Electron Holography of the interface between metal and ionic conductor

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Abstract: Fuel cells attract a great deal of attention by the high concern about environmental problems. Solid oxide fuel cells (SOFC), which use solid ionic conductors for the electrolytes, have many advantages. However, there are some problems in SOFC concerning the electrostatic potential distribution near the interface of electrode-electrolyte. The observation of this potential distribution should contribute to solving many problems including the over potential effect \cite{1}.

In order to observe the metal—ionic conductor interface structure, we have developed a new specimen preparation technique using focused-ion-beam equipment, and observe by high resolution transmission electron microscopy (HRTEM) and electron holography\cite{2}. It is found that the electrostatic potential bends near the interface of Pt and YSZ.

Keywords: Electron Holography, Fuel Cells, Structure of Interface,

1. INTRODUCTION
The demand for electric energy is constantly increasing as the population and economic development increase. Currently, most electricity is supplied by the combustion of fossil fuels, but this causes acid rain and emits greenhouse gases. In addition, the consumption of fossil fuels such as oil, coal, and natural gas for electric generation exceeds quantity of discovery, and it is predicted that natural reserves will eventually be depleted. From the viewpoint of such problems, the development of new energy sources is required.

Fuel cells are one new potential source of energy. A solid oxide fuel cell (SOFC) is operated at a high temperature ($600\sim1000\,^\circ \mathrm{C}$). These temperatures promote electrode reactions without any catalyst such as platinum, which will reduce the production cost. In addition, if we reuse the waste heat, we can expect the efficiency of SOFCs to be the highest of fuel cells.

However, there are some problems associated with SOFCs, the most severe of which is the lowering of the output voltage from the expected value as the output current increases, an over-potential effect \cite{1}. This problem seems to involve the electrostatic potential distribution near the electrode-electrolyte interface. We report the observation potential distributions by electron holography \cite{2}. The results of this investigation will contribute to our ability to overcome the over-potential effect.

2. EXPERIMENTAL
A platinum thin film is deposited by pulsed laser deposition (PLD) on a piece of sintered yttria-stabilized zirconia (YSZ), see Figure 1. The sample is shaped to fit into the sample chamber of a transmission electron microscope (TEM) with a focused ion beam (FIB) \cite{3}.

Electron holography is an image formation method consisting of two steps: recording holograms and recounting wave functions. Figure 2 shows a schematic diagram of reconstruction. An electron wave that penetrates a specimen (object wave) and an electron wave that passed through the vacuum area (reference wave) are deflected by an electron biprism and interfere each other. This is called a hologram. The phase and amplitude information of the electron wave is recorded as the curvature and amplitude of fringes. The electrostatic potential information is included in the hologram. With this method, we visualized the potential distribution in the neighborhood of the Pt/YSZ interface.

The hologram photography used an HF-2000 with an acceleration voltage of 200 kV. The hologram was recorded digitally with a 1024 X 1024 pixel CCD camera system.

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3. RESULTS

Figure 3 shows a TEM image of a Pt/YSZ interface taken with a magnification of 150000x. A hologram of a Pt/YSZ interface obtained with a magnification of 165000x is shown in Figure 4. The width of interference area is 60 nm and the distance between fringes is 0.2 nm.

The phase image is reconstructed by a Fourier method and the phase profile at the interface are shown in Figure 5. The white and black stripes in Figure 5(a) are due to the noise in the process of phase unwrapping. In Figure 5(b), the position of the broken line represents the boundary between the two materials and is determined using the digital micrograph; the vertical scale is arbitrary.
4. DISCUSSION AND CONCLUSION

The mean inner potential \( V_0 \) is formed by the nuclei and electrons that have an influence on the electron beam in the specimen. When the thickness of the specimen is \( t \), the delay of the phase of the electron wave \( \Delta \Phi \) which penetrated the specimen is expressed in Equation (1) on the basis of the phase of the electron wave that passed through the vacuum.

\[
\Delta \Phi = C_E V_0 t
\]

(1)

\( C_E \) is a constant determined by the accelerating voltage. Therefore, if the thickness of the specimen is constant, we can determine the change of the inner potential in the specimen based on measurements of the delay of the phase.

We observed the interface of a Pt and a YSZ by HRTEM and electron holography. It was formed that reconstructing phase of the electron wave shifted near the interface.

REFERENCES

4. The present work was supported by the Grant-in-Aid for Scientific Research on Priority Area, “Nanoionics” (439) by the Ministry of Education, Culture, Sports, and Technology, Japan.