Enhancement of magnetoresistance by geometric and physical factors

Jinseo Lee[1], Jinki Hong[1], Kungwon Rhie*[1], Seyoung Ahn[2], Jinsang Kim[2], Jehyung Lee[2], Kyung-Ho Shin[2] and Byung Chan Lee[3]

[1] Department of Physics, Korea University, Chochiwon, Chungnam, Korea
[2] KIST, Hawolgok-dong, Seongbuk-gu, Seoul, Korea
[3] Department of Physics, Inha University, Incheon, Korea

*Corresponding author: e-mail: krhie@korea.ac.kr, Phone: +82 2 3290 3972

Generally, two kinds of mechanisms contribute to magnetoresistance (MR), i.e. physical MR (PMR) and geometric MR (GeMR). PMR originates from magnetic field dependence of the intrinsic material properties. In many cases of PMR, the mobility of material is suppressed by applied magnetic field. On the other hand, GeMR comes from geometric factors (sample shape and electrode configuration etc.) which can affect the electric current path within the sample [1,2]. As the mobility of sample is higher, GeMR effect is larger, but PMR effect tends to be suppressed. Thus, there may be competition between PMR and GeMR effects when the mobility decreases with magnetic field increasing.

In this report, we compare two extreme cases. One is the large GeMR sample with no PMR (InAs case), and the other is the small GeMR and large PMR sample (HgCdTe case). High GeMR effect is shown in Fig. 1(a) for InAs 2DEG whose mobility is independent of magnetic field. To maximize GeMR effect, we made the shape of InAs square and measured using 2 point probe method with negligible contact resistance. The solid curves in Fig.1 are numerically calculated MR using finite difference method (FDM).

For HgCdTe, the mobility decreases rapidly with increasing magnetic field [inset of Fig. 1(b)], which shows that the mobility strongly depends on magnetic field. The shape of HgCdTe sample was made rectangular with relatively large aspect ratio (1:3) to minimize GeMR. From the calculation [Fig. 1(b)], we can tell that the field dependence of mobility plays a crucial role in MR, and the dominant mechanism of this sample is PMR. By adjusting the aspect ratio of this kind of sample, we can obtain the optimized MR using our FDM calculation. Therefore, to maximize MR when designing a device, it is very important to take into account the geometric factor for given material with some PMR property.

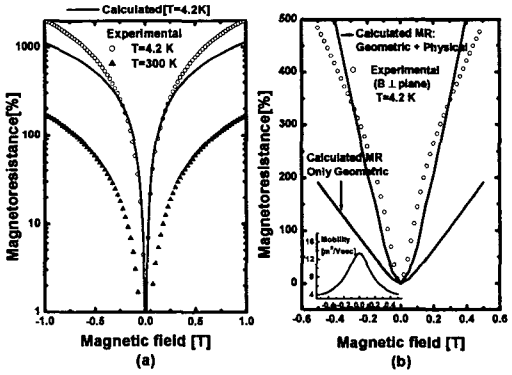

Fig. 1. MR versus magnetic field for (a) InAs (2DEG) and (b) HgCdTe. The inset of (b) is the field-dependence of mobility.

References

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