Chiral Spintronic Device: Cluster Octupole and Thermally Driven Spin Polarization

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The recent studies on spintronic devices on magnetic or structural chiral systems are reviewed in this talk. The first half of this talk pertains to the chiral antiferromagnet Mn_3Sn. Charity induces a ferroic ordering of cluster octupole polarization to the non-collinear antiferromagnetic spin structure. The octupole polarization induces a large Berry curvature owing to magnetic Weyl points in momentum space. We have developed epitaxial thin films of Mn_3Sn by molecular beam epitaxy and realized current-induced full switching of the octupole polarization [1]. Furthermore, we find a tunnel magnetoresistance effect in an all-antiferromagnetic tunnel junction consisting of $Mn_3Sn/MgO/Mn_3Sn$ [2]. We believe that unique characteristics of the octupole polarization, such as exchange-enhanced ultrafast dynamics, anisotropic spin-polarized current [2], and non-vanishing magnetic dipole T_z term [3], with the novel spin-transfer and magnetoresistance effects above, provide a basis for future spintronics devices.

The latter half of this talk pertains to organic chiral molecules. For two decades, chiral-induced spin selectivity (CISS) has been intensively studied. While the current-induced spin polarization in chiral molecules is widely recognized as a fundamental principle of the CISS, there are only a few studies on the CISS with no net current. The recent studies i.e. exchange bias [4] and current-in-plane magnetoresistance [5] indicate that a chiral molecule at the interface possesses thermally driven broken-time-reversal symmetry, whereas the freestanding chiral molecule is nonmagnetic. We also discuss the linear magnetoelectric effect of the interfacial chiral molecule and its influence on the CISS-induced current-perpendicular-to-plane magnetoresistance reported thus far.

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[1] T. Higo, K. Kondou, T. Nomoto, M. Shiga, S. Sakamoto, X. Chen, D. Nishio-Hamane, R. Arita, Y. Otani, S. Miwa, and S. Nakatsuji*, *Perpendicular full switching of chiral antiferromagnetic order by current*. Nature **607**, 474 (2022).

[2] X. Chen, T. Higo, K. Tanaka, T. Nomoto, H. Tsai, H. Idzuchi, M. Shiga, S. Sakamoto, R. Ando, H. Kosaki, T. Matsuo, D. Nishio-Hamane, R. Arita, S. Miwa, and S. Nakatsuji*, *Octupole-driven magnetoresistance in an antiferromagnetic tunnel junction*. Nature **613**, 490 (2023).

[3] S. Sakamoto*, T. Higo, M. Shiga, K. Amemiya, S. Nakatsuji, and S. Miwa*, *Observation of spontaneous x-ray magnetic circular dichroism in a chiral antiferromagnet*. Phys. Rev. B **104**, 134431 (2021).

[4] S. Miwa*, K. Kondou, S. Sakamoto, A. Nihonyanagi, F. Araoka, Y. Otani, and D. Miyajima, *Chirality-induced effective magnetic field in a phthalocyanine molecule*. Appl. Phys. Express **13**, 113001 (2020).

[5] K. Kondou*, M. Shiga, S. Sakamoto, H. Inuzuka, A. Nihonyanagi, F. Araoka, M. Kobayashi, S. Miwa*, D. Miyajima, and Y. Otani, *Chirality-induced magnetoresistance due to thermally driven spin polarization*. J. Am. Chem. Soc. **144**, 7302 (2022).

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