Carrier effects on ferromagnetism of Mn-doped Ge Quantum dots

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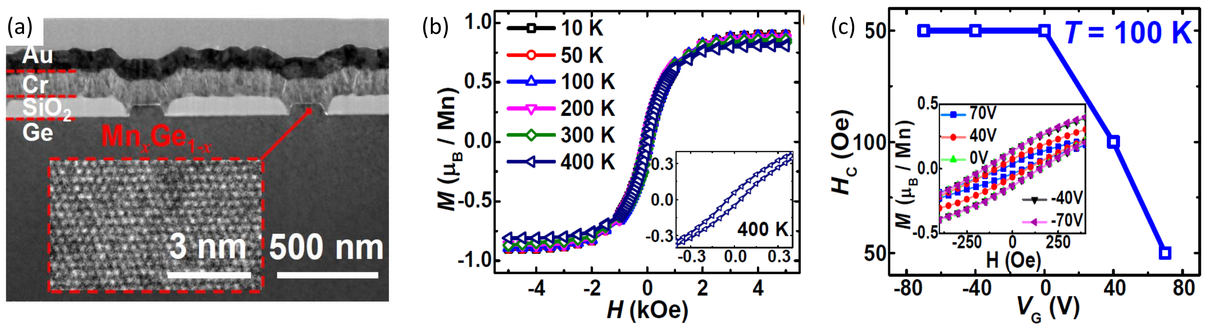
Background

Electric Field-Controlled Ferromagnetism in Mn_xGe_{1-x} FMS Nanowires



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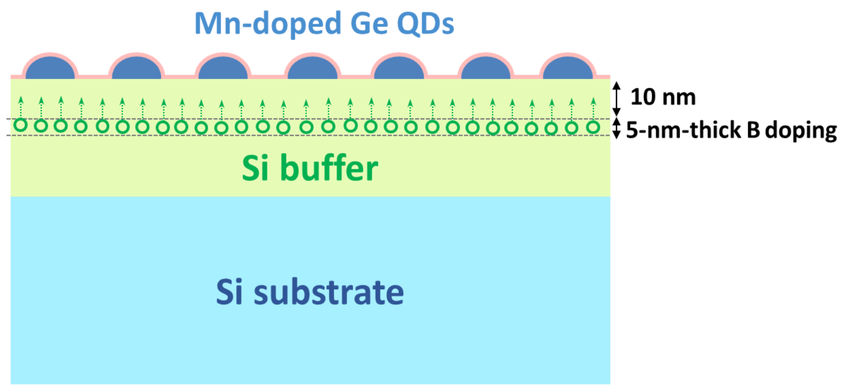
Dilute ferromagnetic semiconductors attract extensive attention due to the possibility to integrate the properties of semiconductor and ferromagnet. However, the origins and controlling of ferromagnetism in FMSs are still debatable.

In this work, the carrier effects on ferromagnetism and T_C of the Mn-doped Ge QDs were investigated. Those results provide more evidences for carries-mediated ferromagnetism model.

Schematic of sample structure



In the previous studies on MnxGe1−x materials, in order to study the carrier effect on ferromagnetism, the carrier concentration was normally changed by applying a gate voltage. No results of carrier effect on ferromagnetism in which the carrier concentration was changed by varying dopant concentration have been reported.

Results and discussions

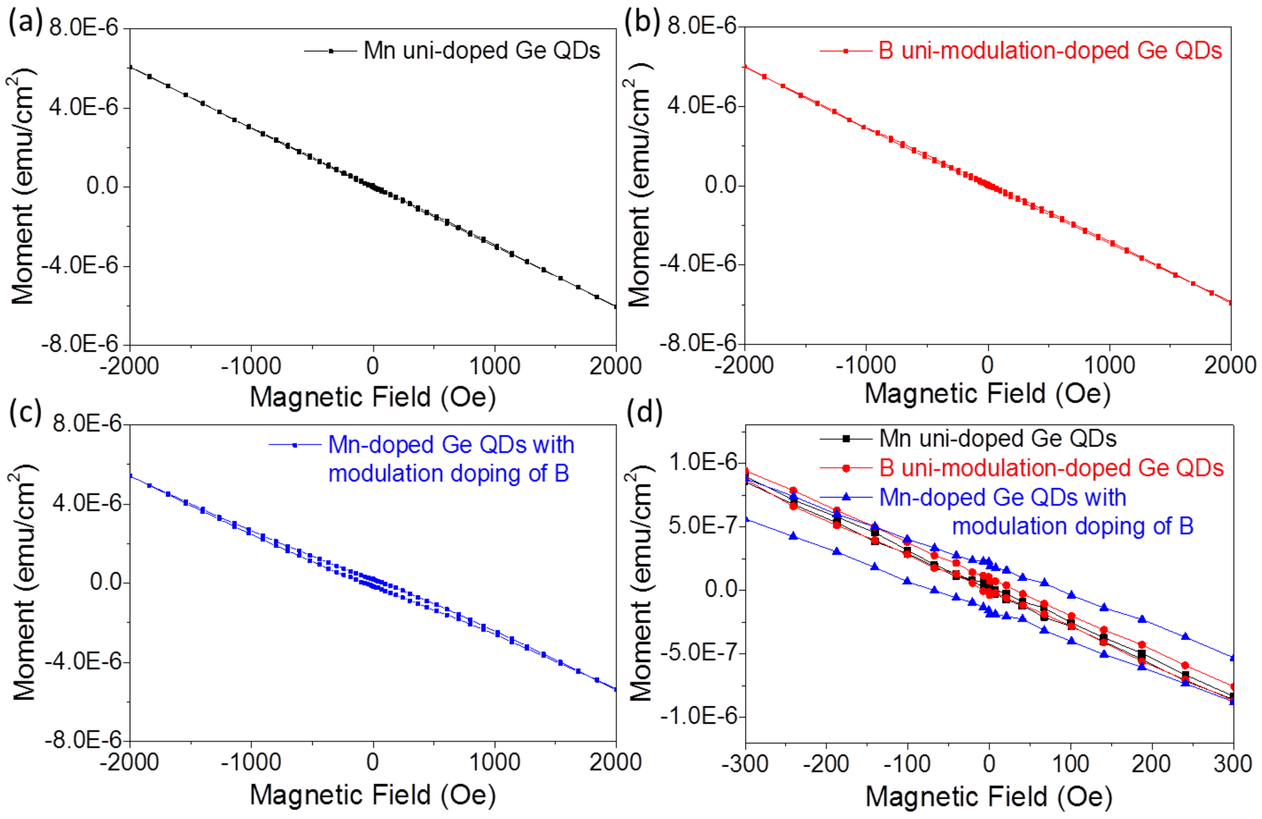


Fig. 1 (a)-(c) Hysteresis loops of Mn uni-doped Ge QDs, B uni-modulation-doped Ge QDs and Mn-doped QDs with modulation doping of B ($3.4x10^{19}$ cm^{-3}) at 2 K. (d) Comparison of the three hysteresis loops at low magnetic fields.

For Mn uni-doped and B uni-modulation-doped Ge QDs samples, no credible ferromagnetic signals in hysteresis loop were observed, while, a significant ferromagnetic signal was observed for the Mn-doped Ge QDs samples with a high modulation doping of B.

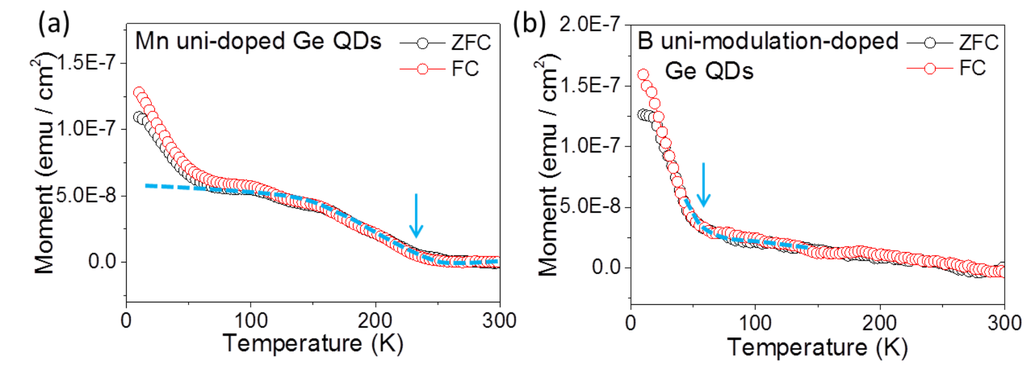


Fig. 2 Temperature dependences of magnetization at a magnetic field of 500 Oe for the five Mn-doped Ge QDs samples with or without modulation doping of B.

Fig. 3 (a-e) Reciprocal susceptibility versus temperature for the five Mn-doped Ge QDs samples with different modulation dopings of B. The curves could be used to estimate the T_C by Curie–Weiss fitting. (f) The relationship between T_C and modulation doping concentration of B in the Mn-doped Ge QDs.

Fig. 4 Zero-field-cooled and field-cooled magnetizations of (a) the Mn uni-doped QDs sample, (b) the B uni-modulation-doped QDs sample at a magnetic field of 100 Oe.

The ferromagnetic component associates with the Mn-doped Ge QDs. B dopants only contribute the paramagnetic signals .

Conclusions

- Mn-doped Ge QDs sample with the modulation doping of B shows a significant ferromagnetism, which is in contrast to no credible ferromagnetic signal in hysteresis loops for the Mn uni-doped and B uni-modulation-doped Ge QDs samples.
- In magnetization curve, the magnetic moment of Mn-doped Ge QDs samples is found to increase with B dopant concentration.
- The T_C of Mn-doped Ge QDs samples obtained by Curie–Weiss fitting was also found to increase with B dopant concentration.
- These results indicate that the exotic holes in the QDs from B dopants could enhance coupling between holes and localized Mn dopants in the QDs and thus enhance the ferromagnetism and T_C, which is consistent with carries-mediated ferromagnetism model.