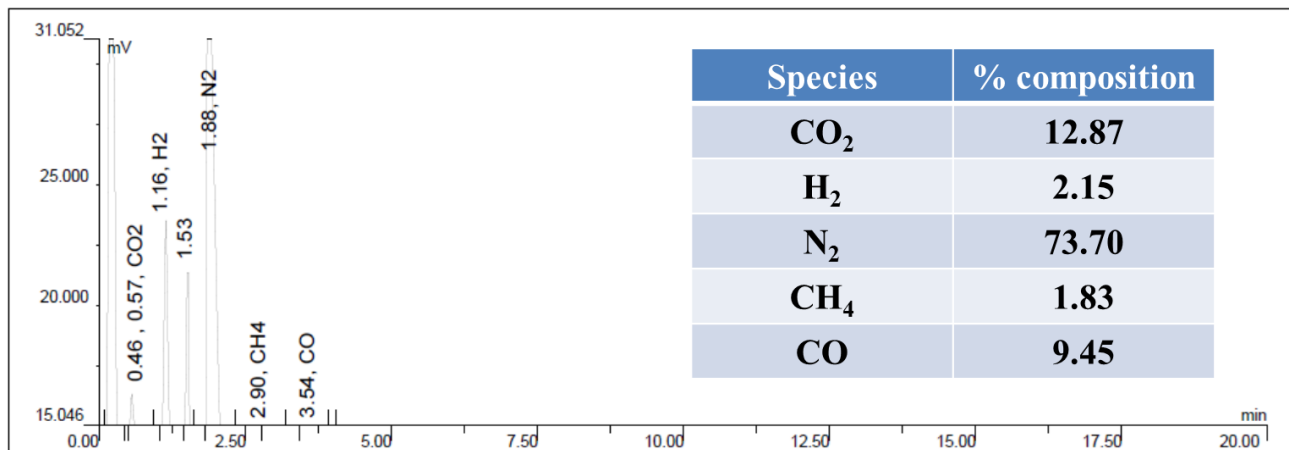


Figure 3. Chromatograph for rice husk syngas showing distinct peaks for CO₂, H₂, N₂, CH₄ and CO. The table in the inset shows the v/v % composition of the constituent gases.

The biomass fuels were analyzed for the key species using GC. Firstly the Biomethane sample was analyzed and the concentrations along with the chromatograph are shown in Fig. 2. It is noted that only CH₄ and N₂ were present in the Biomethane. As reported in [15], the Biomethane constitutes CH₄ (54.2%), CO₂ (42.1%) and N₂ (3.7%) as prime constituents, the presence of CO₂ is not delineated in our sample as determined from Fig. 2. Similarly for rice husk syngas, the results are shown in Fig. 3. Here it is observed that CO₂ concentration is higher than CO. Calvo et al. [16] delineates the composition as CO₂ (14%), H₂ (6%), N₂ (63%), CH₄ (4%), CO (10%), and O₂ (3%). Here is seen that the constitutions of the key species are more or less equal to over observations.

3.2 Performance of μ – SOFC using biomass fuels

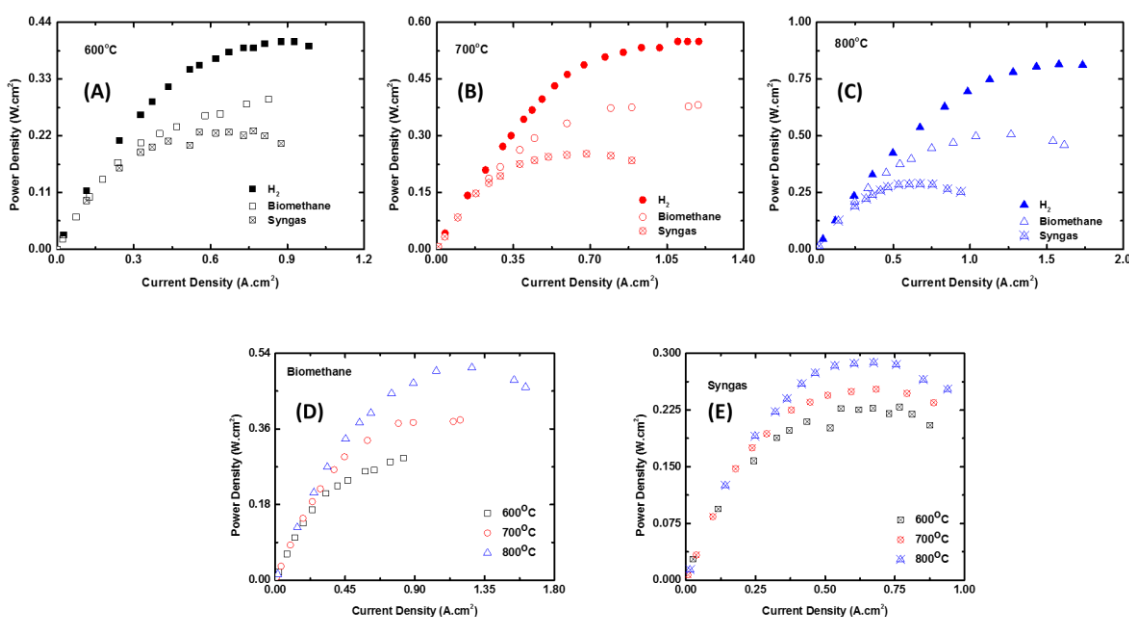


Figure 4. Polarization plots for all fuels are shown at (A) 600°C, (B) 700°C, and (C) 800°C also as a highlight polarization plots for (D) Biomethane and (E) Syngas as a function of temperature.

In order to compare the μ -SOFC performance, H_2 fuel was used to benchmark characteristics of the cell. The biomass fuels were fed to the μ -SOFC and the output power density as a mapping of current density and temperature were noted. The temperature of the μ -SOFC was varied from 600°C to 800°C . The resulting plots are shown in Fig. 4. Fig. 4 (A), (B), and (C) show the comparison of output characteristics of the μ -SOFC at various temperature, moreover (D) and (E) depicts the temperature dependency of power density for both the biomass fuels. Since syngas has CO_2 content as a prime species, in that respect is a formation of Gas induced Ion Barrier (GIIB) at the Electrode Electrolyte Interface (EEI) which is explained in [3]. Therefore the power density is observed to be lower. This reasoning has not been cited by any other research group. Biomethane when used as fuel shows a restrained performance as compared to H_2 and syngas.

In order to employ this for portable applications, μ -SOFC needs to run at peak power density for better functioning. The peak power density as a function of temperature for all the three fuels is shown in Fig. 5. Here it is observed that there is an exponential increase in peak power density as temperature is increased. The fitting equation governed by this growth is given by

$$y = A_1 \times e^{-x/t_1} + y_0$$

where y_0 is the peak power density at $1000/T$ equal to 0

A_1 is the span of peak power density

x is the temperature increment rate constant

t_1 is the $1000/T$ value

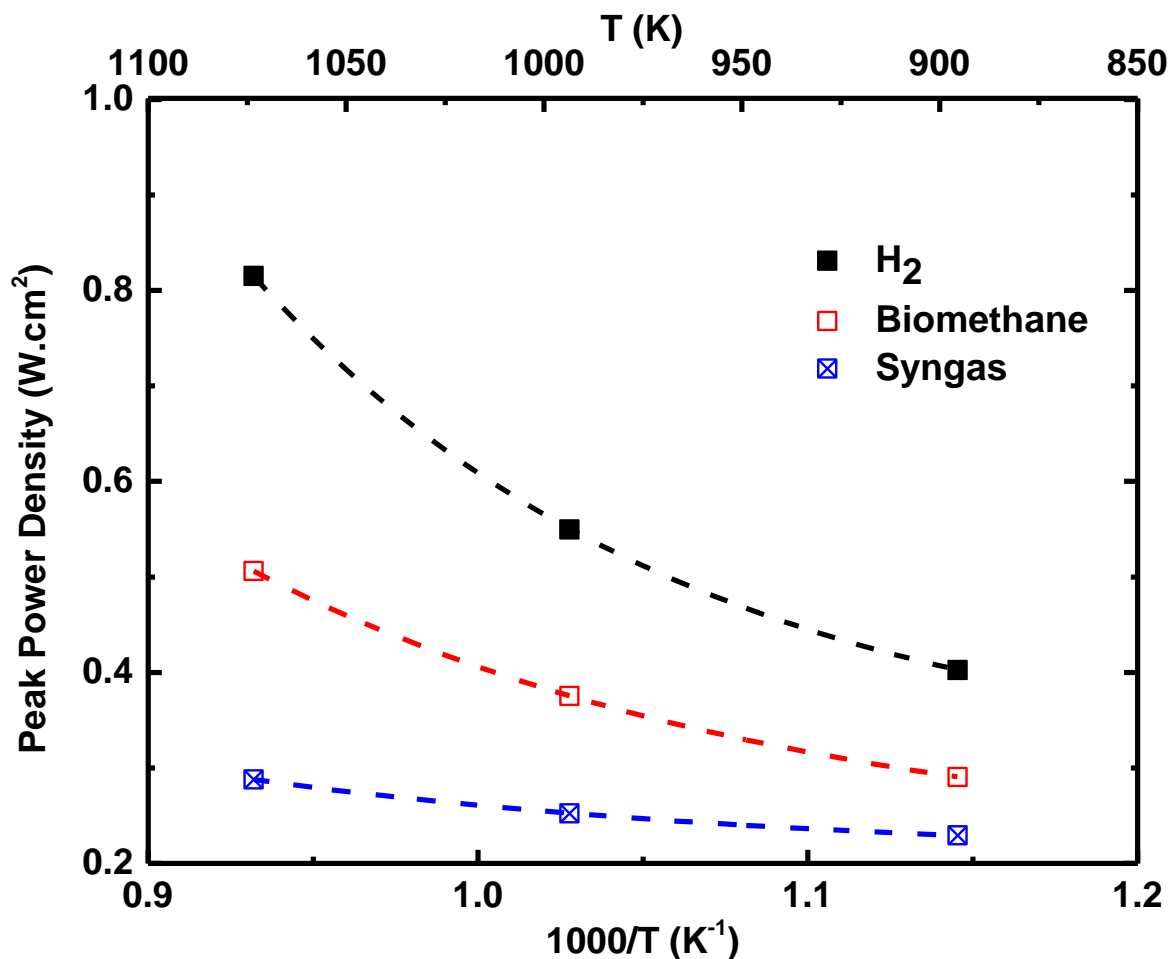


Figure 5. Temperature dependence of peak power density for the biofuels, along with standard H₂ fuel is seen here as a trend of exponential growth.

4. CONCLUSION

In this study, the biofuels were so taken that they are easily usable even in remotest place. Further the chromatographies study showed the Biomethane used in this experiment is free from CO₂ species, whereas CO₂ is the species with highest % composition after N₂. The presence of CO₂ is of large worry as it creates a GIIB layer at EEI, this has been noted during the testing of biomass capable μ-SOFC for probable portable applications. As per the demand of the application appropriate choice of fuel and temperature can be attained. This will aid in reaching maximum performance from the μ-SOFC. If the Syngas is purified to eliminate CO₂ content, it is supposed to give better performance. The biofuels can be supplied using portable cartridges which would be replenished from time to time.

ACKNOWLEDGEMENTS

The authors would like to thank the financial support provided by CSIR-HRDG, Government of India.

References

1. T. Patil, S. Kulkarni, S. Duttgupta and G. Phatak, "Oxygen Ion Transport through the Electrolyte in Solid Oxide Fuel Cell," International Conference on Renewable Energy Research and Applications (ICRERA) 2013, Madrid, Spain, October 20-23 2013, doi: 10.1109/ICRERA.2013.6749728
2. T. C. Patil, S. G. Kulkarni, S. P. Duttgupta, G. J. Phatak, "Multi-Fuel Modeling of Oxygen Ion Transport in Solid Oxide Fuel Cell," 8th WSEAS International Conference on Energy & Environment, Rhodes Island, Greece, July 16 – 19, 2013, Recent Advances In Energy And Environmental Management, ISBN: 978-960-474-312-4G.
3. T. C. Patil, and S. P. Duttgupta, *J. Power Sources* (**Submitted**)
4. M. Dudek, *Int. J. Electrochem. Sci.*, 7 (2012) 2874.
5. G.A. Tompsett, C. Finnerty, K. Kendall, T. Alston, and N.M. Sammes, *J. Power Sources* 86 (2000) 376.
6. K. Kendall, and M. Palin, *J. Power Sources*, 71 (1998) 268.
7. D. Nikbin, *The Fuel Cell Review*, (April – May 2006) 21.
8. D. Sateesh, R.N. Mandapati, S.M. Mahajani, A. Ganesh, P. Aghalayam, D.K. Mathur, and R.K. Sharma, *Energy*, 35 (2010) 2374.
9. A. Ganesh and R. Banerjee, *Renewable Energy*, 22 (2001) 9.
10. W. Liu, W. Mu, M. Liu, X. Zhang, H. Cai and Y. Deng, *Nat. Commun.*, 5 (2014) 3208.
11. C. Bang-Møller, M. Rokni, and B. Elmegaard, *Energy*, 36 (2011) 4740.
12. F.P. Nagel, S. Ghosh, C. Pitta, T.J. Schildhauer, S. Biollaz, *Biomass and Bioenergy*, 35 (2011) 354.
13. A. Paethanom, S. Nakahara, M. Kobayashi, P. Prawisudha, and K. Yoshikawa, *Fuel Processing Technology*, 104 (2012) 144.
14. T. C. Patil, and S. P. Duttgupta, "Portable Micro–Solid Oxide Fuel Cell Testing Setup" (Indian Patent Pending [2129/MUM/2014] Filed In July 2014).
15. S. Rasi, J. Lantelä, and J. Rintala, *Fuel*, 115 (2014) 539.
16. L.F. Calvo, M.V. Gil, M. Otero, A. Morán, A.I. García, *Bioresource Technology*, 109 (2012) 206.