International Research Center for Elements Science - Advanced Solid State Chemistry -

http://msk2.kuicr.kyoto-u.ac.jp/

Prof
TAKANO, Mikio
(D Sc)

Assist Prof
SAITO, Takashi
(D Sc)

Assist Prof (SER)
YAMAMOTO, Shinpei
(D Eng)

PD
YAMADA, Ikuya
(D Sc)

Lecturer (pt)

KUMADA, Nobuhiro (D Eng) University of Yamanashi

Students

OKA, Kengo (M2)
HORIUCHI, Daisuke (M2)

Scope of Research

Novel inorganic materials and devices that have new, useful or exotic features such as superconductivity, ferromagnetism and quantum spin ground state are synthesized and fabricated by novel methods. For example:

- Oxides containing transition-metal ions in unusually high-valence state.
- Nonequilibrium materials that can be obtained by high pressure method or epitaxial thin film deposition method.
- Inorganic nanomaterials with useful functionality such as superparamagnetism and quantum size effect.

Research Activities (Year 2006)

Presentations

Magnetic Structure of $SrCo_6O_{11}$ with Magnetization Plateau, Saito T, Takeda Y, Williams A, Attfield P, Wuernisha T, Kamiyama T, Ishiwata S, Shimakawa Y, Takano T, 61st Annual Meeting, The Physical Society of Japan, 27–30 March (Matsuyama).

Neutron Diffraction Study of a Layered Cobalt Oxide $SrCo_6O_{11}$, Saito T, Williams A, Attfield P, Wuernisha T, Kamiyama T, Ishiwata S, Takeda Y, Shimakawa Y, Takano M, 17th International Conference on Magnetism, 20–25 August (Kyoto).

Spin Frustration in $SrCo_6O_{11}$, Saito T, Williams A, Attfield P, Wuernisha T, Kamiyama T, Ishiwata S, Takeda Y, Shimakawa Y, Takano M, Kyoto Conference on Solid State Chemistry, 14–18 November (Kyoto).

Single Crystal Growth of Calcium Oxychloride Superconductors $Ca_{2-x}Na_xCuO_2Cl_2$ and $Ca_{2-x}CuO_2Cl_2$ at High Pressure, Yamada I, Azuma M, Ohish K, Shimakawa Y, Takano M, Kyoto Conference on Solid State Chemistry, 14–18 November (Kyoto).

Synthesis and Magnetic Properties of $L1_0$-FePt Nanoparticles, Yamamoto S, Morimoto Y, Tamada Y, Takahashi Y K, Hono K, Ono T, Takano M, Kyoto Conference on Solid State Chemistry, 14–18 November (Kyoto).

Synthesis, Structural and Physical Properties of A-site Cation Deficient Single Layer Oxychloride Superconductor $Ca_{2-x}CuO_2Cl_2$, Yamada I, Azuma M, Belik A, Harjo S, Kamiyama T, Shimakawa Y, Takano M, 8th International Conference on Materials and Mechanisms of Superconductivity and High Temperature Superconductor, 9–14 July (Dresden).

High Pressure Single Crystals Growth of Calcium Oxychloride Superconductors, Yamada I, Azuma M, Shimakawa Y, Takano M, Fall Meeting 2006, The Physical Society of Japan, 23–26 Fall (Chiba).

Preparation of $L1_0$-FePt Nanoparticles Dispersible in Nonpolar Organic Solvents, Yamamoto S, Morimoto Y, Tamada Y, Takahashi Y K, Hono K, Ono T, Takano M, The 30th Annual Conference on Magnetics in Japan, 11–14 September (Shimane).

Blue-light Emission at Room Temperature from Ar^+-irradiated $SrTiO_3$, Kan D, Terashima T, Kanda R, Masuno A, Ishizumi A, Kanemitsu Y, Shimakawa Y, Takano M, APS March Meeting 13–17 March (Baltimore).

Blue Luminescence at Room Temperature from Electron-doped $SrTiO_3$, Kan D, Kanda R, Masuno A, Terashima T, Ishizumi A, Kanemitsu Y, Shimakawa Y, Takano M, The 53rd Spring Metting, 2006; The Japan Society of Applied Physics and Related Societies, 22–26 March (Tokyo).

$SrCo_6O_{11}$ with Anomalous Magnetotransport Property

$SrCo_6O_{11}$ is a layered cobalt oxide with anomalous magnetoresistance, first synthesized using a high pressure technique in our group. It was found that $SrCo_6O_{11}$ comprises itinerant electrons and Ising-like local spins of $S = 2$ on separate crystallographic sites, having strong interactions with each other. The spin structure at the 1/3 magnetization plateau state was found to be ferromagnetic in the *ab*-plane and like ↑-↑-↓-↑-↑-↓ along the *c*-axis. The quick reorientation of the ferromagnetic layers from the ↑-↑-↓ (M/M_0 = 1/3; M_0 = saturated magnetization) manner to the ↑-↑-↑ (M/M_0 = 1) manner under magnetic field should result in a major change of the magnetic scattering of conduction electrons penetrating through the ferromagnetic layers, which explains the negative, sharp and two-stepped magnetoresistance.

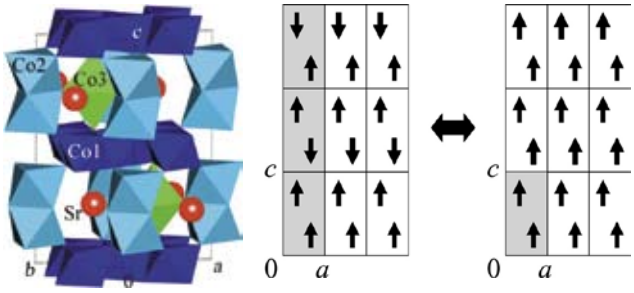

Figure 1. The crystal structure and spin structures of $SrCo_6O_{11}$.

Monodisperse and Highly Coercive $L1_0$-FePt Nanoparticles Dispersible in Nonpolar Organic Solvents

The FePt alloy with the $L1_0$ structure possesses a very high uniaxial magnetic anisotropy of ca. 6×10^6 J/m^3, which is more than ten times as high as that of the currently utilized CoCr-based alloys. Superparamagnetic fluctuation of the room temperature magnetization can thus be suppressed even for particles of 3 nm in diameter, making an appropriate array of these nanoparticles to be a promising candidate for future ultra-high density magnetic recording media of >1 Tbit/inch^2. The most basic requisite for the practical use would be the formation and the fixation of an array on a substrate with the magnetic easy axis, *i.e.,* the tetragonal *c* axis, oriented normal to the substrate surface. Such a close packed triangular array structure may be formed through self-organization under an external magnetic field if the $L1_0$-FePt nanoparticles could be dispersed in a polymer binder. We developed a method to prepare monodisperse and highly coercive $L1_0$-FePt nanoparticles which are dispersible in nonpolar organic solvents such as toluene, chloroform, and hexane. By vigorously stirring the SiO_2-coated $L1_0$-FePt nanoparticles synthesized by the "SiO_2-nanoreactor" method (*Appl. Phys. Lett.* **2005**, *87*, 032503) in a mixture of an aqueous NaOH solution, chloroform, and hexadecyltrimethlyammonium bromide, the SiO_2 coating was dissolved off and bare FePt nanoparticles could be extracted to the chloroform phase without degrading their magnetic properties. The present success may promote the practical application to ultra-high density magnetic recording and also may open the door to providing these particles with new physical and/or chemical functions.

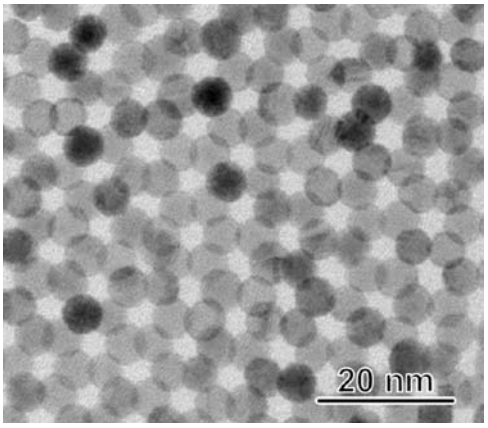

Figure 2. TEM image of the $L1_0$-FePt nanoparticles.

Grant

Takano M, Chemistry and Physics of 3d Transition Metal Oxides Equipped with Deep 3d Levels: Search for New Materials and New Functions, Grant-in-Aid for Scientific Research (S), 1 April 2005–31 March 2010.

Award

Yamamoto S, MSJ Outstanding Presentation Award, The 30th Annual Conference on Magnetics in Japan, "Preparation of $L1_0$-FePt Nanoparticles Dispersible in Nonpolar Organic Solvents," The Magnetics Society of Japan, 22 November 2006.