Nickel - Gadolinia Doped Ceria Cermet Thin Films for Micro Solid Oxide Fuel Cells

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The deposition of nickel oxide (NiO) and nickel oxide / gadolinia doped ceria (CGO) thin films on yttria stabilised zirconia (YSZ) substrates for the application in solid oxide fuel cells using spray pyrolysis has been investigated. The spray pyrolysis process offers the opportunity to deposit dense electrolyte or porous electrode thin films. A liquid precursor containing metal salts of the desired stoichiometry is sprayed on a heated substrate. Sprayed droplets reaching the substrate undergo pyrolytic decomposition, resulting in an amorphous metal oxide thin film which can be crystallized upon annealing.

Dense and crack-free NiO films in the thickness range of 100 - 500 nm have been deposited using a precursor solution of a nickel salt in a mixture of organic solvents. The effect of precursor flow rate, deposition temperature and deposition time on film morphology was studied. The as deposited films can be annealed at temperatures up to 1000 °C without cracking. The resulting layers can be reduced in a hydrogen rich atmosphere to yield a porous nickel film (see Figure 1).

NiO-CGO films were deposited using a precursor solution of nickel salts, gadolinium chloride and cerium nitrate in a mixture of ethanol, methoxy propanol and diethylene glycol mono butyl ether acetate. Again, the effect of precursor flow rate, deposition temperature and deposition time on film morphology was studied. Additionally, various nickel salts were used in the spray solution, resulting in very different morphologies. With nickel nitrate very smooth, dense and crack free films with maximum thicknesses ranging up to 1 µm can be obtained. Thicker films result in crack formation upon deposition and annealing. Nickel chloride and bromide containing precursors form very uneven layers with large pores, but thicknesses can be increased up to 20 µm without cracking. All layers can be annealed at temperatures up to 1200 °C without crack formation.

Reduction of dense NiO-CGO layers in H_2 prepared with the nickel nitrate solution results in a porous Ni-CGO cermet (see Figures 2 and 3). Electrical conductivity of these films deposited on a sapphire substrate was measured from room temperture up to 1000 °C in air. Upon exposure to a mixture of hydrogen and nitrogen the conductivity increased by several orders of magnitude.

After having established the fabrication process for the films a 500 nm thick layer of NiO-CGO was deposited on a Foturan® wafer sputter coated with a 200 nm thick layer of silicon. The wafer was then annealed at 550 °C and holes with diameters between 100 and 500 µm were back etched up to the protective Si layer with HF. The Si was removed by RIE. Free standing membranes with a diameter of up to 300 µm (see Figure 4) were obtained. The suitability of these films as anodes for micro SOFCs will be further investigated.

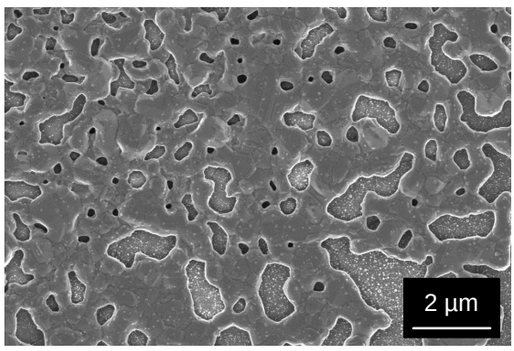

Figure 1: Top view of porous Ni film on YSZ.

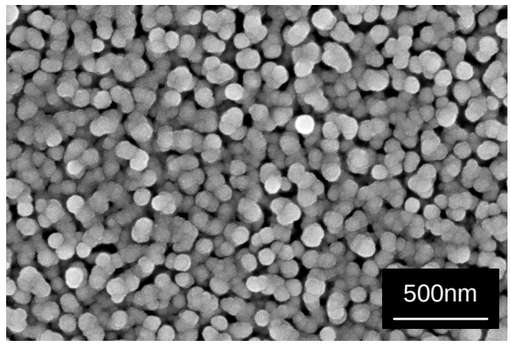

Figure 2: Top view of Ni-CGO film on YSZ after annealing and reduction at 1000 °C under H_2.

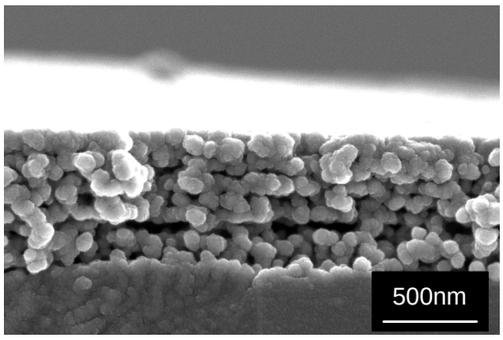

Figure 3: Cross section of Ni-CGO film on YSZ after annealing and reduction at 1000 °C.

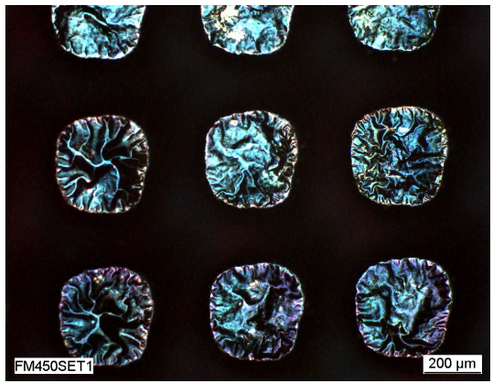

Figure 4: Free standing NiO-CGO membranes on Foturan®.