Spin Scattering for Magnetic Element Doped Indium Tin Oxide

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Diluted magnetic semiconductors with iron group (IG) element and rare earth (RE) one have attracted much attention to their unique magnetic properties. Indium tin oxide (ITO) achieves higher carrier concentration than that of other oxide semiconductors by means of Sn intentionally doping and double donors due to oxygen defects. It is experimentally expected that carrier-induced ferromagnetism (FM) can be realized by doping a magnetic element with a large magnetic moment into ITO. Previous reports of ITO doped with a magnetic element in bulk or thin films include Cr, Mn and so on, and Harinath Babu *et al*. have reported that Cr doped ITO nanoparticles (NPs) show FM at low temperatures [1]. Fe^{3+} and Dy^{3+} ions are one of the chemical species with the largest magnetic moment among IG element and RE one. The respective value is 5.9 μ_B and 10.6 μ_B, respectively, where μ_B is the Bohr magneton. So far, we have synthesized ITO NPs dispersed in toluene using a chemical thermolysis method with organic complexes such as indium fatty acids in the absence of solvents, and have already reported some interesting magneto-transport properties up to 6 T in our ITO NP thin films [2]. Furthermore, we are synthesizing ITO-based magnetic semiconductor NPs with Fe and Dy, and evaluating the magneto-transport properties. The conductance exhibits quantum correction at low temperatures (LT), originating from weak localization (WL). WL is the constructive quantum interference effect produced by electron waves at LT. In the case of spin scattering caused by magnetic elements, two electron waves interfere at the opposite phase, resulting in weak antilocalization (WAL), which is the destructive quantum interference effect, as a result, positive magnetoresistance (MR) appears at LT.

Here we will show the experimental results of Fe doped ITO (Fe-ITO) NPs thin films. Fe-ITO NPs dispersed in an organic solvent were spin-coated on a corning glass substrate. The samples were annealed at 500 degrees C for 30 min in air. As a result of X-ray diffraction spectra of the Fe-ITO NPs thin films, (222) diffraction peak of cubic indium oxide was clearly observed at 30.6°, and we confirmed that our Fe-ITO NPs have good crystallinity. Figure 1 shows the transverse MR under the magnetic field perpendicular to the film surface at 4.5K for ITO NPs and Fe-ITO NPs thin films, which have approximately the same Sn concentration. Fe-ITO is co-doped with 3.4% Sn concentration and 2.9% Fe one. The vertical axis in Fig.1 represents the rate of MR to the resistance in the absence of magnetic field. The ITO NPs thin film shows only negative MR, on the other hand, the negative MR effect is suppressed for the Fe-ITO NPs thin film. This might be a precursor to the WAL effect caused by Fe atoms, indicating that Fe atoms play an important role in electron spin scattering. We will also show the results of Dy-ITO in the conference.

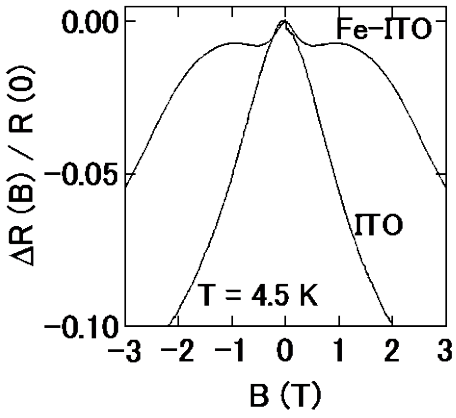

Fig.1. MR at 4.5 K for ITO and Fe-ITO NPs thin films.

References

[1] S. Harinath Babu *et al*., Physica B **500** 126 (2016).
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