

# Spin Conversion Phenomena in Spintronics

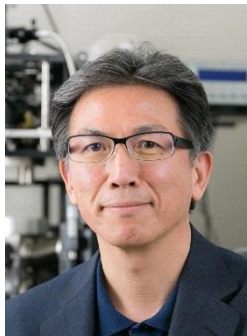
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Since the discovery of giant magnetoresistance, spintronics research has been evolving and has reached a new phase in which the concept of spin currents, i.e., the flow of spin angular momenta, helps us understand various spintronics phenomena. These include all the recently discovered conversion phenomena, such as the direct and inverse spin Hall effects, spin Seebeck and Peltier effects, spin pumping, and the inverse Faraday effect. More recently, Rashba interfaces and the surface states of topological insulators were found to exhibit the so-called Edelstein effect, in which spin-momentum locking behavior brings about non-equilibrium spin accumulation.

These interface and surface effects thus provide an effective means of interconversion among spin, charge, and heat currents. Most of the above-mentioned spin conversion phenomena take place at simple nanoscale interfaces between two different types of materials (e.g., magnets, non-magnets, semiconductors, and insulators). These structures may enable us to advance spin-mediated interconversion among physical entities such as electricity, light, sound, vibration, and heat.

I will first give an introduction to the general spin-mediated spin-conversion processes and then will focus on magneto-electric spin conversion in conductive solids, including spin Hall effects and new conversion mechanisms: Edelstein effects arising at Rashba interfaces [1] and surface states of topological insulators [2], as discussed in a recently published progress article [3].

- [1] S. Karube, K. Kondou, and Y. Otani, “Experimental observation of spin-to-charge current conversion at non-magnetic metal/Bi<sub>2</sub>O<sub>3</sub> interfaces,” *Appl. Phys. Exp.*, vol. 9, 033001, 2016.
- [2] K. Kondou et al., “Fermi-level-dependent charge-to-spin current conversion by Dirac surface states of topological insulators,” *Nature Phys.*, vol. 12, pp. 1027-1031, 2016.
- [3] Y. Otani et al., “Spin Conversion on the nanoscale,” *Nature Phys.*, vol. 13, pp. 829-832, 2017.



**YoshiChika Otani** received the B.S., M.S., and Ph.D. degrees from Keio University, Japan, in 1984, 1986, and 1989. He was a research fellow at the Physics Department of Trinity College Dublin, the University of Dublin, Ireland (1989–1991), and a researcher at the Laboratoire Louis Néel, CNRS, France (1991–1992). He was an assistant professor at the Department of Physics, Keio University (1992–1995) and an associate professor at the Department of Materials Science, Tohoku University (1995–2002). In 2001–2004 he led the Quantum Nano-Scale Magnetism Research Team at the RIKEN Frontier Research System (FRS). In 2004 he became a professor at the Institute for Solid State Physics (ISSP), University of Tokyo. Since 2013 he has additionally been the leader of the Quantum Nano-Scale Magnetism Research Team at the RIKEN Center for Emergent Matter Science (CEMS).

Prof. Otani has published over 250 technical articles in peer-reviewed journals, including book chapters and review articles, and has given more than 100 invited and plenary presentations at international conferences. He has been coordinating the Nano Spin Conversion Science project, supported by the Japanese Ministry of Education, Culture, Sports, Science, and Technology, since 2014 to elucidate the interconversion mechanisms among phonons, photons, magnons, and electrons. He has been a committee member of Commission on Magnetism (C9) of the International Union of Pure and Applied Physics since 2011 and will become vice chair in 2018.

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