$MgO/Mg_2Si/MgB_2$ナノ複合結晶の超伝導特性

Superconducting properties of dense $MgO/Mg_2Si/MgB_2$ nanocomposites

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Many efforts are under way to control the structure of heterointerfaces in nanostructured composite materials for designing functionality and engineering application. However, the fabrication of high-quality heterointerfaces is challenging because the crystal/crystal interface is usually the most defective part of the nanocomposite materials. In this work, we show that fully dense insulator(MgO)/ semi-conductor(Mg_2Si)/superconductor(MgB_2) nanocomposites with atomically smooth and continuous interfaces, including epitaxial-like MgO/Mg_2Si interfaces, are obtained by solid phase reaction between metallic magnesium and a borosilicate glass.

The dense $MgO/Mg_2Si/MgB_2$ nanocomposite was prepared by reacting metallic Mg with sodium borosilicate glass with a typical composition of $68SiO_2$-$24B_2O_3$-$8Na_2O$ (mol %) at 700 °C for 5 h under Ar environment. Figure 1 shows a typical X-ray diffraction (XRD) pattern of the reaction zone. The XRD pattern exhibits the diffraction peaks corresponding to MgO, Mg_2Si and MgB_2. The resistivity of the sample shows the negative temperature coefficient in the 40–300 K region, indicating that the semiconducting Mg_2Si phase in the Mg_2Si- and MgO-rich layers is responsible for the electric transport properties in this temperature region. Upon further cooling, a transition from a semiconducting to a superconducting state is observed at T=36 K (Fig. 2). Note also that the slope of the resistivity versus temperature changes at ~24 K, suggesting the presence of a second transition. When the temperature of the system drops below ~17 K, the sample eventually shows near-zero (<~10^{-4} Ωcm) resistivity. In the temperature region from 36 to ~25 K, the initial $M(H)$ curve is a straight line under applied magnetic fields at least up to ~2000 Oe (Fig 3). The initial slope becomes steeper as the temperature of the system decreases. Careful investigation of the initial $M(H)$ curves further reveals that an additional diamagnetic component begins to emerge in the low applied field region with decreasing temperature below ~26 K. Since the temperature at which this magnetic component emerges (~26 K) almost coincides with the second resistive superconducting transition temperature, it would be reasonable to assume that these two phenomena are derived from the same origin.

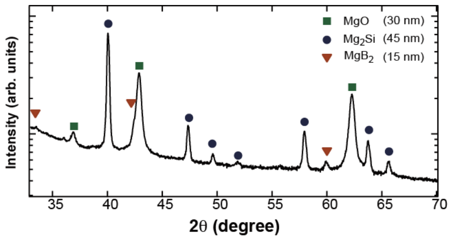

Fig. 1 XRD pattern of the nano-composite.

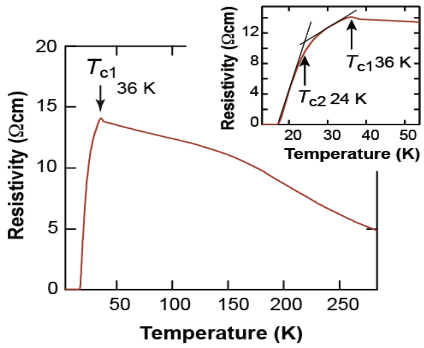

Fig. 2 Electrical resistivity of the nanocomposite. The inset shows a magnified view around the transition region.

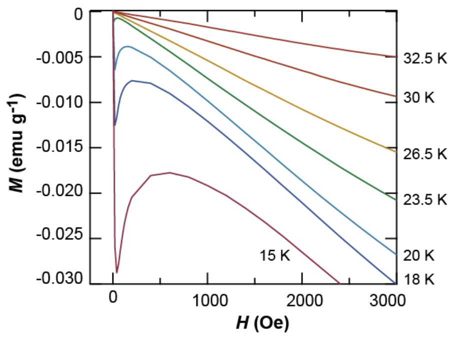

Fig. 3 Initial $M(H)$ curves of the nanocomposite.