Diluted magnetic semiconductors

Electrons possess both charges and spins. The motion of charges forms the current. The ability to control or modulate the charge transport has made it possible to form functional devices such as diodes and transistors. This is so far only possible in semiconductors instead of metals because the latter has too many electrons per unit volume; the variation of charge distribution, if any, is limited to a few atomic layers at the surface that can hardly cause any measurable change in the conductance of the metal. On the other hand, metallic magnetic materials have another additional degree of freedom which can be used to vary their electronic transport properties - the spin of electrons. As the spin of electrons in magnetic materials can be easily manipulated using an external magnetic field without suffering the electrostatic screening effect as the charges do when they are subjected to an electric field, it is possible to alter the conductivity of magnetic materials without changing the carrier distribution inside the material. This forms the basis of GMR-based electronics or sometimes is also called magnetoelectronics. In order to realize full control of both the charge and spin degrees of freedom, currently intensive researches are being carried out in worldwide research organizations to explore room temperature diluted magnetic semiconductors. The ISML group is currently involved in the development of group IV, oxides, II-VI and other exotic types of DMS, in collaboration with the Data Storage Institute.

Nanoscale magnetic imaging (High resolution MFM tips)

Magnetic force microscopy (MFM) has become a standard tool to investigate the magnetic nanostructures by visualizing the magnetic stray field distribution above the surface of a magnetic sample on a sub-100 nm scale. The research on MFM has been centered mainly on two aspects, i.e., resolution enhancement and tip-sample interaction reduction. So far, many efforts had been made to improve the resolution of MFM through sharpening the tips using different approaches such as attaching carbon nanotubes to the original tips, trimming the tips by focus ion beam (FIB), electron beam lithography, and ion beam etching, selective deposition by self-field emission, electron beam irradiation and focused electron beam decomposition and deposition. One of the difficulties involved in the preparation of a nanometer-sized MFM tip lies in how to make a stable magnetic coating on the tiny tip. We have demonstrated that the stability and resolution of FIB-trimmed tips can be improved by using an exchange-coupled ferromagnet/antiferromagnet (FM/AFM) double layer structure. We have also shown that the resolution of the MFM tips can be further improved by using an FM/Ru/FM trilayer as the magnetic coating. The improvement was attributed to the formation of a point-dipole tip because of the antiferromagnetic coupling between the two FM layers. This technique has the advantage that the tips can be prepared in a batch-processing fashion. This project is in collaboration with the Data Storage Institute.