Clustered Ge(Mn) Magnetic Semiconductor: Preparation and Magnetic Properties

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The injection of spins into nonmagnetic semiconductors has recently attracted great interest due to the potential to create 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 ferromagnetsemi conductor 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. A more promising strategy to achieve spin injection into nonmagnetic semiconductors is to use a diluted ferromagnetic semiconductor ~DFS, prepared by substituting magnetic ions such as Cr_2^+, Mn_2^+, Co_2^+, Ni_2^+, and Fe_2^+ into nonmagnetic semiconductors.

Since the discovery of FM in GaMnAs, a variety of systems such as (GaIn)(AsP), (GaAl)N, (CdZn)(SeTe), CdTe, Ge, Si, (ZnCd)GeP_2, ZnO, and TiO_2 , etc, have been investigated. Commonly accepted mechanism is hole mediated ferromagnetism even though the mechanism for some oxides such as ZnO is still unknown. The issue in this type of research is to evaluate the origin of the observed FM. Does this come from the substituted transition metals in semiconductor host or the clusters unintentionally formed during the growth? In order to suppress the formation of the clusters, the growth temperature is maintained as low as possible, which is the reason for the needs for MBE (molecular beam epitaxy).

In the group IV-based Mn-doped Ge, Park *et al.* were the first to report that Currie temperature (TC) was increased linearly with Mn concentration from 25 to 116 K. Chen *et al.* reported a TC of 213 K in homogeneous ferromagnetic semiconductor Mn:Ge alloy with extremely Mn concentration up to 57?s in Mn:Ge alloy. It wassmaller than that TC of Mn-doped Ge in the bulk samples of 285 K. Since the solubility of Mn in Ge were limited under thermal equilibrium condition, and Mn-Ge alloy were easily formed when samples were grown at high temperature or during annealing process . It were the reasons that TC of DMS of Mn-doped Ge have not been archived the room temperature even the theoretically were predicted that the estimated TC ranged up to 400 K.

Here we report on both electron and hole carrier polarization at room temperature in magnetic cluster embedded in Ge semiconductors. We obtained the p-type conduction in post-annealed samples in Ar, while the n-type ferromagnetic conduction in post-annealed samples in H_2 and N_2. Interestingly, both carriers are spin-polarized up to room temperature.