Topology-enabled functionalities of non-collinear antiferromagnets for emerging electronics

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Antiferromagnetic (AF) materials have recently attracted growing interest as promising candidates for next-generation electronic devices, including non-volatile memory[1]. Due to their compensated magnetic structure, antiferromagnets (AFMs) generate negligible stray fields, making them well-suited for high-density device integration. Moreover, they are highly robust against external magnetic fields, and their spin dynamics reach the THz regime—features that enable energy-efficient and high-speed computing. Although reading and writing magnetic information in AFMs has long been considered a challenge, several innovative concepts have recently been proposed to functionalize them. In particular, non-collinear spin structures[2] and altermagnetism[3], which macroscopically break time-reversal symmetry, as well as topological band structures that give rise to large Berry curvature in momentum space[4], have emerged as key guiding principles for realizing AFMs as active components in electronic devices.

A representative example is the non-collinear antiferromagnet Mn_3Sn[5], which hosts an inverse triangular spin structure that breaks global time-reversal symmetry, giving rise to a topological band structure with Weyl points and large Berry curvature in momentum space[6]. Owing to these unique magnetic and electronic structures, Mn_3Sn exhibits unconventional transport phenomena such as the anomalous Hall effect, anomalous Nernst effect, and magneto-optical effect at room temperature, despite possessing nearly zero net magnetization. These macroscopic responses have traditionally been expected only in ferromagnets.

Recently, the research focus has shifted from fundamental studies using bulk crystals to the exploration of device functionalities in thin films. This presentation highlights recent advances in Mn_3Sn-based heterostructures. Bilayers composed of Mn_3Sn and heavy metals have been shown to enable current-induced control of the non-collinear AF order via spin–orbit torque (SOT)[7]. Notably, the use of epitaxial Mn_3Sn thin films grown by molecular beam epitaxy has led to the first demonstration of SOT-induced perpendicular full magnetic switching in AFMs[8]. These high-quality films exhibit anomalous Hall conductivities of ~40 $\Omega^{-1}cm^{-1}$, comparable to those of bulk single crystals. Furthermore, tunnel magnetoresistance (TMR) has been successfully observed at room temperature in magnetic tunnel junctions consisting of $Mn_3Sn/MgO/Mn_3Sn$ trilayers[9], and evidence of interlayer magnetic coupling has also been identified[10]. These results, which are directly relevant to essential functions for memory applications, represent a significant step toward the practical application of functional AFMs.

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