Spin transport in Diluted Magnetic Semiconductors

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***Abstract*—** Some research works of magnetic properties and transport properties on DMSs (Diluted Magnetic Semiconductors) in our group have been presented.

1. INTRODUCTION

As we know, silicon is the backbone of microelectronics industry in the modern society. Therefore, Si-based DMS is very interesting topic in spintronics. However, according to the phase diagram of Si-Mn, the solubility of Mn in Si is very low except some compounds such as MnSi;Mn_3Si; Mn_4Si_7;Mn_5Si_2 etc. in which only appear weak magnetism at low temperature (T<50K). How to dope a reasonable amount Mn into Si is a key processing for Si-based DMS. Moreover, as spin transport in organic materials have recently attracted much attention of researchers because of the much longer spin diffusion length of electron in organic materials than in metals [1], we have studied Fe_3O_4 nanoparticles coated with oleic acid. Furthermore, although DMSs have been rapid wide investigated in this century for their potential in providing effective spin injection for semiconductor spintronic devices [2], the experiment data for properties of DMSs are dispersed very significantly even for the same composition in the literatures. It is believed that the clustering of impurities could be one of important factors. So we investigate the effect of clustering on the ferromagnetism by the mean-field theory.

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2. Si-BASED DMS

$Si_{1-x}Mn_x$:(BH) films on Si(001) were fabricated by sputtering deposition. In order to dope reasonable amount Mn into Si , the films were treated by a rapid thermal annealing process in the Ar ambient. According to temperature dependence of the resistivity, with thermal annealing, a transition from weakly insulating amorphous to crystallized semiconducting states occurred for the films. As –deposited films shown weakly insulating disorder behavior and it is shown semiconductor characteristic for annealed films. (Fig1.) Typical specific magnetization with temperature for the films ($Si_{0.95}$ $Mn_{0.05}$） was measured by SQUID system. The Curie temperature is over 400K [3].

In order to study the mechanism for Si-base DMS, polycrystalline $Si_{1-x}Mn_x$:(B,H) films were fabricated and a mechanism of hole-mediated ferromagnetism was confirmed..[4,5]

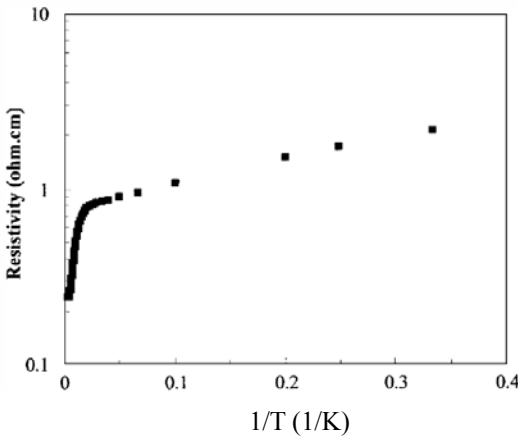

Fig1. Temperature dependence of the resistivity for crystalline ($Si_{0.95}$ $Mn_{0.05}$） film

3. OLEIC COATED Fe_3O_4 COMPOSITE NANOPARTICLES SYSTEM

Self-assembled monolayers of oleic acid molecules chemically bond to 10nm Fe_3O_4 nanoparticles were fabricated by chemical method. The field dependence of (MR) is measured at 115 K for different oleic acid coverage（Fig. 2）. The MR of monolayer oleic acid coated Fe_3O_4 is up to about 17.5% and drops to 7.3% for pure Fe_3O_4 nanoparticles. This enhanced MR is likely arising from the spin-polarized electrons hopping through the oleic acid molecules.

The inset is the temperature dependence of resistivity ρ for the three samples The resistivity of all samples closely follow the $\log\rho \sim T^{-1/4}$ relation [6]., suggesting the variable range hopping mechanism.

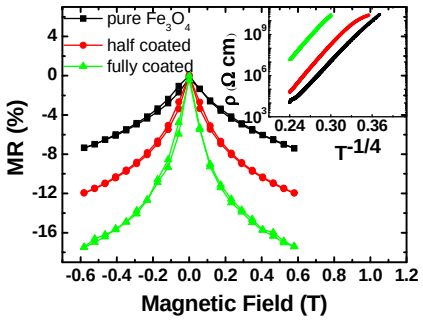

Fig.2.. The field dependence of MR for Fe_3O_4 nanoparticles with different oleic acid coverage.

4. THE EFFECT OF CLUSTERING OF MAGNETIC IMPURITIES ON DMS

From experimental point, it is very difficulty to avoid clustering of impurities during preparation processes of DMS. This is why the magnetic properties of DMSs are very sensitive to sample preparation and annealing processes. The Curie temperature is calculated by the mean-field theory on a lattice with randomly distributed clusters of magnetic impurities which are interacting with each other by carrier mediated RKKY exchange coupling together with the nearest-neighbor (NN) direct exchange interaction [7]. Theory calculation indicated that the Curie temperature can be enhanced by the clustering if the NN interaction is ferromagnetic or is weekly antiferromagnetic. The clustering of impurities maybe is not the bane of DSM. It could be used to tailor desirable properties of DMS [8]. In some cases the structures with clustering may have spin polarization at even higher Curie temperature, but the magnetic moments become more concentrated in the space and the ferromagnetism is ununiform.

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