Oxide spin-orbitronics

J. Matsuno
(Department of Physics, Osaka University & PRESTO, Japan Science and Technology Agency)

To date, extensive studies on *oxide* spintronics have been devoted for 3*d* transition-metal oxides mainly due to its unique magnetic properties such as half-metallicity. Here we suggest that 5*d* electron systems are promising class of spintronic materials because of its strong spin-orbit coupling (SOC). This type of spintronics utilizing strong SOC can be called as “spin-orbitronics”; a strong SOC inherent to 5*d* Ir oxides recently emerged as a new paradigm for oxide spin-orbitronics. For example, we investigated novel physics of spin-orbital Mott insulators [1] and possible topological insulators [2] by tuning the electronic phases through superlattice technique. We also demonstrated a large spin Hall effect of IrO_2, one of the simplest 5*d* oxides, indicating that Ir oxides are promising class of spin-orbitronic materials [3].

In this talk, we focus on yet another topic on spin-orbitronics – magnetic skyrmion as a topological spin texture. We have studied transport properties of bilayers consisting of m unit cells of ferromagnetic $SrRuO_3$ and 2 unit cells of $SrIrO_3$. We observed an anomaly in the Hall resistivity in addition to anomalous Hall effect (AHE); this is attributed to topological Hall effect (THE) [4]. The topological term rapidly decreases with m, ending up with a complete disappearance at $m = 7$. These results suggest that magnetic skyrmions of 10–20 nm are generated by Dzyaloshinskii-Moriya interaction, which might be caused by both broken inversion symmetry at the interface and strong SOC of $SrIrO_3$. Even more surprising is that we can control both AHE and THE by electric field in the $SrRuO_3$-$SrIrO_3$ bilayers [5]. We observed the clear electric-field dependence only when $SrIrO_3$ is inserted between $SrRuO_3$ and a gate dielectric. The results established that strong SOC of nonmagnetic materials such as $SrIrO_3$ is essential in electrical tuning of these Hall effects. Considering that AHE and THE are governed by momentum-space and real-space topology, respectively, we may have a chance to approach a triple point for topology, correlation, and spin-orbit coupling through Ir oxides.

We are also searching for spin-current applications in oxide systems beyond the spin Hall effect already shown in Ref. 3. Among them, promising is spin-current-driven thermoelectric conversion through spin Seebeck effect; high conversion efficiency is expected by utilizing and controlling SOC in Ir oxides. We will report on the latest results of spin Seebeck effect at interfaces between magnetic oxides and nonmagnetic Ir oxides.

<u>Reference</u>

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5) Y. Ohuchi *et al*., Nat. Commun. **9**, 213 (2018).