Study of the Thickness and Temperature Dependence of the Ionic Conductivity of $Hf_{0.05}Si_{0.95}O_2$ Nano-Films

N. Bernasconi, Y. Aoki, H. Habazaki, K. Oogawa
Laboratory of Interfacial Electrochemistry, Hokkaido University, Sapporo, Japan

Introduction:

Fuel cells today are usually one of two types, polymerelectrolyte (PEFC) and solid oxide fuel cells (SOFC). However, there is a somewhat large gap in the temperature ranges in which these types of fuel cells can work effectively. Fuel cells which can operate in the intermediate temperature range of 200-400°C are desirable as a multipurpose fuel cell system, because this temperature range allows for the use of inexpensive materials including non-noble metal catalysts and normal stainless-steel components and may enable *in situ* reforming of hydrocarbons and biofuels (ethanol). In this temperature range, SOFC are more suitable than polymer-electrolyte fuel cells due to their durability and robustness. Suitable ceramic electrolytes are still being developed.

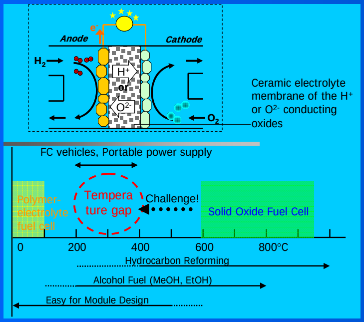

Figure 1: Current fuel cells

One possible solution to this problem was recently investigated by Yoshitaka Aoki et. al. It is a phenomenon called finite size scaling of a percolation system. Simply put its says that if there is a 3D matrix of points with a certain percentage of conducting points, the probability of a complete pathway across the system increases as the size of the system decreases.

In this study, $Hf_{0.05}Si_{0.95}O_2$ was chosen because it was predicted to also demonstrate this phenomena and due to its amorphus nature and decent chemical activity, making thin films with it was easier

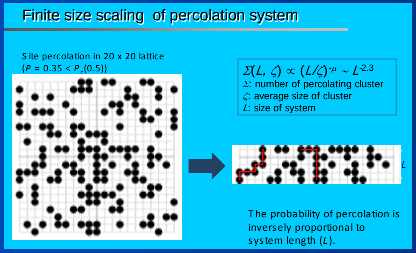

Figure 2: Diagram of percolation system

Objective:

The objective of this study is to investigate the ionic conductivity of Hf0.05Si0.95O2 thin films and observe the effects of the finite size scaling of the percolation system at various temperatures.

Experimental:

Preparation of Hf-Si mixed precursor sol (Hf/Si = 5/95)

ITO-coated glass substrate
- Mark the back of glass
- Cut in half
- Wipe the ITO surface with Kimwipe
- Sonicate in EtOH for 10 min

1-PrOH (10 ml)
1M HCl (29 µl, H2O/Si = 2/1)
$Si(OEt)_4$ (0.158 g)
Stir for 1h at R. T.
$Hf(OC_4H_9)_4$ (0.0188 g)
Stir for 30 min at 70°C
Filtrate by 0.2 µmϕ porous membrane
Dilute with 10 ml of 1-PrOH
0.04 mol L^{-1} Hf-Si mixed precursor sol

Figure 3: Process for preparation of precursor sol

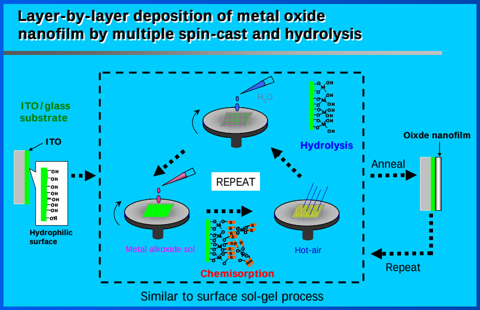

Figure 4: Sol-gel spin coating method

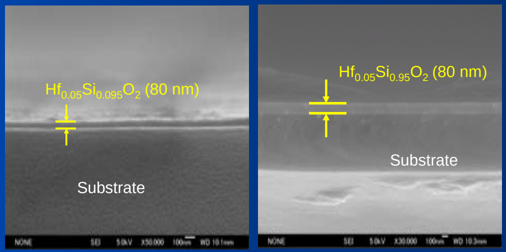

Figure 5: SEM images of the 80 (left) and 130nm(right) samples

Results:

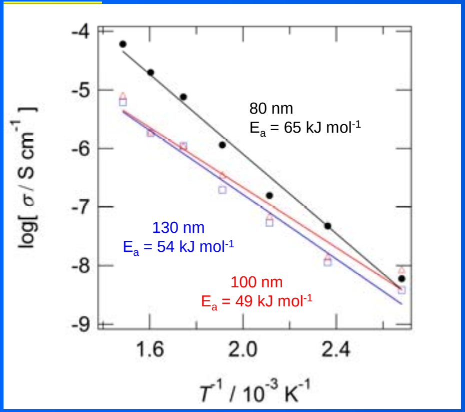

Figure 6: Arrhenius plots of proton conductivity across the $Hf_{0.05}Si_{0.95}O_2$ nanofilms

Summary and Conclusions:

- $Hf_{0.05}Si_{0.95}O_2$ films were made on ITO glass substrates on the nanometer scale.
- Impedance spectroscopy was successfully run on samples in order to determine proton conductivity.
- The 100 and 130nm samples showed roughly the same proton conductivity. However, the 80nm sample showed significantly higher proton conductivity.
- This data supports the finite scaling of a percolation system.

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