Old materials revisited for spintronics

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Spintronics utilizes spin current (a flow of “angular momentum”) instead of charge current for next-generation energy-saving electronic devices. Triggered by the giant magneto-resistance, spintronics is rapidly progressing. In addition to many applications, spintronics shows a rich variety of new phenomena (Table 1) [1-2]. If the study on magnetoresistance is assigned to be the first stage, utilization of spin current is the second stage. For example, the spin Seebeck effect is a new principle of power conversion via spin currents. A spin current accompanied by a spatial variation of the magnetization such as a magnetic domain-wall induces the so-called spin motive force. Here, the spintronics enters the third stage. To apply these effect, better understanding on materials is necessary. Furthermore, choices of materials should be extended from ferromagnet to antiferromagnet, ferrimagnet, and spin liquid state. Collaboration with theory and experiment is also crucial.

We will discuss old materials, e.g., rare-earth (RE) garnets. But these may become new materials for spintronics. Some ferrimagnets show compensation temperatures, at which a magnetization and/or a total angular momentum disappears below Curie temperature. Notably, a speed of magnetic domain wall is enhanced at angular momentum compensation temperature. In general, RE elements have a large spin-orbit coupling. It means that RE will be an origin of magnetic anisotropy and will induce a large magnetic damping. On the other hand, the large spin-orbit coupling of RE elements leads to a phonon Hall effect. This is a kind of thermal Hall effect and may lead to a thermal management by magnetic field. Comparing theory with experiments by neutron and X-ray, we will be able to find new materials for spintronics.

Table 1.

1st stage (1975-)	Magnetization	$\vec{M}$	Magnetoresistance HDD, MRAM
2nd stage (2000-)	Spin current	$\vec{J}_s \propto \frac{\partial \vec{M}}{\partial t}$	Spin-Seebeck effect Thermoelectricity
3rd stage (2009-)	Spin-electric field	$E_i \propto \vec{M} \cdot \left(\frac{\partial \vec{M}}{\partial t} \times \frac{\partial \vec{M}}{\partial x_i} \right)$	Spinmotive force Power generation & converter

[1] https://asrc.jaea.go.jp/publication/note/pdf/37kagaku/37_04.pdf
[2] https://asrc.jaea.go.jp/soshiki/gr/spinenergy/index.html