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Anisotropy and Barkhausen jumps in diluted magnetic semiconductor (Ga,Mn)As

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Abstract

We measured electronic transport and magnetization of a metallic and ferromagnetic (Ga,Mn)As thin film epitaxially grown on a GaAs [0 0 1] substrate. In-plane ((0 0 1)) anisotropic magnetoresistance (AMR) was affected by the current direction to the crystalline, which is phenomenologically explained by the anisotropy of the magnetization. The magnetoresistance for perpendicular field showed reproducible irregular oscillations, which are attributed to the Barkhausen effect. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Anisotropic magnetoresistance; Barkhausen jump; Diluted magnetic semiconductors

The electronic transport in (Ga,Mn)As is strongly coupled to the magnetism, showing spectacular effects such as giant magnetoresistance [1]. Furthermore, the ferromagnetism itself is considered to be driven by the charged carriers. These properties awaken the expectations that the magnetism can be externally controlled via the control of the carriers and such external control would shed new light on the magnetism and its relation to the transport. In this report, we present the results of detailed measurement of magnetic anisotropy and transport in a metallic (Ga,Mn)As film.

(Ga,Mn)As film was grown by molecular beam epitaxy on a (0 0 1) GaAs substrate at 220°C. Details of the growth are described in Ref. [2]. Mn content determined from X-ray diffraction is 4.7% and the film thickness was 150 nm. The Curie temperature T_c was about 110 K. The film was mesa-etched into an L-shaped Hall bar [3], which is along [1 1 0] and [1 $\bar{1}$ 0]. The dimensions are 200 μm × 50 μm.

Fig. 1 shows weak-field magnetoresistance at 18 K when the external field was in the growth plane (i.e. (0 0 1)). At the first sight, the data seem to show ordinal AMR. However, there is big difference between the two current directions ([1 1 0] and [1 $\bar{1}$ 0]). The bulk zincblend structure has no anisotropy between these two directions, but the surface has, and some anisotropy would naturally introduced during the growth. Hence the anisotropy in AMR would reflect that of ferromagnetism.

This inference can be confirmed by the measurement of magnetization. In (Ga,Mn)As on (0 0 1) GaAs substrate, the easy axis of magnetization lies in the growth plane. Clear anisotropy appears in Fig. 2, which shows magnetization of the film for the field directions along [1 1 0] and [1 $\bar{1}$ 0]. The anisotropic energy is estimated to 330 J/m^3, which is $\frac{1}{40}$ of that between in-plane and normal-to-plane directions. The anisotropy in AMR can be well explained with the observed in-plane anisotropy of the magnetization based on a phenomenological theory [4]. This result would be a clue to clarify the origin of AMR effect.

When the external field is perpendicular to the plane, the sample is divided into several magnetic domains around zero-magnetic field. This results in small Barkhausen structures in the magnetoresistance at 4 K shown in Fig. 3. Surprisingly this is not "noise" at all, i.e., the structure is reproducible and even symmetric to

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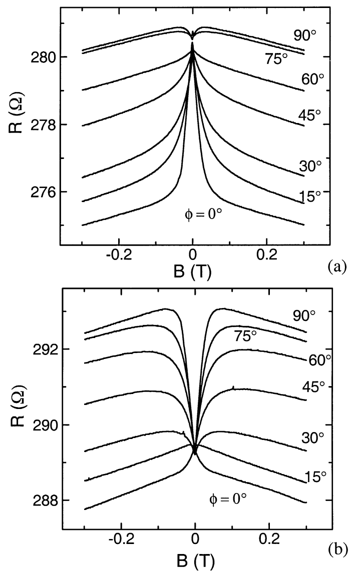

Fig. 1. In-plane magnetoresistance of (Ga,Mn)As. ϕ denotes the angle between the current direction and the external magnetic field. The current is along [1 1 0] in (a) and along [1 $\bar{1}$ 0] in (b).

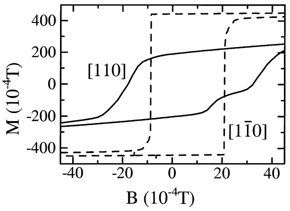

Fig. 2. Magnetization hysteresis loop of (Ga,Mn)As at 4 K.

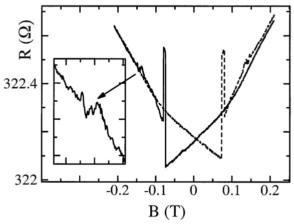

Fig. 3. Low field magnetoresistance for field perpendicular to the growth plane. The inset shows an enlargement of Barkhausen jumps with scales 0.02 T and 0.05 Ω.

the zero field. The structure completely changes after the sample experiences a temperature above T_c. This indicates that some spontaneous magnetic disorder is introduced above T_c and frozen during the cooling.

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