2013 International Conference on Solid State Devices and Materials
= Short Course B =
Fundamentals and Applications of Spintronics Frontier
September 24, 2013 Hilton Fukuoka Sea Hawk, Fukuoka, Japan

Organizer

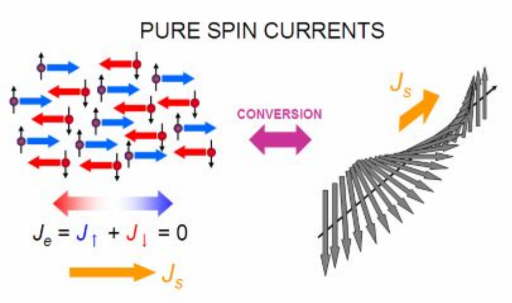
Dr. Akira Fujiwara (NTT Corporation)

Speakers

13:00-13:55 "Advanced Spintronic Materials: for Generation and Control of Spin Current"

Prof. Koki Takanashi (Tohoku University)

"Spin current", *i.e.*, the flow of spin angular momentum, in magnetic nanostructures has emerged as a fascinating physical concept during the recent development of spintronics. In magnetic nanostructures, magnetism correlates strongly with electronic transport and also other physical properties, leading to the mutual control of magnetic, transport, and other physical properties. Spin current is the most basic concept relevant to the mutual control, and efficient generation and precise control of spin current in magnetic nanostructures are key technologies for the further development of spintronics[1].

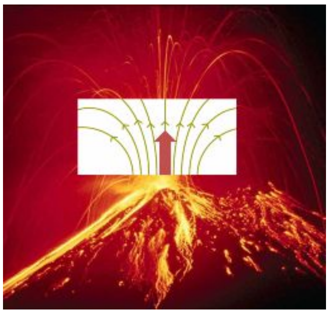


In my lecture, the concept, historical background, and recent progress in research of spin current will first be reviewed, and then some topics on advanced materials for the generation and control of spin current will be introduced, particularly focusing on magnetic ordered alloys such as half-metallic Heusler alloys and $L1_0$-oredered alloys with high magnetic anisotropy.

[1] For review, K. Takanashi, *Jpn. J. Appl. Phys.*, **49** (2010) 110001.

13:55-14:50 "Spin Caloritronics - more than spin-dependent thermoelectrics"

Prof. Gerrit E.W. Bauer (Tohoku University)



The spin degree of freedom of the electron affects not only charge, but also heat and thermoelectric transport, leading to new effects in small structures that are studied in the field of *spin caloritronics* (from calor, the Latin word for heat).

This Short Course addresses the basic physics of spin caloritronics. Starting with an introduction into thermoelectrics and Onsager's reciprocity relations, the generalization to include the spin dependence in the presence of metallic ferromagnets will be addressed. Using this foundation I will describe several recently discovered spin-dependent effects in metallic nanostructures and tunneling junctions in terms of a two spin-current model of non-interacting electrons.

A different class of spin caloritronic effects can be explained only by the collective spin dynamics in ferromagnets. The thermal spin transfer torque that allows excitation and switching of the magnetization in spin valves as well as the operation of nanoscale heat engines is complemented by thermal spin pumping. The latter generates the so-called spin Seebeck effect, which is generated by a heat current-induced non-equilibrium of magnons at a contact between an insulating or conducting ferromagnet and a normal metal. Under these conditions a net spin current is injected or extracted from the normal metal that can be detected by the inverse spin Hall effect.

Further issues to be addressed are the relation between electric, thermal and acoustic actuation of the magnetic order parameter, as well as the application potential of spin caloritronics.

More details and a bibliography can be found in Ref. [1].

[1] G.E.W. Bauer, E. Saitoh, and B.J. van Wees, *Spin Caloritronics,* Nature Materials **11**, 391 (2012).

Break (15min.)

15:05-16:00 "MTJ-based Spintronics"

Prof. Yasuo Ando (Tohoku University)

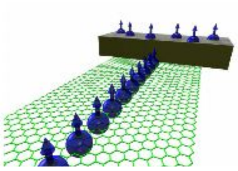
In this lecture, MTJ-based Spintronics will be reviewed. The first part of this lecture is the history of developing MTJs. The concept of spin-dependent tunneling will be explained. And, in order to understand spin polarization in MTJs, tunnel magnetoresistance in variety of layer materials will be shown. Then, we discuss about the relationship between the bulk spin polarization and that of the thin film.

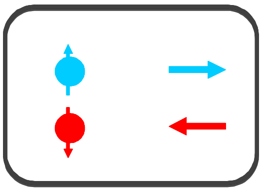
The second part of this lecture is about recent progress of tunnel magneto-resistant effect. New devices and new applications of MTJs with new materials will be explained. Based on these talks, we consider how to design new devices in future.

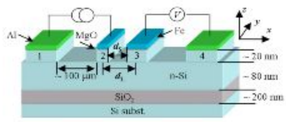
16:00-16:55 “Group-IV Spintronics”

Prof. Masashi Shiraishi (Osaka University)

Carbon, silicon and germanium are categorized as “Group-IV semiconductors”, and apart from germanium, carbon and silicon are ubiquitous materials. Spintronics using these group-IV semiconductors has been attracting tremendous attention in recent several years, because carbon-based molecules and silicon possess a small spin-orbit interaction, resulting in long spin coherence of injected spins. Among group-IV spintronics, generation and transport of pure spin current at room temperature is one of the most significant milestones for practical applications since pure spin current is a flow of only spin angular momentum without a charge flow, and thus, it is ideally a dissipationless current. In this talk, I introduce how to generate and how to control pure spin current, and also introduce spin transport properties in group-IV semiconductors.







16:55-17:40 “Light and Spintronics”

Prof. Hiro Munekata (Tokyo Institute of Technology)

The past half-century has been devoted primarily to build a framework in which spins and charge motions both participate. Thanks to those efforts, knowledge in spintronics has been materialized into the realization of ultra-high-density magnetic storage and development of integrated non-volatile memory. At present, scientists worldwide are about to start building the second framework in which spin information is input, processed, and output without the charge motion. To this end, I, with my colleagues, am studying the way to manipulate spins in magnetic materials with light, kinds of high-frequency electromagnetic waves of around 10^{15} Hz and higher. Why use light? It is mass-less, propagates very fast, and it has both non-local and local characters. At the present stage, it is very important to pave the way toward establishing fundamental concepts of optical manipulation of spins. A key is the spin-orbit interaction. In order to understand this interaction, we pursue experimentally (i) how fast we can manipulate ordered-spins and (ii) to what extent the power of optical excitation can be reduced to manipulate ordered-spins, incorporating the development of new materials to pursue (i) and (ii). Another important subject is establishing fundamental concepts of devices for mutual conversion between light and spins; we study this with (iii) circularly polarized light emitters/detectors and (iv) spin-controlled optical waveguides.