Defect driven-ferromagnetism from 2H-MoS_2

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Inducing the ferromagnetism from the diamagnetic 2H-MoS_2 have attracted a great interest for possible spintronics and quantum information devices. The MoS_2 becomes ferromagnetic when MoS_2 nanoribbons are formed with zigzag-edges, defects are induced, or non-metals [1]. Experimentally, while the significant ferromagnetism (1-2 emu/g) was obtained in the vertically aligned nanosheets with a high Curie temperature (T_C) of 685 K, the very weak ferromagnetism has been obtained in the freestanding nanosheets and in the bulk MoS_2 irradiated by proton [2], which increases the T_C up to 895 K. However, although the achieved magnetic moments are remarkable, it is still obscure whether the magnetism originates intrinsically from the existence of 1T phase or edge effect driven by the various defects [3]. Here, we will report an effective method to induce the ferromagnetic order, which persists up to room temperature with the improved transport property from a diamagnetic MoS_2 single crystal by either employing proton/electron irradiation or annealing in the hydrogen ambient condition.

The electron irradiation of a certain condition improves the mobility, but slightly reduces a crossover temperature (T_C, as indicated by arrow) of the pristine MoS_2 (200 K) to 175 K (Fig. 1a). Above and below T_C, the mobility is mainly subject to the phonon and impurity scatterings, respectively. The electron dose of 300 kGy induces the diamagnetic to a ferromagnetic phase transition (Fig. 1b). The higher electron dose of 600 kGy induces the diamagnetic to a paramagnetic phase transition along the in-plane direction while the out-of-plane direction still remains diamagnetic (Fig. 1b). Especially along the in-plane direction, the diamagnetic state also retains over the magnetic field of ±40 kOe, similarly to the case of the out-of-plane direction for the sample irradiated at 300 kGy. At room temperature, however, the temperature-dependent paramagnetic state disappears, while the relatively temperature-insensitive diamagnetic state remains (Fig. 1c). Furthermore, the different magnetic states due to the different electron doses are elucidated in Fig. 1(d) and (e) of the AFM and MFM images (Fig. 1d and 1e).

References

[1] Y. Li, *et al.*, J. Am. Chem. Soc. **130,** (2008)16739.
[2] S. Mathew *et al*., Appl. Phys. Lett. **101,** (2012)102103.
[3] W. Zhou, *et al., Nano Lett*. **13**, (2013) 2615.

Figures

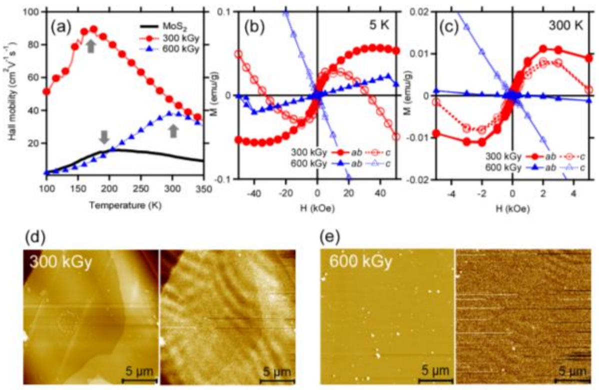

Figure 1: Comparison of single-crystalline MoS_2 and electron-irradiated samples for (a) Hall mobility as a function of temperature, magnetic hysteresis loops of 5 K(b) and 300 K (c), and AFM (left) and MFM (right) images with scan areas of 20 × 20 μm² (d, e). The magnetic field (H) is applied parallel (*ab*) and perpendicular (*c*) to the basal plane of samples.