Ni-YSZ Composite Particles Synthesized by a Dry Mechanical Method for SOFC Anode Material†

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The solid oxide fuel cell (SOFC) is one of the most attractive power generation systems, because of its high efficiency, low pollution and fuel flexibility. The basic unit of the cell consists of a three-layer structure: anode, electrolyte, and cathode. A conventional SOFC is usually operated at high temperatures near, 1000°C, which causes some serious problems such as physical and chemical degradation of the materials of the SOFC components. Therefore, it is desirable that SOFC operates at intermediate temperatures below 800 °C. Since operating SOFC at reduced temperature causes an increase in the polarization losses of both anode and cathode as well as ohmic loss in the electrolyte, high performance electrodes are crucial.

The nickel (Ni) and yttria-stabilized-zirconia (YSZ) cermet has been widely studied as an anode material in SOFC. The fuel gas is electrochemically oxidized at the Ni/electrolyte/fuel gas interface, at what is called a three-phase boundary (TPB) region1, 2). Therefore, the Ni-YSZ anode performance depends strongly on its microstructure, and it is very important to increase the TPB length in order to develop a high performance Ni-YSZ anode. The possible microstructure of Ni-YSZ anode expected to increase the TPB region appreciably is sketched in Fig. 1. As shown schematically, Ni grains form a skeleton with well-connected YSZ grains finely distributed over the Ni grains surface.

In order to create such a microstructure, we have been applying a Ni-YSZ composite as a starting powder, because the final microstructure of advanced materials such as cermets and ceramics is strongly influenced by the starting powder morphology. In this brief report, we show the synthesis of coating type Ni-YSZ composite particles in which the core Ni powder is covered with YSZ powders by an advanced dry mechanical method. The mechanical method is one of the most suitable methods to synthesize coating type composite particles 3, 4). This process creates the composite particles simply, i.e., mixing of two kinds of powders in a dry ambient atmosphere.

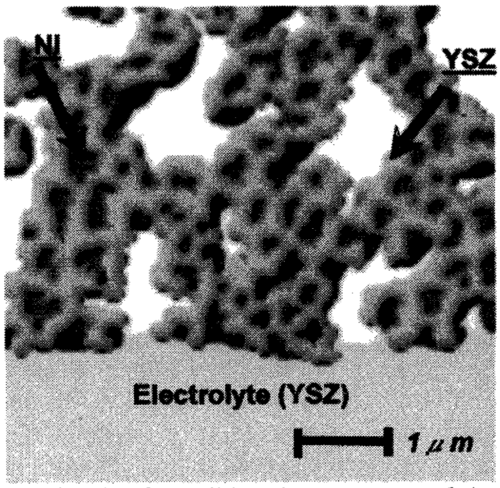

Fig. 1. Sketch of possible microstructure of the Ni-YSZ anode

The coating type Ni-YSZ composite particle was synthesized by the Theta-Composer (TOKUJYU Corp.). The apparatus used in this study is shown in Fig. 2, which consists of the elliptical rotor and vessel. The rotor and vessel rotate in the opposite directions during mechanical treatment of the powders. In the coating, the rotation speed of the rotor and vessel for mechanical treatment is an important factor in order to obtain high quality composite particle. Filament shape Ni powder (INCO210, average particle size: about 0.8 μ m) and fine YSZ powder (Toso TZ-8Y, average particle size: about 0.1 μ m) were used as starting materials. The mixture of Ni and YSZ powders were treated for 15 min by the Theta-Composer. The mass ratio of YSZ to Ni was set to at 30 mass%.

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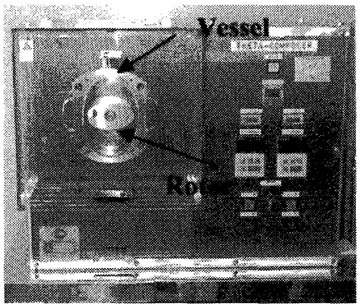

Fig. 2 Theta -Composer system

The microstructure of the composite particle was observed by a scanning electron microscopy (FE-SEM, Hitachi, S-800).

Figure 3 shows SEM photographs of the starting powders and composite particles synthesized by the Theta-Composer. The filament shape Ni powder, fine YSZ powder, and the coating type Ni-YSZ composite particle correspond to Fig. 3 (a), (b), and (c), respectively. As evident from Fig. 3 (c), the fine YSZ powders fix onto the surface of the Ni powder without changing the structure of the filament shape Ni. It confirms that the coating-type Ni-YSZ composite particle is successfully synthesized from the filament shape powder by the dry mechanical process. In general, the filament structure of the powder is easily deformed by mechanical effects such as grinding force. However, the composite particles coated with fine YSZ powders synthesized by this method retain the filament structure. It is considered that mechanical forces such as shear and compression under the grinding force are repeatedly exerted onto the surface of the filament shape Ni as well as fine YSZ powders during operation in the Theta-Composer. The optimum condition for mechanical treatment in this study was found to be a rotation speed of rotor and vessel of 2000 and 50 rpm, respectively.

As can be seen, the coating type Ni-YSZ composite particles for Ni-YSZ anode can be easily obtained by the dry mechanical method. Recently, we have observed that the Ni-YSZ anode sintered at 1300°C shows a high performance for operating at the reduced temperature of 800°C. The detailed results including the electrode performance and microstructure for Ni-YSZ anode will be reported in a near future

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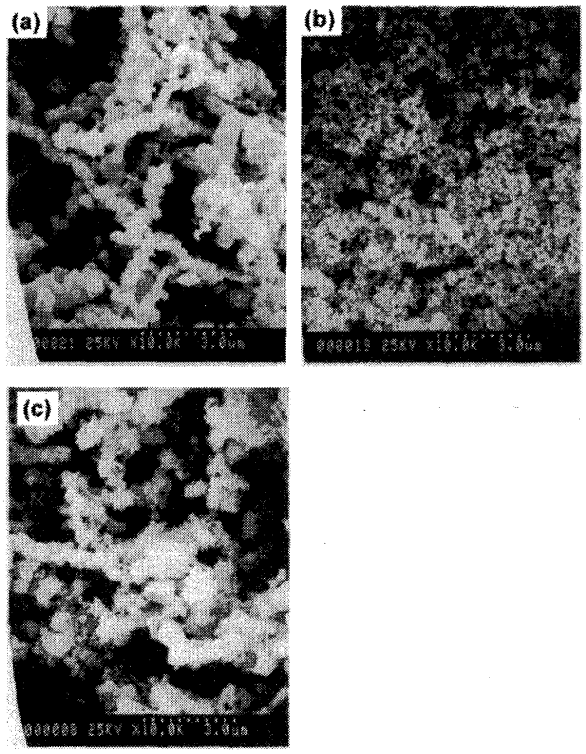

Fig. 3 SEM photographs of (a) filament shape Ni powders and (b) fine YSZ powders as starting materials and (c) Ni-YSZ composite particles synthesized by the Theta-Composer.

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