Enhancement of Intrinsic Spin Hall Effect in Chiral Topological Semimetals

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Abstract: The spin Hall effect (SHE), which transduces charge current into spin current, is one of the essential cornerstones of spintronics. Here we propose a new intrinsic SHE (ISHE) enhancement mechanism in topological semimetals with high Chern numbers, and present a series of promising material candidates with large intrinsic spin Hall conductivities (ISHC) and spin Hall angles (SHA) for potential spintronic applications. By way of model Hamiltonian calculations and statistical analysis of 260 non-magnetic semimetals with chiral crystal structure, we unravel a positive correlation between the maximum Chern number and the ISHE, i.e., the ISHC and, under specific conditions, the SHA. Such positive correlations in topological gapless systems represent a novel mechanism to enhance ISHE, distinct from the conventional spin-orbit induced anticrossing mechanism in gapped systems. Additionally, our first-principles calculations of 38 chiral topological semimetals from space group 198, which can support zero-dimensional nodes with the highest Chern number (C = 4), reveal multiple realistic materials with large ISHC and even larger SHAs than Pt. Our discovery not only enriches the fundamental understanding of SHE but also provides an ideal material system conducive to efficient charge-to-spin conversion applications.

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