Conductive Oxide with Surface Polarity for Device Applications

A layered delafossite, $PdCoO_2$, is one of the most conductive oxides with a bulk conductivity comparable with those of Au metals. Charged layers of Pd^+ and $[CoO_2]^-$ alternate in the $PdCoO_2$ crystal structure, generating surface polarities that strongly influence the surface/interface properties. Using pulsed laser deposition, we successfully grew high-quality thin films of $PdCoO_2$ and fabricated functional devices: a nanodevice showing quantum transport and a diode that can operate at elevated temperatures. The superior properties of these devices are attributed to the anisotropic electrical conductivity of $PdCoO_2$ that originates from its unique layered crystal structure.

The layered oxide $PdCoO_2$ has attracted significant attention as a highly conductive metal comparable to the noble metals (Fig. 1). Using $PdCoO_2$ thin films [1], we are currently exploring novel electronic functionalities that originate from two key features of $PdCoO_2$: the high electron mobility (~51000 cm^2/Vs for bulk single crystals) and surface polarity induced by the ionic layered structure (inset of Fig. 1). By fabricating submicron-scale Hall-bar devices using electron beam lithography, we carried out the first observation of quantum transport in $PdCoO_2$ thin films [2]. We found that the surface polarity of $PdCoO_2$ significantly affects the surface electronic states, giving the inherently nonmagnetic $PdCoO_2$ unique magnetic states in the vicinity of the Pd-terminated surfaces [3]. The interplay between surface magnetic states and quantum effects would be an interesting subject for future study.

The surface polarity of $PdCoO_2$ can improve the performance of practical and useful devices. We fabricated a crystalline heterointerface of $PdCoO_2$ and a wide-bandgap semiconductor β-Ga_2O_3. We found that the $PdCoO_2$/β-Ga_2O_3 interface can function as a Schottky diode that performs current rectification even at a high temperature of 350 °C [4]. The $PdCoO_2$/β-Ga_2O_3 diode can operate in the MHz frequency, which shows promise for high-frequency power electronic devices [5]. The $PdCoO_2$ exhibits superior Schottky properties by forming a bilayer with an elemental metal (tandem electrode). The junction between the tandem electrode and β-Ga_2O_3 has a wide range of Schottky barrier heights that can be fine-tuned by changing the thickness of $PdCoO_2$ [6]. The interface dipole effect was also found in the junction between β-Ga_2O_3 and $PdCrO_2$, a sister compound of $PdCoO_2$ [7], suggesting the universal role of surface polarity in these polar oxides.

These results demonstrate that $PdCoO_2$ and related metallic delafossites are a fascinating class of materials for basic physics and various applications. We will continue to explore exotic phenomena and functions in the heterostructures of metallic delafossites, which have high-mobility electrons and surface polarity in their simple (and beautiful) alternating layered crystal structures.

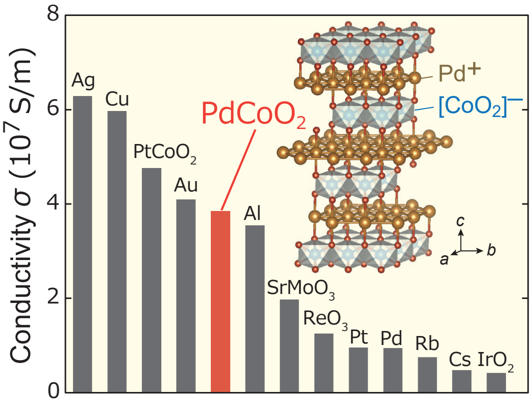

Fig. 1 Electrical conductivity of $PdCoO_2$ and various metals at room temperature. Inset: the crystal structure of $PdCoO_2$. The ionic layers of Pd^+ and $[CoO_2]^-$ are indicated.

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