Interplay between altermagnetism and nonsymmorphic symmetries generating large anomalous Hall conductivity by semi-Dirac points induced anticrossings

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Introduction

CrAs belongs to the family of the Pnma space group, which is known to possess non-symmorphic symmetries and is a rare itinerant antiferromagnet. The C-type is the only magnetic phase which exhibits altermagnetic spin splitting [1] while in the A-type and G-type, it is absent. The C-type antiferromagnet CrAs was studied, where the interplay between its nonsymmorphic symmetries and altermagnetism was discussed [2]. This interplay has induced a network of band crossings and anti-crossings visible in the band structure which we describe in terms of semi-Dirac points and glide symmetries. With the addition of the spin-orbit coupling effect, we find that the relativistic splitting at the time-reversal invariant momenta and the anomalous Hall effect depend on the Néel vector orientation[3]. We found out that the intricate network of band crossings and anti-crossings produced and visualized in the band structure generates a contribution to the anomalous Hall effect.

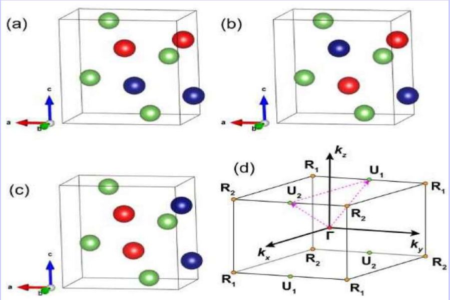


Figure 1: Crystal structure and collinear magnetic orders for CrAs as (a) *A*-type, (b) *G*-type and (c) *C*-type. (d) the irreducible Brillouin zone of the orthorhombic primitive cell for the *C*-type.

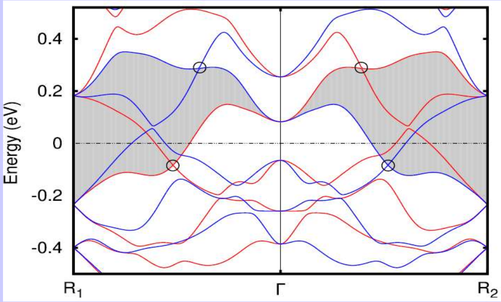


Figure 2: Band structure of the *C*-type magnetic order along the *k* path R1--R2. Spin up (blue) and spin down (red) and the black circles represent the band crossings protected by glide symmetry.

Results of the band structures

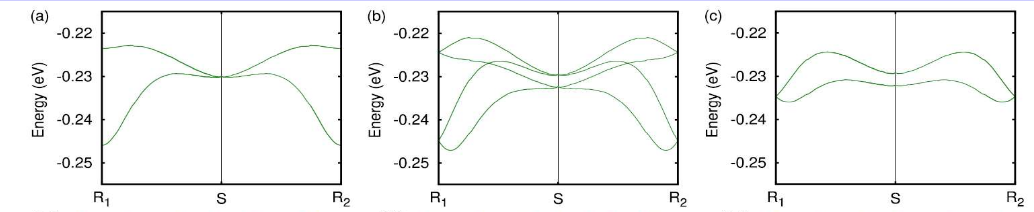


Figure 3. Band structure along the R1-S-R2 *k* path for the *C*-type magnetic order including SOC with the Néel vector along the (a) *x* axis, (b) *y* axis and (c) *z* axis.

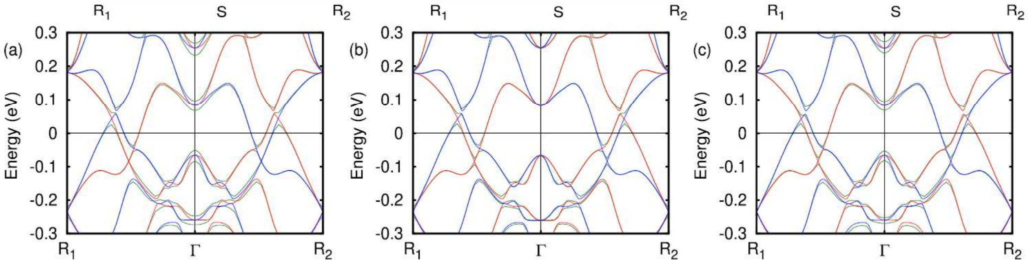


Figure 4. Band structure of the *C*-type magnetic order along the *k* path R_1--R_2 with Néel vector along the (a) *x* axis, (b) *y* axis, and (c) *z* axis, respectively. The band structure in the presence of SOC is shown in green.

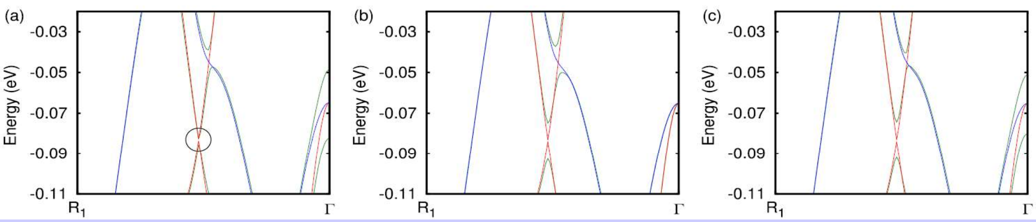
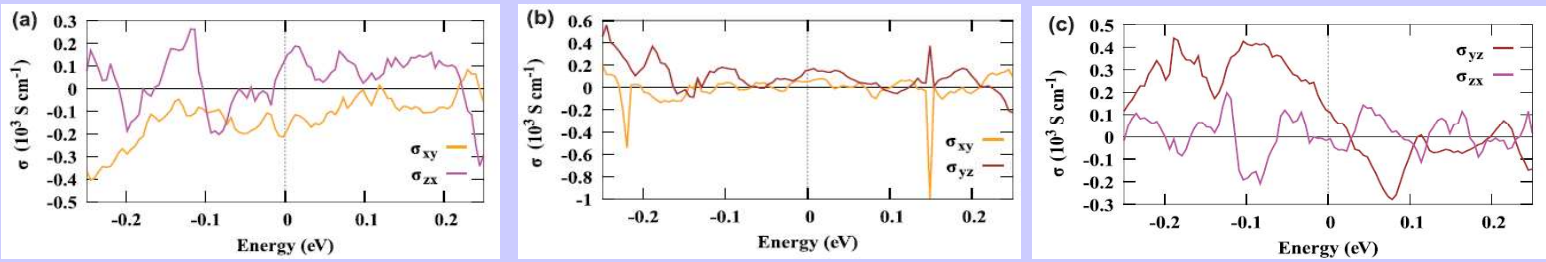


Figure 5. Magnification of the band structure in Fig. 4. Band structure of the *C*-type magnetic order along the *k*-path. The black circle in panel (a) describes the band crossing between opposite glide eigenvalues not split by SOC when the Néel vector is along *x*.

Results of the Anomalous Hall Effect



The semi-Dirac points and the glides linked to the nonsymmorphic symmetries are key ingredients to the generation of these several crossings and anticrossings. When we add the SOC, avoided band crossings are obtained and a large AHC is expected. In order to demonstrate our claim, we have done the AHC calculations between −0.25 and +0.25 eV for different Néel vector orientations as shown in the figures. A strong change of all the AHCs is observed when we switch the Néel vector from the one axis to another.

Conclusions

The presence of altermagnetism (AM) varies with the magnetic configuration, affecting the magnetic space group type. In certain configurations like C-type, nonrelativistic spin splitting occurs, while it's absent in others like G-type or A-type. The direction of the Néel vector categorizes the magnetic space group as type I or III. Selective removal of spin degeneracy at certain points is influenced by the magnetic space group. Interactions between AM and non-symmorhic symmetries lead to various band crossings and avoided crossings, resulting in significant anomalous Hall conductivity (AHC) with spin-orbit coupling (SOC), similar to the altermagnetic RuO_2 and $CaCrO_3$.

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References

[1] L. Šmejkal, J. Sinova, and T. Jungwirth, Phys. Rev. X 12, 040501(2022).
[2] A.Fakhredine, S.M. Sattigeri, G. Cuono, and C. Autieri. Phys. Rev. B 108, no. 11 (2023): 115138.
[3] C. Autieri, R. M. Sattigeri, G. Cuono, A. Fakhredine. https://arxiv.org/abs/2312.07678 (2024).

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