Fracture and Electrical Properties of Doped Ceria Ceramics for SOFC Electrolytes under High Temperature Conditions

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The influences of the sintering additive content of rare-earth oxide on mechanical and electrical properties of ceria ceramics were investigated by small specimen technique and AC impedance method.

Rare-earth oxide doped ceria powder with a composition of $(CeO_2)_{1-x}(RO_{1.5})_x$ (R = Y, Gd, Sm, x=0, 0.10, 0.15, 0.20, 0.30, 0.40 and 1.0) were synthesized from CeO_2, Y_2O_3, Gd_2O_3 and Sm_2O_3 by a co-precipitation method. The powders were then pressed into disks (ϕ12 x 1.0mm) using a die press made of a hard metal at 50MPa, followed by isostatic press at 120MPa. The disks were then sintered in atmospheric condition at 1500˚C for 5h. Specimens were polished with Emery paper (#4000). After polishing, the specimens were annealed at 1000˚C for 3h to remove the induced residual stresses. The specimen densities of the sintered bodies were measured by the Archimedes method. The doped ceria ceramics with Y_2O_3, Gd_2O_3 and Sm_2O_3 are designated by YDC, GDC and SDC, respectively.

The mechanical properties of the sintered bodies, the Young's modulus and fracture stress were measured by a small punch (SP) testing method[1)] using miniaturized disk specimens. The punch and specimen holder, designed for SP tests, are shown in Figure 1.

The test specimens used in this study had a relative density of 99±0.2% and an average grain size of 1.2~2.5mm for YDC, GDC, and SDC (Pure ceria 4.1mm). Figure 2 summarizes the fracture strength of the doped ceria ceramics determined using the SP method. All the doped ceria ceramics gives lower fracture stress values than that of the pure ceria within the range of the dopant content used in this study. In the case of the SDC, σ_{SP} appears to decrease as the dopant content is increased and give a minimum value at the dopant content of 20mol%. The YDC and GDC show a similar trend and give a minimum σ_{SP} value at the dopant content of 15mol. Thus, the strength reduction induced by the doping may be due to the increased concentration of oxygen vacancies. Fracture strength usually increases with the decreasing grain size. However, the fracture strength shows a minimum value approximately for the range of the smallest grain size (10~20mol% dopant). It appears that the influence of the increased oxgen vacancies override strengthening effect due to the finer grain size.
Figure 3 shows the effect of testing temperature on the Young's modulus E_{SP} and fracture stress σ_{SP} for 10YDC. All specimens tested up to 800˚C exhibited a linear elastic brittle fracture, without significant nonlinear load - displacement response. It can be seen that the E_{SP} and σ_{SP} decrease linearly as a function of testing temperature. Both the mechanical properties shows an approximately 30% reduction with respect to the room temperature value.

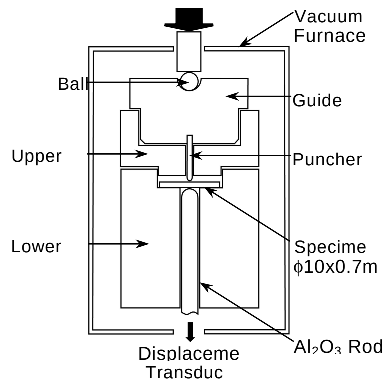

Fig.1 Schematic illustration of Small Punch testing method.

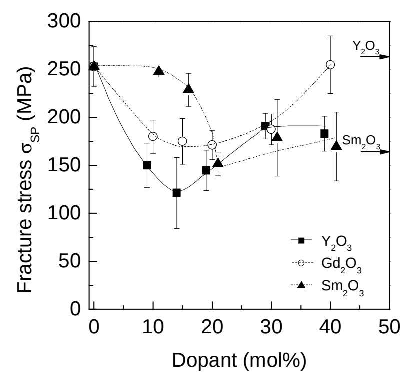

Fig.2 Fracture stress σ_{SP} of $(CeO_2)_{1-x}(RO_{1.5})_x$ as a function of the dopant content

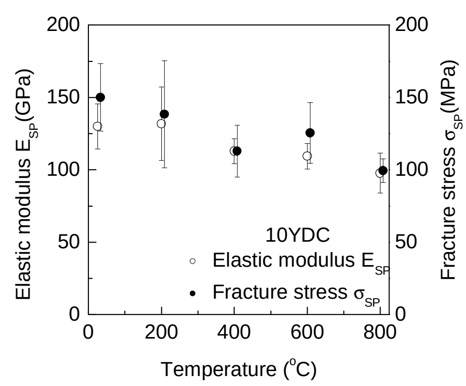

Fig.3 Young's modulus E_{SP} and Fracture stress σ_{SP} of 10YDC as a function of the testing temperature.