Investigations of the magnetic transport properties of normal metallic films under the non-uniform magnetic field

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Abstract

We have measured the magnetoconductance(MC) of two dimensional Bi films subjected to a periodic magnetic field H, which is produced by a superconducting intermediate state of thick Pb film placed in the immediate vicinity of metal films. Non-linear H dependence of MC has been observed at low magnetic fields. This is not expected from a simple magnetic distribution of normal($H = H_c$) and superconducting ($H = 0$) domain structure in the intermediate state. For specimen of which Pb film has sharp edges, MC shows the step-like structure. This indicates the strong surface flux pinning effect. On the other hand, in the case of broad edge of Pb film, MC shows the oscillation behavior.

Key words: ; magetoconductance ; inhomogeneous magnetic field ;intermmediate state;weak localization

1. Introduction

There has been considerable attention on the MC defined by $\Delta\sigma = \Delta(H)-\Delta(0)$ in a disordered two dimensional electron gas(2DEG), in which the magnetic field H is spatially modulated. For the technique to produce such a field, many methods have been proposed. One is the deposition of type II superconductor on the top of 2DEG.[1,2] In this case, the magnetic field penetrates the film as a quantum fluxoid. Recently, large scale of random magnetic field has been achieved on 2DEG .[3–5] Further, for creating a periodic magnetic field, regulated periodic array of superconducting stripes was patterned on the top of the film.[6]

In this paper, we report the MC of thin Bi films, on which neighboring surface, the modulated magnetic field is projected by the macroscopic domain structure in the intermediate state of type I superconductor. The period of alternating normal(N) and superconducting(S) domains changes as a function of H and temperature T.

2. Results and Discussions

The Bi films with thickness of 150-200Å were made by the vacuum deposition onto a glass substrate. For the insulating layer, SiO with 75-90Å was deposited on the Bi film. This procedure has been repeated four times. We prepared three types of Bi/SiO/Pb multilayers with different shapes of the edge of Pb film of 4000Å; We obtain Pb film with broader edges, by taking longer distance L between the SiO/Bi film and the mask with a hole during the deposition of Pb. The $\Delta\sigma$ has been measured with a DC four-terminal configuration. After the film was cooled bellow T_c at $H = 0$, the field was swept up to positive fields above the critical magnetic field $H_c(T)$, and then subsequently down and up cyclically. For the case of inhomogeneous field produced with a mixed state, the week localization effect gives $\Delta\sigma \propto H$ at low magnetic fields.[1,2] For the case created with the domain structure in the intermediate state, it can be considered that the only neighboring regions to the N domains with $H_c(T)$ contribute to $\Delta\sigma$.[5] Therefore, if the Bi film is sufficiently close to the Pb film, it is expected that $\Delta\sigma$ shows also lin-

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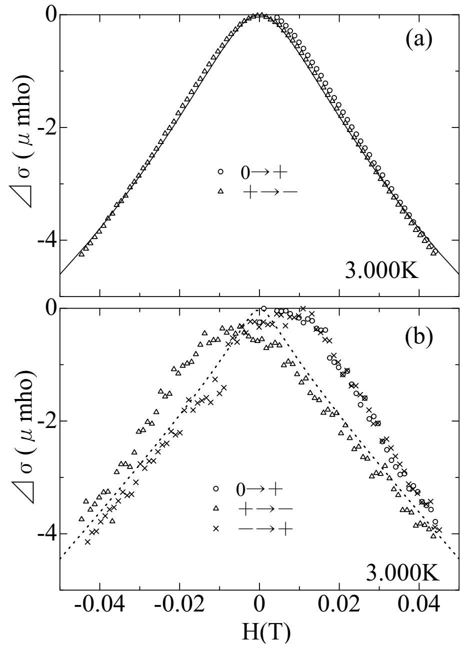

Fig. 1. $\Delta\sigma$ of thin Bi film in multi-layers of (a)Bi/SiO and (b)Bi/SiO/Pb films. The Pb film has middle sharp-edges. The solid and dotted lines show the theory for homogeneous magnetic field and a simple model for an intermediate domain structure, respectively.

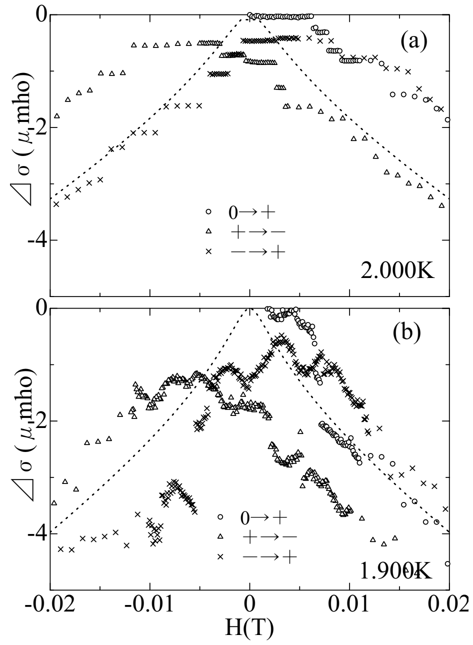

Fig. 2. $\Delta\sigma$ of Bi in multi-layers of Bi/SiO/Pb with (a)sharp-edge Pb film and (b)broad-edge Pb film.

ear dependence of H. However, SiO layer is not so thin to neglect the smearing of the magnetic field emerging from the Pb film. The solid lines in Figs.1(b)and 2 show the $\Delta\sigma^{\mathsf{inhomo}}(H)$ calculated from a simple model taking account of expanding of N domains due to field smearing and the flux conservation.

Figure 1 shows the data of $\Delta\sigma$ for (a) Bi/SiO and (b)Bi/SiO/Pb with a middle length L. The values of $\Delta\sigma$ in (a) fit well with the solid line calculated from the localization theory for homogeneous magnetic field with use of a fitting parameter, inelastic scattering timeτ_{in}.[7] On the other hand, the values of $\Delta\sigma$ in Fig.1(b) deviate from the calculation especially in the up field process and shows hysteretic loop. This suggests the irreversible flux domains due to the surface pinning effect. The data of $\Delta\sigma$ on down process of the magnetic field seem to agree with the simple model.

Figure 2(a) shows the data of $\Delta\sigma$ on Bi/SiO/Pb with a short length of L, that is, sharp edge of Pb film. We can see clearly that the surface pinning effect is stronger than that shown in Fig.1(b). The data of $\Delta\sigma$ show step-like behaviour in every up and down processes at relatively small fields. This is consistent with a following result; Near zero field except for the initial increase, $\Delta\sigma$ does not take zero value because the contribution of the trapped flux on $\Delta\sigma$ is independent of the direction of the magnetic field.

Figure 2(b) shows the data of Bi/SiO/Pb with broad edges of Pb film. It is obvious that there are oscillations of $\Delta\sigma$ at low fields. Although there remains hysteresis due to the bulk pinning, this system is considered to have weaker surface pinning effect. It is difficult to consider that these oscillations are due to occurring of the alternating of entry and escape of the N domains. Because of small surface pinning, the smooth change of the period S-N alternating structure is expected to be realized. Although we have not an exact explanation for the oscillation, there is a possibility of some matching effect between the width of N domain and Fermi length of Bi or inelastic scattering length.

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