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Electron Holography of Hetero-Interfaces in Solid Oxide Fuel Cells

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Electrostatic potentials at the interface of an oxide ionic conductor and a metal electrode are observed with applying an external electric field.
Solid oxide fuel cells (SOFC) are expected as a new large-scale energy source, which is operated at a high temperature. It has many advantages to other fuel cells such that many kinds of fuel gas can be utilized, Pt catalysts are not necessary, high electricity-generation efficiency is expected and so on. It is required, however, to solve some problems. One of them is a so-called over-potential effect, that is, a drawable voltage decreases from the expected value in an open circuit as an operating current. One of the origins of this effect is to the stacking and/or lacking oxygen ions near the electrodes.
If an external electric field is applied to the solid electrolytes in a vacuum, oxygen ions may be drawn to the anode. The shift of oxygen ions causes the shift of the potential, then the ion flow might be blocked unless new oxygen ions are reserved from a cathode. This is the same phenomenon as the overpotential effect.

Electron holography has been utilized to the observation of electrostatic inner potentials at the interface between platinum electrodes and oxide-ionic-conductors i.e. solid electrolytes. In order to reveal the origin of problems, we have to measure the electrostatic potential with applying an external voltage at a high temperature in an oxygen atmosphere. In the first step, we have reported the effect of the external voltage on the inner potential of Gd doped Ceria (GDC) with Pt electrodes. This material is a mixed conductor of electrons and oxygen ions, at a room temperature in a vacuum. Here, we will report the effects of the external potential and the specimen temperature on another kind of solid ionic conductor, Yt stabilized zirconia (YSZ), and electric band bending with contact voltage effects on the oxygen conductor YSZ and a proton conductor St doped zirconium oxide (SZO).

A noble specimen holder shown in Fig.1 has three electrodes, two of them are for heating the specimen more than 1100˚C and the other is for applying the voltage to the specimen up to 5V. Specimen was mounted on the edge of the Ta heater, and connected with one of the electrodes on the specimen holder with an Au thin wire and then shaped a thin wedge by the micro-sampling method with focused ion beam (FIB) for the cross-sectional electron-holographic observation as shown in Fig.2. The YSZ sample was prepared by depositing Pt onto a YSZ single crystal by Pulse Laser Deposition (PLD). The SZO sample was prepared by pasting Pt particles on a sintered SZO plate and heating at 1400˚C

The inner potentials are investigated with the voltage applied up to ±1.0V. Figure 3 shows differences of inner potentials at the Pt/YSZ interface between the specimen with and without the external field, where positive potential corresponds to the delay of electron phase (i.e. negative in the figures). Figure 3a shows the profile of the reconstructed phase when V=+1.0V applied to the Pt electrode and Fig.3b shows that when V=-1.0V. Although the electrostatic potential at the anode

side interface shows an expected behavior, that at cathode side seems as if the interface was destructed. These results are far different from the case of GDC. [1].
Figure 4 shows the effect of heating the specimen on the inner potential of YSZ. The higher specimen temperature is, the lower the potential shifts.

References

[1] T.Tanji et al., Microscopy and Microanalysis 2007, Fort Lauderdale, FL, USA, Aug.5-9, 1224CD.
[2] 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.

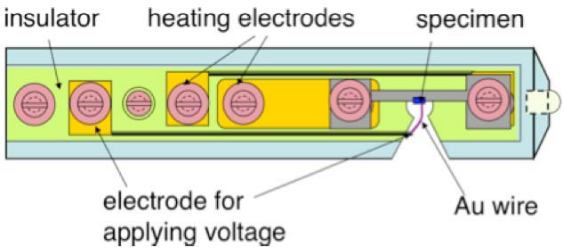

Fig.1 Three electrode specimen holder.

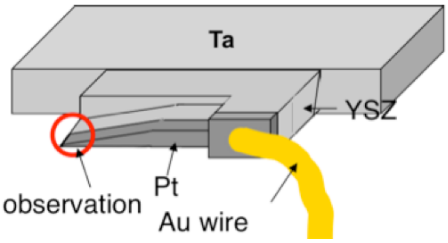

Fig.2 Specimen shaped by FIB.

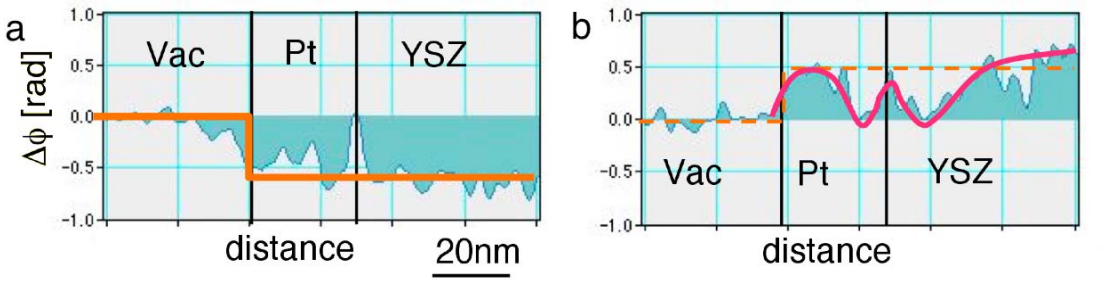

Fig.3. Line profiles of reconstructed phases, which are subtracted the phase without an external field from those with applying +1.0V (a) and -1.0V (b) to the Pr electrode.

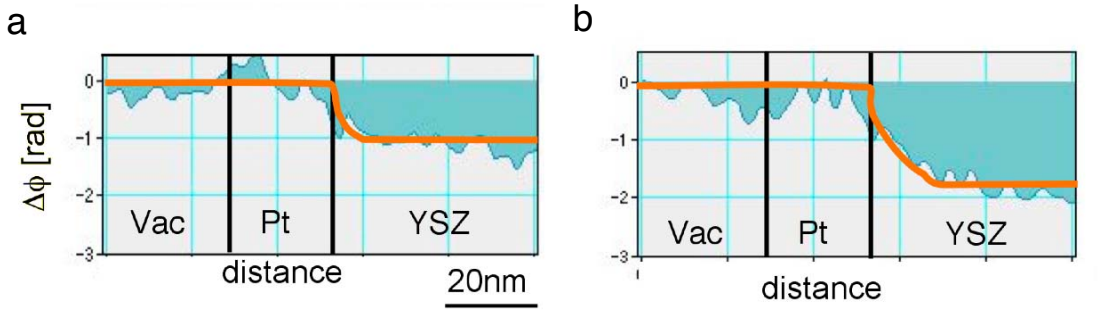

Fig.4 Line profiles of reconstructed phases which are subtracted the phase at 20°C from those at 430°C (a) and 930°C (b).