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Electrical transport properties of porous Bi thin films

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Bismuth (Bi) is categorized as semimetal and has unique electronic properties different from typical metals. Bi exhibits a large mean free path (λ) of ~100 nm at 300 K and ~400 μm at 4 K due to small effective mass, in sharp contrast to usual metals with λ of ~ Å. In addition, the Fermi wavelength of Bi is as large as ~40 nm and the charge carrier density is 4-5 orders of magnitude smaller than those of most metals. These unique features make Bi as an attractive material to explore quantum size effect. So far, it has been revealed that Bi thin films thinner than 30 nm show characteristic features different from bulk Bi, such as carrier type inversion and semimetal to semiconductor transition [1]. In this work, we focused on Bi thin films with anti-dot shape fabricated on ordered porous array substrates.

Experimental

The ordered porous alumina substrates were fabricated by two step anodization of 1 μm-thick Al thin films with 0.3 M oxalic acid electrolyte on constant voltage of 40 V. After the second anodization, the oxidized alumina membrane was dipped into phosphoric acid for controlling the pore size and removing residual Al metal. On the obtained porous alumina substrate, Bi was deposited by thermal evaporation at room temperature. The surface structures of Bi film were investigated by field-emission SEM. Electronic transport properties were characterized by four probe resistance and Hall measurements.

Results and Discussion

Figs 1(a) and (b) show SEM images of Bi thin films (thickness 47 nm) on glass and porous alumina substrates, respectively. The average width of pore wall, corresponding to the width of conductive path, was 36 nm, which is less than the Fermi wavelength of Bi. The plane Bi films thicker than 30 nm showed p-type properties except at low temperatures like 2 K, while in the Bi anti-dot film electron are majority carrier from 2 K to 300 K (Figs. 1(c) and (d)). These suggest that dimensionality substantially affects the electronic structure of Bi.

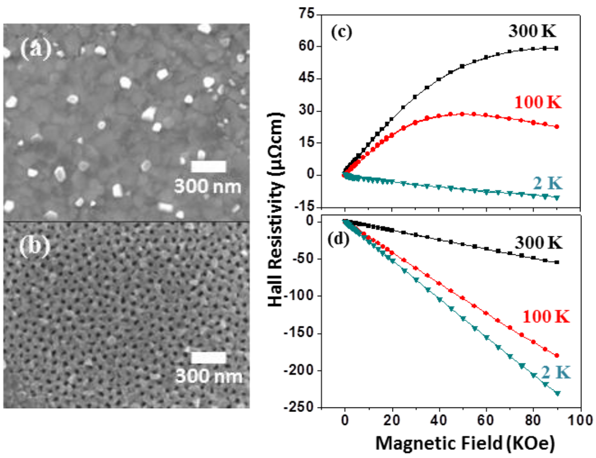

Fig. 1 (a, b) SEM image of 47 nm-thick Bi films grown on (a) glass and (b) porous alumina substrates. (c, d) Magnetic field dependence of Hall resistivity of 47 nm-thick Bi films on (c) glass and (d) porous alumina substrates.

References

[1] N. Marcano *et al.*, Phys. Rev. B 82, 125326 (2010).