PREPARATION OF NI-YSZ NANO-FIBER COMPOSITE AS FUEL CELL ANODE MATERIAL

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ABSTRACT

A novel route to fabricate nano-fiber anode material for solid oxide fuel cells (SOFCs) is presented. Firstly, uniform nano-fibers of 8 mol % Yttria Stabilized Zirconia (8YSZ) were formed in an electrospinning process; then, these electrospun fibers were calcined at temperatures up to 1300 °C; and finally the ceramic 8YSZ nano-fibers were coated with nickel in an electroless plating process. The coated Ni-YSZ nano-fibers can be applied as a novel material for the anode of SOFCs.

A solid oxide fuel cell (SOFC) is a ceramic electrochemical device that converts chemical energy directly into electrical energy. SOFCs usually operate at temperatures between 700°C and 900°C. Nickel(Ni) -Yttria Stabilized Zirconia (YSZ) cermet is the most intensively investigated material for SOFC anodes [1,2].Although various approaches and methods have been used to fabricate and to investigate the anode materials and structures [3,4], requirements for a perfect SOFC anode material, such as good transportation for the fuel, ion, and electron; good thermal compatibility with the electrolyte layer, etc., were rarely met simultaneously.

The 8YSZ nanofibers were fabricated in an electrospinning process using a sol-gel containing the desired composition. The polymer-ceramic nano-fiber mats collected from the electrospinning machine were sintered under different temperatures ranging from 1000 to 1300 ˚C for 3 hours, which completely removed PVP from the as-spun fibers[5]. The fibers fired under different temperatures showed different morphological characteristics as expected In a typical nickel electroless coating process, the white 8YSZ nanofiber mats were sequentially treated by acidified tin chloride solution and palladium chloride hydrosol, and then were immersed in the plating solution, which was maintained at temperatures from 55 to 70 ºC in a beaker sitting in a water bath.

Energy dispersive spectrometer (EDS) was used to investigate the compositional information of the nickel coated YSZ nanofibers (Fig. 1 left). It was shown that the atomic ratio (see insert) between Yttrium and Zirconium was very close to the expected ratio of 8 mol.% of Yttria in Zirconia. The presence of nickel element indicated the effectiveness of the plating techniques employed here. Although nickel content shown was 15.76 mol.%, it could be adjusted and controlled by varying the process parameters such as PdCl2 concentration and deposition time , reaction conditions (temperature, pH value, etc.) [6], and additional cycles of activation plating.

X-ray Diffraction analysis (Fig. 2 right) shows that the

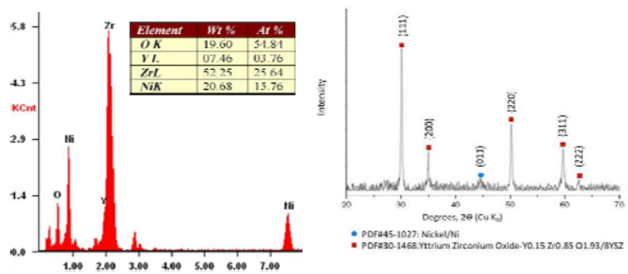

Fig. 1. EDS analysis (left) and XRD pattern (right) of the Ni-YSZ nano-fibers.

8YSZ fibers had a cubic crystalline structure with a lattice parameter of 5.139 Å. The coated Ni phase was also identified as having a hexagonal crystalline structure rather than being amorphous, which was often the case in Ni-P and Ni-B electroless plating processes [7]. Unlike other Ni-coating techniques [8,9], it is apparent no unintended traceable elements were found either in the EDS results or in the XRD pattern.

Figure 2 shows the FEG-SEM (Quanta 3D FEG, FEI Company, USA) images of the as-spun and sintered nano-fibers. It can be noted from Fig. 2 (top left and right) that 8YSZ fibers with a typical diameter of ~ 300 nm have been successfully fabricated. These fibers are highly uniform in diameter without beads or other defects. Also the fiber surfaces are smooth and no Y2O3 or ZrO2 particles can be seen. The nano-fibers fired under 1000 ˚C for 3 hours, shown in Fig. 2 (bottom left), shows considerable coarsening of initial particles , bearing a rough and porous structure because of polymer removal and 8YSZ grain growth. From the insert it is estimated that after the heat treatment the 8YSZ particles have grown to ~ 50 nm from the initial ~ 10 nm in the dispersions. From the cross-section of the fibers (indicated in the graph), it is found that the fibers have a uniform porous structure inside and out.

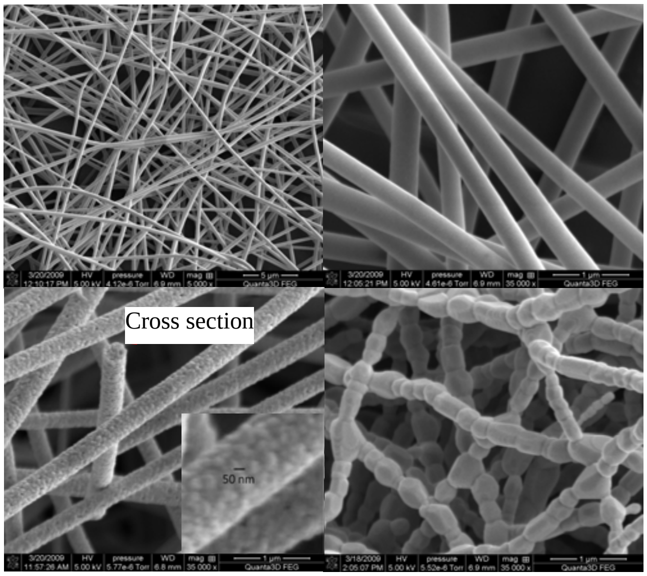

Fig. 2. FEG-SEM images of 8YSZ fibers: as-spun (top left) and (top right); after sintering at 1000 °C (bottom left) and 1300 °C (bottom right) for 3 hours.

It is interesting to see Fig 2 (bottom right), where the fibers bear pearl-necklace shape with the boundaries between two large grains clearly shown when the temperature for calcinations was raised to 1300 ºC [10]. This is assumed owing to the normal grain growth with the decrease in the free energy of the ceramic material when fired to high temperatures [11,12], i.e., higher temperatures boosted the diffusion and interaction between nearby grains and let them aggregate.

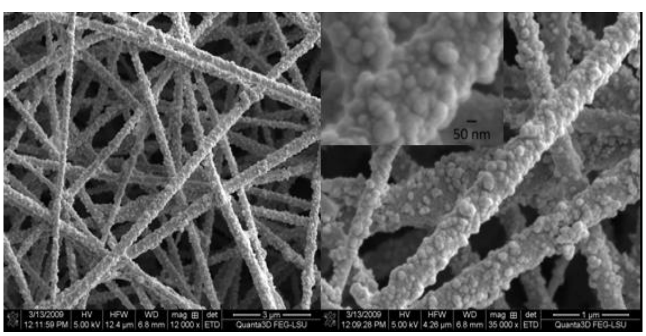

Fig.3. FEG-SEM images of Ni-coated 8YSZ fibers that were sintered at 1000 °C for 3 hours before coating. Ni additions on fiber surfaces could easily be noted when compared with Fig 2 (bottom left). From insert, those coated Ni particles were estimated having particle sizes of ~70 nm.

After forming pure YSZ ceramic nanofibers through calcinations, electroless plating was employed to coat the YSZ fibers with nickel. Ni adhesions on YSZ fiber surfaces are evident when comparing Fig. 3 to Fig. 2. The coated surfaces appear rougher than the pure YSZ surfaces because of the large Ni particle addition. From Fig. 3, Ni particles are found to distribute evenly and uniformly on the fiber surfaces, with no major defects such as Ni agglomeration, spallation or separation . It can also be estimated from Fig. 4 that the coated Ni particles have particle sizes of ~70 nm.

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