Mn이 치환된 게르마늄 반도체에서 강자성 현상 발견

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Ferromagnetism in Mn-doped Germanium

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1. 서론

The injection of spins into nonmagnetic semiconductors has recently attracted great interest due to the potential to create new classes of spin-dependent electronic devices. In order to inject spin-polarized currents into nonmagnetic semiconductors, many groups have tried to use ferromagnetic (FM) metals (i.e., Fe) as spin sources, forming metal-semiconductor heterostructures. However, the spin orientation of the carriers tends to be quickly lost at a ferromagnet-semiconductor interface via spin-flip scattering due to the dissimilar crystal structure and chemical bonding and the energy difference between the charge carriers in the ferromagnet and the semiconductor.[1] A more promising strategy to achieve spin injection into nonmagnetic semiconductors is to use diluted ferromagnetic semiconductor (DFS), prepared by substituting magnetic ions such as Cr^{2+}, Mn^{2+}, Co^{2+}, Ni^{2+}, and Fe^{2+} into non-magnetic semiconductors.

2. 실험방법

For the preparation of single-crystalline $Ge_{1-x}Mn_x$, we used high-purity (99.999%) germanium (Ge) and manganese (Mn) powders as starting materials with a particle size of < –200 mesh to maximize the surface area and thereby enhance the reaction kinetics. First, the powders were weighed and loaded into thick-walled quartz ampoules. Then the ampoules were evacuated (< 10^{-6} Torr) and sealed. After encapsulation, the sealed ampoule was mixed, loaded into a vertical furnace, and heated slowly to form single-phase ($Ge_{1-x}Mn_x$). For single crystal growth, the temperature was slowly cooled at 0.5 °C/h to a point below the melting temperature (933 °C for Ge) and

thereafter at 100 °C/h. We have prepared 8 mm × 8 mm single crystals with x = 0, 0.0044, 0.013, 0.038 and 0.062.

3. 실험 결과 및 고찰

We have successfully fabricated highly Mn-doped (up to 6%) bulk Ge single crystals. Alloys with lower Mn concentrations showed paramagnetism due to localized magnetic ions. $Ge_{0.94}Mn_{0.06}$ showed ferromagnetic ordering at 274 K, as determined from temperature dependent magnetization and resistance measurements. The coersive field was 1260 Oe at 250 K.

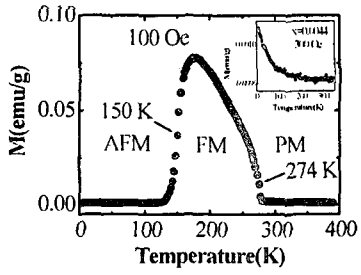

Fig. 1 Temperature dependent magnetization (M) of $Ge_{0.94}Mn_{0.6}$ in a 100 Oe magnetic field. The inset shows PM ordering for the sample with x = 0.0044.

4. 결론

Raising T_C above room-temperature might be achievable with additional doping, as observed in highly doped II-VI and III-V diluted ferromagnetic semiconductors, and/or other magnetic ions, such as Cr, Co, Fe, and Ni. It is plausible that magnetically doped Ge and Si and related materials can open the way to room temperature spintronic devices.

5. 참고문헌

[1] G. Prinz, K. Hathaway, Phys. Today 48, 24 (1995).