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Stray Field Effect of Py Electrodes in Spin FET

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Datta-Das spin transistor geometry[1] is essential to fabricate spin-FETs. Unlike the spin-valve geometry, the two ferromagnets (FMs) are parallel to the transport channel (Fig.1), and the edges of FMs are located on top of the channel in the spin transistor geometry (Fig.2). Consequently, the magnetic fringe fields at the edges cause a local Hall effect on the carriers of the channel. Therefore, it is necessary to examine a possible role of the fringe field carefully in order to minimize side effects.

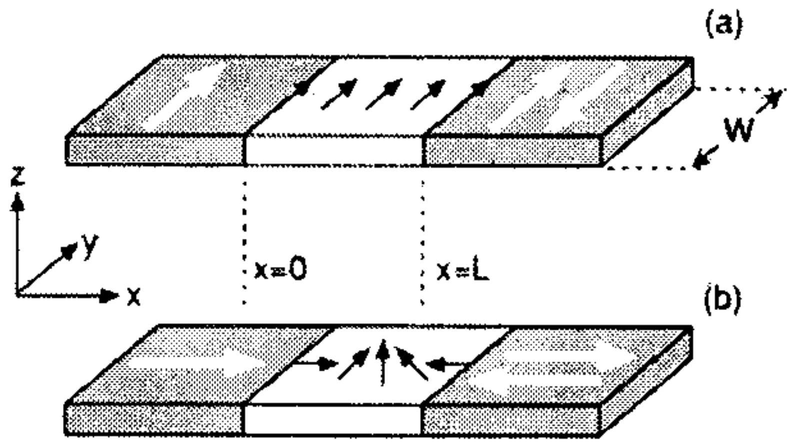


Fig. 1. (a) Spin-valve Geometry, (b) Spin-transistor geometry.

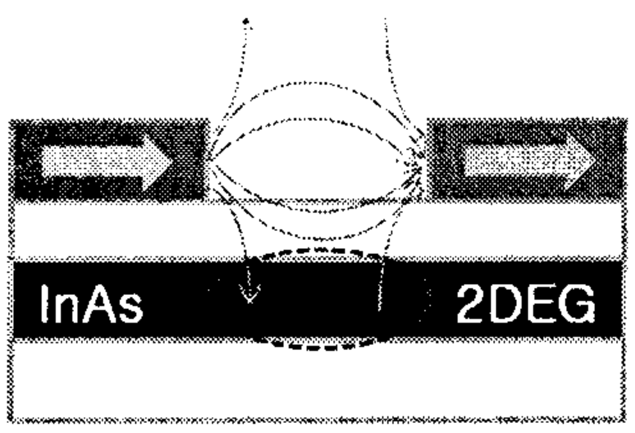


Fig. 2. Stray fields from FMs to the channel.

We fabricated Hall bar channel of InAs 2DEG, and on top of the channel, we located two Py FMs whose gap is located at the center of the Hall bar cross. To have different coercivity (Hc), the two FMs were designed to have different aspect ratio. In this work, we compared two different cases. One is that the aspect ratio of the FMs are 3:1 and 1.5:1 (Fig.3(a)). The other case is that the aspect ratio of the FMs are 3:1 and 1:1 (Fig.4(a)). The magnitudes of magnetic stray fields were evaluated by Hall bar method. We investigated magnetization of FMs using Magnetic force microscopy (MFM) sweeping external magnetic field. Finally, we simulated stray fields from the FMs and magnetization change of the FMs, and compared the result with the measured data.

In general cases of spin transistor geometry, the two FMs with opposite magnetization directions are facing each other in very close distance when their magnetization directions are antiparallel. At this time, stray fields increase abruptly and become comparable to the sweeping external field.

On the other hand, MFM observation clearly shows that the magnetic state of square FM is vortex when external field is less than Hc. If one of the FMs is square, the stray field from the square FM is negligible when external field is small enough, and the stray field is mostly dependent on the magnetization of the other FM. Therefore, the Hall bar voltage shows hysteresis in this situation.

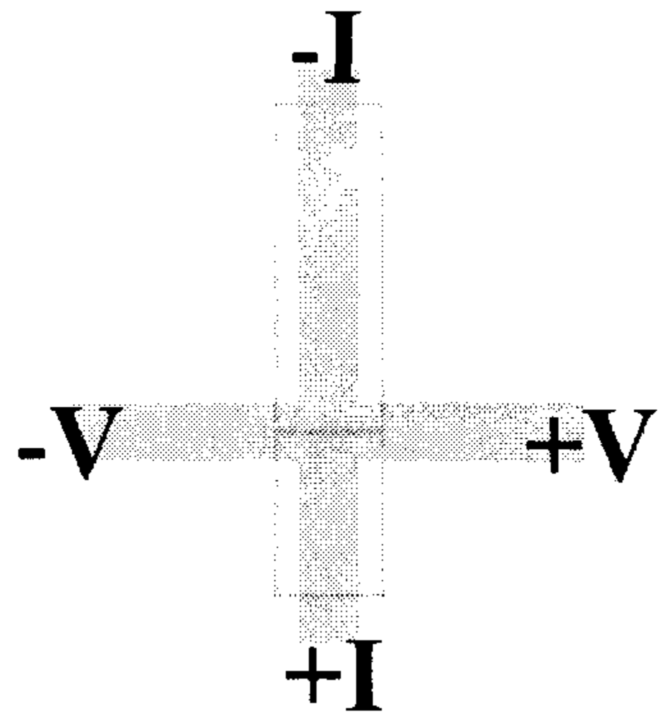
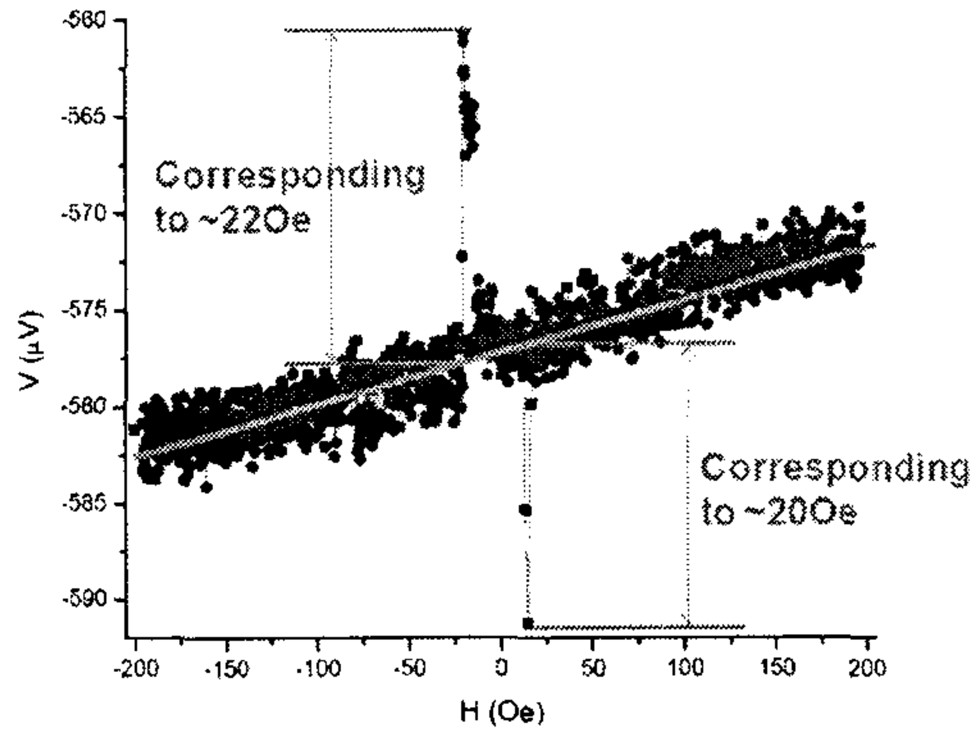


Fig. 3. (a) Both FMs are quadrangle, but not square.



(b) External field vs. Hall voltage.

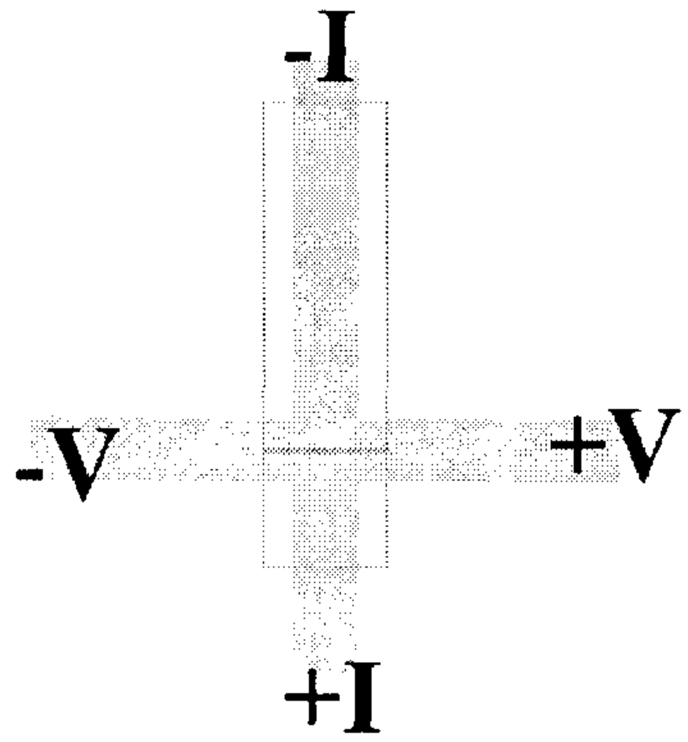
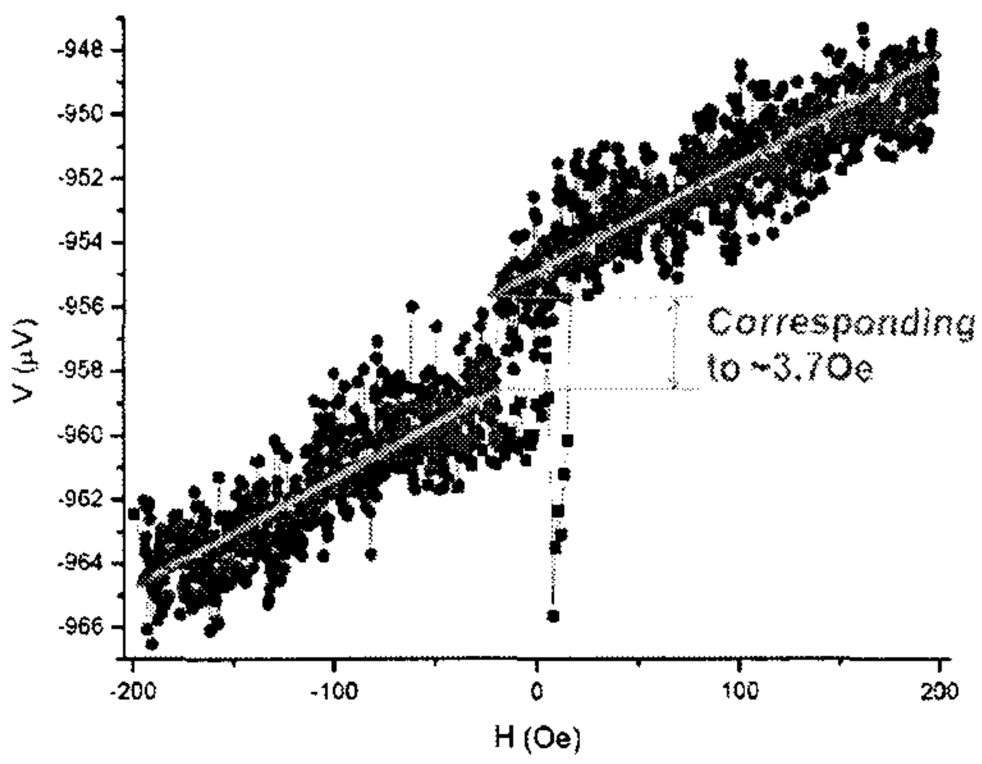


Fig. 4. (a) One of the FMs is square.



(b) External field vs. Hall voltage.

References
[1] S. Datta and B. Das, Appl. Phys. Lett. **56**, 665 (1990).