Controlling thermal conductivity in tungsten trioxide by ion-intercalation

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We are developing "thermal switching materials", whose thermal conductivity varies over a wide range. It has a wide range of applications such as temperature controls, thermal energy storages and so on. WO_3 is expected as a thermal switching material because the electrical conductivity of WO_3 can widely change owing to the metal-insulator transition (MIT) caused by hydrogen interactions. Moreover, hydrogens can be intercalated into and deintercalated from WO_3 film reversibly and quickly by an electrochemical reaction. Therefore, the thermal conductivity is expected to change reversibly as shown in Figure 1. Here, we report the thermal conductivity changes in WO_3 film associated with hydrogen intercalations.

WO_3 film was prepared on ITO coated glass at room temperature by RF magnetron sputtering method in an Ar-O_2 atmosphere. Hydrogen intercalations into WO_3 film on ITO coated glass were performed in an 0.5 M H_2SO_4 electrolyte with a Pt counter electrode and a calomel reference electrode. The thermal diffusivity of the films was measured by an ac calorimetric method and the thermal conductivity was calculated by the differential method using measured thermal diffusivity. The electrical conductivity was measured by a four-point probe method.

X-ray diffraction measurements showed that the WO_3 films were amorphous. The value of thermal conductivity decreased with increasing hydrogen content x in H_xWO_3, from $x = 0$ to $x = 0.33$, and the value of thermal conductivity increased markedly with increasing x above $x = 0.33$. The hydrogen content of $x = 0.33$ is close to that of MIT. On the other hand, the electrical conductivity after MIT was 1×10^5 times higher than that before MIT. Present results indicate that the thermal conductivity of WO_3 film can be controlled by hydrogen intercalations and potentialize the hydrogen-induced active control of thermal switches.

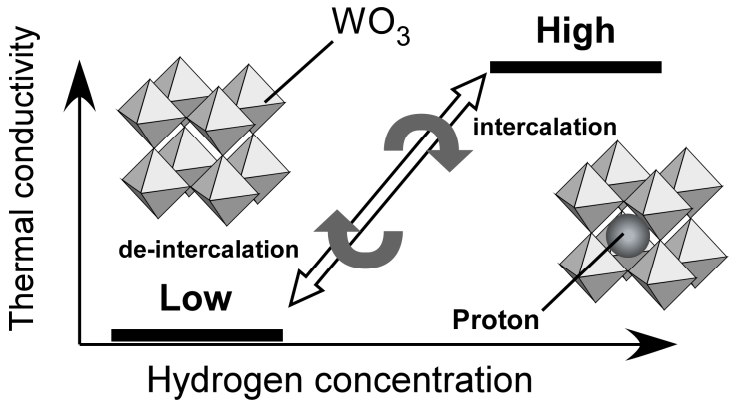

Fig. 1: Concept of thermal switch materials controlled by ion-intercalation in oxide materials