editorial

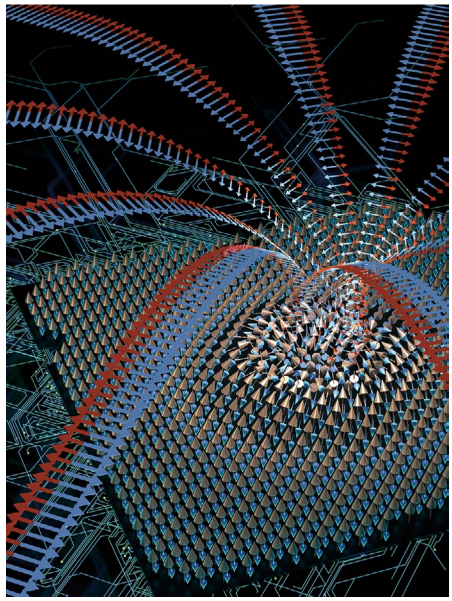
New horizons in spintronics

Ferrimagnets and topological insulators offer new platforms for utilizing the spin of electrons in functional materials.

Electrons possess an intrinsic angular momentum, also known as the spin quantum number. This can be taken advantage of in the field of spintronics. Initial breakthroughs in the field led to the development of spin valves, where the resistance to electronic flow depends critically on the relative orientation of the propagating spin (up or down), and the ordered array of spins inside ferromagnetic materials whose spin direction can be controlled using a magnetic field. The discovery of such giant magnetoresistance effects was recognized by the 2007 Nobel Prize in Physics and contributed to the massive increase in areal density of magnetoelectronic components over the past couple of decades.

However, the push toward smaller length scales and faster timescales has forced the community to face the limitations of using ferromagnetic materials as the active spintronic component. For example, ferromagnets produce stray magnetic fields that can cause cross-talk between individual components on small length scales. The spintronics community is thus actively engaged in identifying new material classes to interface with ferromagnets or indeed new classes of magnetic materials to replace the active ferromagnetic components. In this focus issue of *Nature Materials*, we take a look at recent developments involving ferrimagnetic materials and topological insulators, with an eye on their potential for use in spintronics.

Ferrimagnets are composed of antiferromagnetically coupled inequivalent magnetic atoms, leading to a small net magnetization and properties in between those of ferromagnets and antiferromagnets. In a Review Article by Kyung-Jin Lee and collaborators, they survey advances made toward utilizing this large class of magnetic materials for spintronics. They survey work demonstrating ultrafast magnetization control of ferrimagnetic GdFeCo on femto- and picosecond timescales where the magnetic response of the Gd and Fe can be probed individually. A derivation of the equation of motion for the inequivalent spins is presented and experimental results on the high speed motion of two different nanoscale magnetic textures — skyrmions (pictured) and domain walls — are discussed. Besides these fast dynamics, another example of the advantages of ferrimagnets over ferromagnets is the absence of a skyrmion Hall effect in ferrimagnets, thus simplifying the design of devices such as skyrmion-based racetrack memories. The authors also discuss how spin transport in ferrimagnets is fundamentally different from that in ferromagnets due to conduction-electron spins moving in an antiferromagnetic-like background, leading to a much larger spin coherence length that has already been taken advantage of to realize spin torque switching of thick layers at low current densities. For practical applications, further work is required to handle the strong temperature dependence of ferrimagnets, the reactiveness of commonly used rare-earth elements and related material inhomogeneities, and optimization of the high speed dynamics of ferrimagnetic textures and ultrafast magnetization control.



Ferrimagnetic skyrmions on chip.
Credit: Realmicro (Yoobin Chun)

Another materials platform for spintronics and magnetoelectronics (where electric field control can be enabled by magnetism and vice versa) that is gaining much traction is based on topological insulators — materials with an insulating bulk but conducting surface states exhibiting spin–momentum locking. A Perspective by Qing Lin He, Kang Wang and collaborators emphasizes that the bulk topological order and large spin–orbit coupling in these materials assist in allowing a very large charge–spin conversion (spin Hall angle). This, in turn, leads to an efficient spin–orbit torque allowing low-power manipulation of magnetism adjacent to the topological insulator or even a torque on the magnetism in intrinsically magnetic topological insulators themselves. This is one example of how topological insulator coupling for ferro-, ferri- and antiferromagnetic materials is fostering a new direction toward topological spintronics. The authors also emphasize that intrinsic antiferromagnetic insulators (such as $MnBi_2Te_4$ and its derivatives) have been shown to host quantum anomalous Hall effects and axion insulator phases, and are expected to display a quantized magnetoelectric coupling and even higher temperature axion electrodynamics[1]. Realization of these pursuits will require further materials development including new classes of intrinsic magnetic topological insulators and intelligent heterostructure design.

We would also like to mention other recent studies that have addressed the spin–orbit torque response in non-collinear antiferromagnets[2,3] and reviews covering the potential of van der Waals heterostructures for spintronics[4,5]. Like presents under the Christmas tree, surprises are sure to emerge from the research being undertaken on these various material platforms. And that is something to look forward to in the New Year. ❐

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