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Pulse-induced magnetization switching in (Ga, Mn)As Hall bar

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Introduction

Planar Hall [1] and anisotropic magnetoresistance [2] in high-purity (Ga, Mn)As have been reported. Also, current-induced magnetization switching [3] has been studied by several groups. Magnetization direction controlled by electrons is an interesting research field because this can be applied for new types of spintronic devices including magnetic memory. In this research, we would present the angle dependence of Hall voltage and pulse-induced magnetization switching (PIMS) in our (Ga, Mn)As Hall bar.

Experiments

Figure 1 is a picture of the patterned (Ga, Mn)As Hall bar with coplanar wave guide. (Ga, Mn)As of 70 nm was deposited on the GaAs substrate by MBE. Ti (5 nm)/Au (300nm) was deposited by E-beam evaporation as electrodes. Fig. 2 shows the schematic diagram of the PIMS measurement system utilizing low temperature physical property measurement system (PPMS). All measurements were carried out at the temperature of 5 K. Constant current of 10 μA and voltage pulse of 1 - 10 V amplitude with 200 μs width were applied through the bias tee to detect the hall voltage and switch the magnetization direction, respectively. Hall voltage was detected by differential amplifiers as the voltage gain of 50. Dynamic signals from the Hall devices were monitored by high speed digital sampling oscilloscope. Voltage pulse was applied when the magnetic field was set to 65 Oe with 10 Oe/min rate.

Results and discussion

The angle dependance of output response in the (Ga,Mn)As Hall bar as a function of applied magnetic field is shown in Fig. 3. Both normal and planar Hall vaoltages are observed with varing the angle between current flow direction and the applied magnetic field from 90° to 0°, respectively. The planar Hall signal, which is symmetric via zero field, shows a rapid voltage change at low field of 70 Oe. The amplitude of planar Hall voltage is observed to be lower than that of the normal Hall voltage.

The amplitude of the pulse is varied from 1 V to 10 V. Fig. 4 shows the rectangular pulse response of the Hall bar when the amplitude is 8 V. The signals of applied pulse voltage input and the Hall voltage output are represented by gray lines and black line, respectively. The magnetization direction of the devices is switched by pulse voltage and the transition of the voltage output is achieved after four pulses passing through the devices. When the amplitude is higher than 8 V, the switching quickly occors even after one pulse passing. On the other hands, the lower is the amplitude, the slower switching behaviors are shown.

Conclusion

The angle dependance of Hall voltage and pulse-induced magnetization switching have been studied by electrical transport measurements in the Hall-bar shaped (Ga, Mn)As. Planar Hall data might be governed by a magnetization switching at low field and also the switching could be easily induced by voltage pulses. When the amplitude of the pulse is higher, the switching is more quickly achieved. In a moderate pulse voltage of 8 V, for example, the complete magnetization switching occurs after four pulses passing the devices.

References

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[3] M. Yamanouch, et. al., Nature, vol. 428, 539(2004).

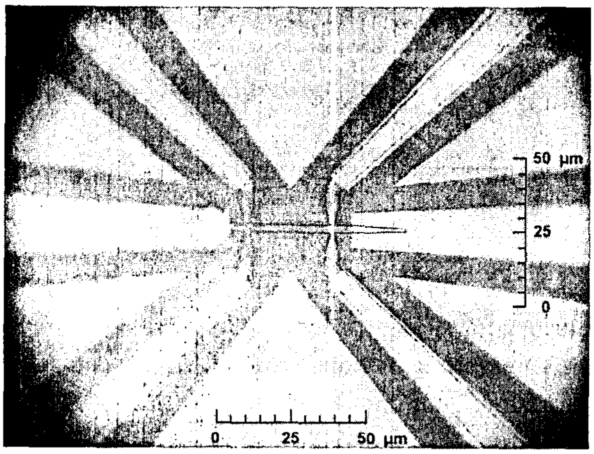

Fig. 1 A picture of the patterned GaMnAs Hall bar.

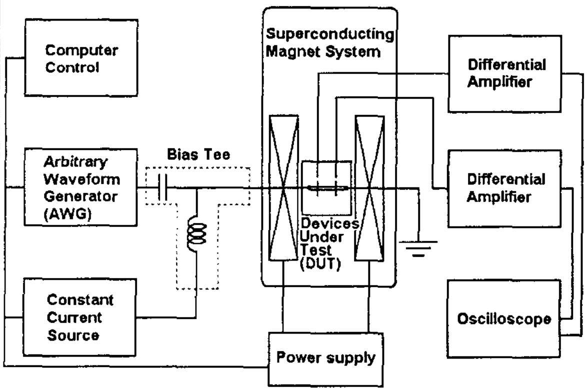

Fig. 2 Schematic diagram of our measurement system.

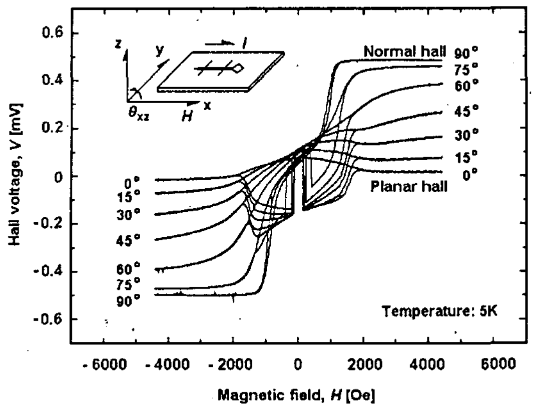

Fig. 3 Angle dependance of Hall voltage as a function of applied magnetic field. The inset shows the geometry of our device with the directions of applied magnetic field and current.

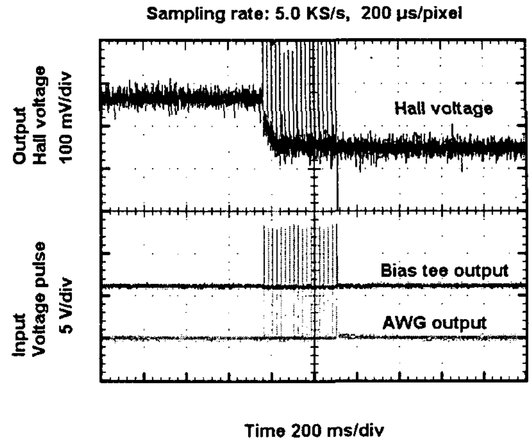

Fig. 4 Planer Hall voltage changes by voltage pulses. Input voltage pulse and output Hall voltage waveforms are plotted in gray lines and black line, respectively.