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The Effect of the Precursor Powder Size on the Electrical and Sensor Characteristics of Fully Stabilized Zirconia-Based Solid Electrolytes

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Abstract : Nowadays, due to their exceptional anion conductivity at high temperatures cubic zirconia solid solutions, stabilized by rare-earth and alkaline-earth metal oxides, are widely used as a solid electrolyte (SE) materials in different electrochemical devices such as gas sensors, oxygen pumps, solid oxide fuel cells (SOFC), etc. Nowadays the intensive studies are carried out in a field of novel fully stabilized zirconia based SE development. The use of precursor powders for SE manufacturing allows predetermining the microstructure, electrical and sensor characteristics of zirconia based ceramics used as SE. Thus the goal of the present work was the investigation of the effect of precursor powder size on the electrical and sensor characteristics of fully stabilized zirconia-based solid electrolytes with compositions of 0,08Y2O3•0,92ZrO2 (YSZ), 0,06Ce2O3• 0,06Y2O3•0,88ZrO2 and 0,09Ce2O3•0,06Y2O3-0,85ZrO2. The synthesis of precursors powders with different mean particle size was performed by sol-gel synthesis in the form of reversed co-precipitation from aqueous solutions. The cakes were washed until the neutral pH and pan-dried at 110 °C. Also, YSZ ceramics was obtained by conventional solid state synthesis including milling into a planetary mill. Then the powder was cold pressed into the pellets with a diameter of 7.2 and ~4 mm thickness at P ~16 kg/cm2 and then hydrostatically pressed. The pellets were annealed at 1600 °C for 2 hours. The phase composition of as-synthesized SE was investigated by X-Ray photoelectron spectroscopy ESCA (spectrometer ESCA-5400, PHI) X-ray diffraction analysis - XRD (Shimadzu XRD-6000). Following galvanic cell O2 (PO2(1)), Pt | SE | Pt, (PO2(2) = 0.21 atm) was used for SE sensor properties investigation. The value of PO2(1) was set by mixing of O2 and N2 in the defined proportions with the accuracy of □ 5%. The temperature was measured by Pt/Pt-10% Rh thermocouple, The cell electromotive force (EMF) measurement was carried out with ± 0.1 mV accuracy. During the operation at the constant temperature, reproducibility was better than 5 mV. Asymmetric potential measured for all SE appeared to be negligible. It was shown that the resistivity of YSZ ceramics decreases in about two times upon the mean agglomerates decrease from 200-250 to 40 nm. It is likely due to the both surface and bulk resistivity decrease in grains. So the overall decrease of grain size in ceramic SE results in the significant decrease of the total ceramics resistivity allowing sensor operation at lower temperatures. For the SE manufactured the estimation of oxygen ion transfer number tion was carried out in the range 600-800 °C. YSZ ceramics manufactured from powders with the mean particle size 40-140 nm, shows the highest values i.e. 0.97-0.98. SE manufactured from precursors with the mean particle size 40-140 nm shows higher sensor characteristic i.e. temperature and oxygen concentration EMF dependencies, EMF (ENernst - Ereal), tion, response time, then ceramics, manufactured by conventional solid state synthesis.

Keywords : oxygen sensors, precursor powders, sol-gel synthesis, stabilized zirconia ceramics
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