On the basis of the results of our papers, published in Phys. Rev. B, 58, 1998-I, 1417; 54, 1996-I, 16349, new composites have been synthesized for use in solid oxide fuel cell (SOFC). The composite materials are made from second phase material particle embedded in a matrix material. The second phase particles could be of nano-size, or even as a coating on the surface. As an example, the results of a composite anode material, inserting ceria-based particles into a matrix of Ni+YSZ are reported and discussed in the present paper.

Introduction

SOFC (solid oxide fuel cell) has been attracting great interest because of its advantages of high efficiency, low pollution, etc. The SOFC is mainly composed of the materials of cathode, electrolyte and anode. To date, a traditional method has been used widely to manufacture these materials, in which the doping of elements as a feature, in the form of atom, has been adopted to substitute partially the elements for the atom in a host compound. However, the another method of composite materials have been rarely used in SOFCs.

A composite material can be made from a second phase material in the shape of particles embedded in a matrix material. The second phase particles could be arrayed periodically and of small size, even nano-size, and even as a coating on the surface of the particles. The investigation on the theory (1-5) of the composite materials has shown that some nonlinear properties of the composite materials may be strongly enhanced to 3-4 factors larger than those of the same component materials. There is one interesting problem of what kinds of component materials can be composed into a composite material to meet the requirements of SOFC for improving its performance. The composite material composed by the particles of Bi2O3 inserted into the cathode matrix of LaSrMn(Co)O3 has been studied (6). The composite anode material has been investigated as well.
The traditional anode material used in SOFC has been the Ni+YSZ (Y2O3–stabilized ZrO2)(7-10). Recently, Murray et al (10) reported that an additional layer of YDC(15%Y2O3+85%CeO2) between the electrolyte YSZ and the anode Ni+YSZ can greatly improve the performance of the SOFC because of the mixed conductivity (ionic and electronic) of YDC. In this paper, we try to apply a new composite material, made up of the Ce0.9Ca0.1O2.5 particles as a second phase material and the conventional anode material Ni+YSZ as a matrix, to a SOFC, and investigate its effect on the performance of SOFC.

EXPERIMENTAL

NiO powder and YSZ powder were pre-sintered at 1373K for about 10h and mixed with a weight ratio of 6:4 before they were doped with Ce0.9Ca0.1O2.5 particles with various weight ratio of 0, 5%, 15%, 25%, 35% relative to the NiO+YSZ. The above evenly mixed powder was painted to a face of the electrolyte YSZ tablet, and then the YSZ tablet was sintered at 1673K for about 10h to prepare an anode. Ag was used as the cathode. The electrolyte YSZ tablet was 0.9mm thick. The fuel was H2 and the oxidant was air. Solartron SI 1287 electrochemical interface was employed to measure the performance of the cell.

RESULTS AND DISCUSSIONS

Fig.1 shows the relationship between the maximum power density of SOFCs with anodes of Ni+YSZ embedded with Ce0.9Ca0.1O2.5 particles and the operating temperature. AX was used to label the anode in which the Ce0.9Ca0.1O2.5 particle possessed a weight ratio of X%. The maximum power density of the SOFC with a Ce0.9Ca0.1O2.5 particles+Ni+YSZ anode is obviously higher than that of the SOFC with a conventional anode of NiO+YSZ.

![Graph showing the relationship between maximum power density and operating temperature.](image)

Fig.1  The relationship between the maximum of power density of SOFCs with anodes of Ni+YSZ embedded with Ce0.9Ca0.1O2.5 particles and the operating temperature.

The dependence of the voltage and power density on current density for SOFCs with anodes of Ni+YSZ embedded with Ce0.9Ca0.1O2.5 particles at 1123K are shown in Fig.2 and Fig.3. The results indicated that A15 SOFC exhibits the highest short circuit current.
density of 0.211A/cm² and the highest power density of 0.0589W/cm² that is about 3 times higher than that of A0 SOFC with the traditional anode without the Ce₀.⁹Ca₀.₁O₂.₅ particles.

As shown in Fig.1, the power density of A15 at 1023K is 0.0256W/cm² that is higher than that of A10 at 1123K of 0.021W/cm², which is equal to decreasing the operation temperature by about 100K. All cells were the same in their electrolyte thickness, cathode, preparation condition and particle size, etc., so a conclusion can be drawn that embedding the conventional anode Ni+YSZ matrix with the Ce₀.⁹Ca₀.₁O₂.₅ particles improves the cell performance.

The Ce₀.⁹Ca₀.₁O₂.₅ particle possesses a mixed conductivity which expands the reaction zone of the anode. Its ionic conductivity is higher than that of YSZ in the temperature range of our experiment, which improves the transport of oxygen ions at the electrolyte-anode interface and in the anode. However, further increase in the ratio of
$\text{Ce}_0\text{.9Ca}_{0.1}\text{O}_2.8$ particles resulting in a reduction of Ni ratio will decrease the electronic conductivity of the anode. Thus 15% is the optimum ratio of the $\text{Ce}_0\text{.9Ca}_{0.1}\text{O}_2.8$ particles in the composite anode material used for SOFC. The effect of the nano particle size and coating of $\text{Ce}_0\text{.9Ca}_{0.1}\text{O}_2.8$ on the cell performance is an interesting problem which is under study.

CONCLUSIONS

The composite anode material embedding the traditional anode matrix of Ni+YSZ with the $\text{Ce}_0\text{.9Ca}_{0.1}\text{O}_2.8$ particles has improved the performance of SOFC by expanding the anode reaction zone. 15% is the optimum ratio of the $\text{Ce}_0\text{.9Ca}_{0.1}\text{O}_2.8$ particles in the new composite anode material used for SOFC.

REFERENCES

(1) C. Zhang, X. Wu, S. Wu and W. Su, Physical Review B, 54(23), 16349 (1996-1).
(2) X. Wu, C. Zhang, S. Wu, and W. Su, Solid State Communications, 99(3), 189(1996).
(3) B. Yang, X. Wu, C. Zhang, S. Wu, Y. Zheng, T. Lu and W. Su, Solid State Communications, 105(1), 53(1998).
(4) B. Yang, C. Zhang, Y. Zheng, T. Lu, X. Wu, W. Su and S. Wu, Physical Review B, 58(21), 14127(1998).
(5) C. Zhang, B. Yang, X. Wu, T. Lu, Y. Zheng, and W. Su, Physica B, 293(1-2), 16(2000).
(6) Z. Lu, J. Zhang, X. Huang, T. He, Z. Liu, X. Du, J. Chen, W. Su, “Study on novel composite Cathode materials doped with Bi$_2$O$_3$ for SOFC”, published in these proceedings.
(7) N. Nakagawa, H. Sakurai, K. Kondo et al., J. Electrochem. Soc., 142, 3474(1995).
(8) U. Anselmi-Tamburini, G. Chiodelli, M. Arimondi, et al., Solid State Ionics, 110, 35(1998).
(9) T. Iwata, J. Electrochem. Soc., 143, 1521(1996).
(10) Murray E.P., Tsai T., Barnett S. A., Nature, 400, 649(1999).