Electrochemical Oxidation and Electron Transports of SrCoO$_{2.5}$ Epitaxial Films

Since strontium cobaltite (SrCoO$_x$) can exhibit three different optical, electrical, and magnetic phases, which can be controlled using oxidation/protonation. Therefore, it has excellent potential as the active material for unique electrochemical memory devices.$^{[1-3]}$ Although atomic scale phenomenon of the oxidation of SrCoO$_{2.5}$ into SrCoO$_3$ is known, the macroscopic phenomenon has not been clarified yet thus far. Here, thermopower analysis is used to clarify the electrochemical oxidation macroscopically. A 6-nm-thick GDC (10 mol% Gd-doped CeO$_2$) film was heteroepitaxially grown on (001) YSZ substrate followed by the growth of ~40-nm-thick SrCoO$_{2.5}$ by pulsed laser deposition. The out-of-plane XRD patterns of the resultant films showed that the SrCoO$_{2.5}$ were heteroepitaxially grown on the GDC/YSZ with the epitaxial relationship of (001)[010] SrCoO$_{2.5}$ || (001)[110] GDC/YSZ. We then deposited Pt electrode on the back side of the YSZ substrate and applied current into the film as schematically shown in Fig. (a) with $-5$ or $-10$ V at 300 $^\circ$C in air. In order to measure the electron transports of the intermediate state, we suspended the electrochemical oxidation several times. From the XRD analyses of the films, we clarified that the conversion rate from SrCoO$_{2.5}$ brownmillerite to SrCoO$_3$ perovskite could be controlled electrochemically. Figure (b) shows the resistivity (upper) and thermopower (lower) of the resultant films at room temperature. Although the resistivity of SrCoO$_{2.5}$ film was high (5.5 $\Omega$ cm), the resistivity dropped after slight oxidation due to the parallel electronic circuit composed of very low resistive SrCoO$_3$ (0.35 m$\Omega$ cm). Furthermore, the thermopower dropped from 70 $\mu$V K$^{-1}$ to $-0$ $\mu$V K$^{-1}$ after slight oxidation. Steep decrease in both resistivity and the absolute value of thermopower of electrochemically oxidized SrCoO$_x$ epitaxial films indicates the columnar oxidation firstly occurred along the oxidation direction and then spread perpendicular to the oxidation direction. This macroscopic image of the electrochemical oxidation would be useful for developing a functional device utilizing the electrochemical redox reaction of SrCoO$_x$.

References