Magnetic structure analysis of antiferromagnets with broken time-reversal symmetry

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In ferromagnets, electric current generally induces transverse Hall voltage in proportion to magnetization (anomalous Hall effect), and it is frequently used for electrical readout of the up and down spin states. While these properties are usually not expected in antiferromagnets, recent theoretical studies predicted that collinear antiferromagnetic order with non-symmorphic crystal structure can often induce large spontaneous Hall effect even without net magnetization or external magnetic field[1]. This phenomenon, often termed "crystal Hall effect", can potentially be used for the efficient electrical readout of the antiferromagnetic states, but its experimental verification has long been elusive due to the lack of appropriate materials hosting such exotic magnetism.

In this study, we focused on a antiferromagnetic metal $FeSb_{2-x}Te_x$ with orthorhombic crystal structure (*Pnnm*), which has recently been found to host large spontaneous Hall effect despite their vanishingly small magnetization. To identify their detailed magnetic structure, we performed the polarized neutron scattering experiments for the $x = 0.16$ sample at 5G PONTA beamline in JRR-3.

In the present setup, the neutron spin direction is aligned along the [010] direction. Figure 1(b) indicates the polarized neutron scattering profile for the (001) magnetic reflection, where the spin flip (SF) and non-spin-flip (NSF) scattering mainly reflects the [100] and [010] spin components, respectively. In this case, only SF scattering is observed, which suggests that the magnetic moment is aligned along the [100] direction. Similar measurement was also performed for the (100) magnetic reflection (Fig. 1(c)). In this case, neither SF nor NSF scattering is observed, which confirms the absence of [001] and [010] spin components. Based on these data, we conclude that the collinear antiferromagnetic order as shown in Fig. 1(a) is realized in the present compound. The magnetic point group is *m'mm'*, which breaks the time-reversal symmetry and allows the emergence of non-zero Hall conductivity tensor σ_{ca}.

The present results indicate that the collinear antiferromagnetic order is indeed responsible for the appearance of large spontaneous Hall effect in $FeSb_{2-x}Te_x$. This compound is also considered as the model system of "altermagnet" with unique spin split electronic structure[2], and further investigation of its unconventional properties associated with time-reversal symmetry breaking would be interesting.

[1] L. Smejkal *et al*., Sci. Adv. **6**, 8809 (2020).
[2] I. Mazin *et al*., PNAS 118, 2108924118 (2021).

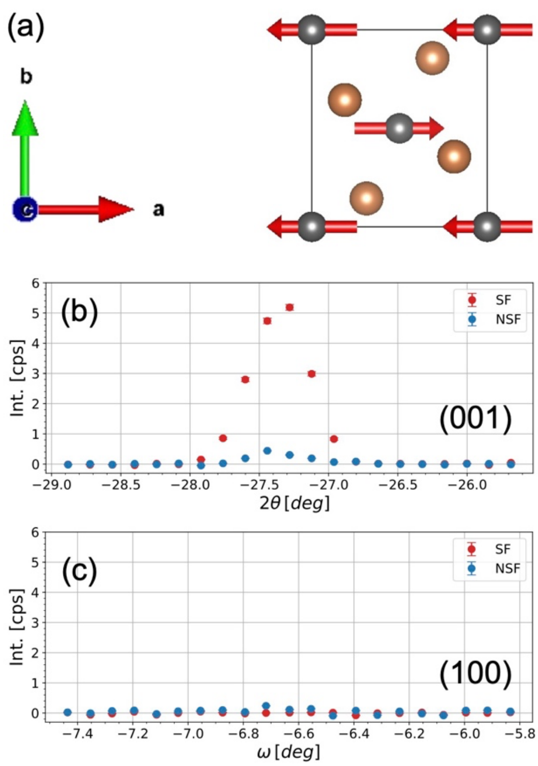

Fig. 1. (a) Magnetic structure and (b,c) polarized neutron scattering results for $FeSb_{2-x}Te_x$.