Magnetic Materials   Prof. **Koki Takanashi** (2000.11~)

【Staff Members】

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【Research Activities】

In the Magnetic Materials group, we work on the development of new materials for the application to spin-electronic devices, and on the fundamental study of magnetic and magneto-transport properties in artificial nanostructures. We have two main research subjects. The first is the study of spin-dependent single electron tunneling in magnetic nanoparticles. We previously reported the oscillation of TMR associated with Coulomb staircases in microfabricated CPP (Current-Perpendicular-to-Plane) structures including a granular film where Co nanoparticles were embedded in an Al-O insulating matrix. Further developing this study in FY2004, we have confirmed the oscillation of TMR showing a periodical sign change, and found that the sign change is caused by spin accumulation in Co nanoparticles (**Ref.*2***). The precise comparison between the experiment and theory has revealed that the spin relaxation time in Co nanoparticles is about four orders of magnitude longer than that in bulk Co, suggesting the potential application of nanoparticles as basic elements of spin-electronic devices. This result was published in Nature Materials (**Ref.*5***), and also reported in a Nikkan-Kogyo newspaper, etc. In order to prepare nanoparticles with more uniform sizes than those in granular films, furthermore, we fabricated a two dimensional assembly of Fe nanoparticles epitaxially grown on a MgO(100) tunnel barrier, and have succeeded in the observation of TMR oscillation in a CPP geometry sample including these nanoparticles (**Ref.*1***). The second subject is the fabrication of $L1_0$ FePt-based nanostructures, and their electric and magnetic properties. $L1_0$ ordered FePt alloy, because of its high magnetocrystalline anisotropy and high corrosion resistance, has attracted much attention in recent years as a candidate material for next-generation magnetic recording media and nano-scale permanent magnets. We previously worked on the $L1_0$ ordering at reduced temperatures, the control of crystal orientation, and the relationship between nanostructure and magnetic properties in FePt thin films. In FY2004, films with highly oriented, highly ordered FePt nanoparticles were fabricated by sputtering. Huge coercivities as high as 70 and 105 kOe have been achieved in a film with single-domain particles at room temperature and 4.5 K, respectively (**Ref.*4***). These values may be champion data for the coercivity in thin films. We have also measured the TMR characteristics in magnetic tunnel junctions with FePt electrodes, suggesting that FePt is also a candidate material for spin-electronic devices (**Ref.*3***).

1. F. Ernult, K. Yamane, S. Mitani, K. Yakushiji, K. Takanashi, Y. K. Takahashi, and K. Hono
Spin-dependent single-electron-tunneling effects in epitaxial Fe nanoparticles
Appl. Phys. Lett., 84 (2004) 3106-3108.

2. K. Yamane, K. Yakushiji, F. Ernult, M. Matsuura, S. Mitani, K. Takanashi and H. Fujimori
Inverse tunnel magnetoresistance associated with Coulomb staircases in micro-fabricated granular systems
J. Magn. Magn. Mater., 272-276 (2004) e1091-e1093.

3. T. Moriyama, S. Mitani, T. Seki, T. Shima, K. Takanashi and A. Sakuma
Magnetic tunnel junctions with $L1_0$-ordered FePt alloy electrodes
J. Appl. Phys., 95 (2004) 6789-6791.

4. T. Shima, K. Takanashi, Y. K. Takahashi and K. Hono
Coercivity exceeding 100 kOe in epitaxially grown FePt sputtered films
Appl. Phys. Lett., 85 (2004) 2571-2573.

5. K. Yakushiji, F. Ernult, H. Imamura, K. Yamane, S. Mitani, K. Takanashi, S. Takahashi, S. Maekawa and H. Fujimori
Enhanced Spin Accumulation and Novel Magnetotransport in Nanoparticles
Nature Materials, 4 (2005) 57-61.

【Plan】

Our research, focusing on the materials development for spin electronics and the fundamental study of spin dependent transport, will be performed with the following three plans:

- Development of fabrication techniques of nano-scaled magnetic superstructures

The development of thin film preparation and microfabrication techniques, leading to the formation of nano-scaled magnetic superstructures, has made spin electronics possible. The study of magnetic superstructures started with the study of magnetic multilayers around 1980. Multilayers possess a layered structure in a certain direction, in other words, one-dimensional superstructure. However, two-dimensional or three-dimensional superstructures, which may give rise to further remarkable and novel magnetic and magneto-transport properties, have not fully been achieved yet. We will work on the development of fabrication techniques of two-dimensional or three-dimensional nano-scaled magnetic superstructures, combining self-assembling and microfabrication processes.

- Fabrication and characterization of magnetic ordered alloys for spin electronics

Fe-Co-Ni-based alloys are major materials which are (or are going to be) in practical use in spin electronics at present. However, devices only using these materials will certainly meet the limit of performance and stability in a few years. New materials with high spin polarization and high magnetic anisotropy are required for the extended progress of spin electronics. Many of magnetic ordered alloys are considered to have high potential, although they have not fully been investigated in terms of materials for spin electronics. $L1_0$ ordered alloys such as FePt and half-metallic Heusler alloys are representative examples. Device structures including these ordered alloys will be fabricated, and their magneto-transport properties will be investigated, in order to develop the ordered alloys that will actually be useful for practical application to spin electronic devices.

- **Study of the effect of spin injection and accumulation in magnetic nanostructures**

Spin-dependent transport phenomena will extensively be studied in magnetic nanostructures such as CPP (Current-Perpendicular-to-Plane) geometry, dot arrays and point-contacts. Particularly, we will pay attention to the effect of spin injection and spin accumulation on transport properties. In addition to giant magnetoresistance (GMR) and tunnel magnetoresistance (TMR), electrical manipulation of magnetic moments and their dynamics will be investigated.