Crystalline Materials with Anisotropic Conduction Polarities

J. E. Goldberger[1]
[1]*Department of Chemistry and Biochemistry, The Ohio State University, 151 W. Woodruff Ave., Columbus, OH 43210*

It is conventionally thought is that a single material will exhibit a single kind of conduction polarity, either n-type or p-type, uniformly along all directions of the crystal. Then, in all modern electronic devices, functionality is achieved by integrating together these p-type or n-type materials together. Here we will describe our recent work in the synthesis, properties, and applications of metals and semiconducting materials that exhibit either n-type or p-type conduction behavior depending on the crystallographic direction, a phenomenon we refer to as "goniopolarity". We will establish the origin of this exotic behavior and the band structure design principles for identifying new goniopolar materials.[1] This has led to a large expansion in the number of compounds that we have experimentally demonstrated to exhibit this effect, such as $NaSn_2As_2$, NaSnAs, WSi_2 and $PdSe_2$.[2-5] Finally, we will show that the unique charge separation in goniopolar materials can overcome limitations of energy-harvesting technologies including thermoelectrics and photocatalysis.

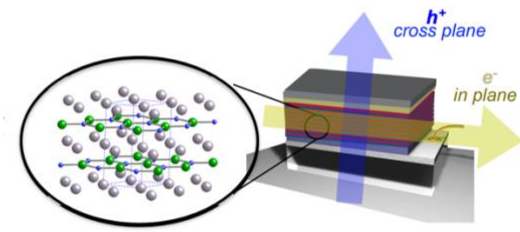

Figure 1. Schematic illustration of a layered material with axis-dependent conduction polarity.

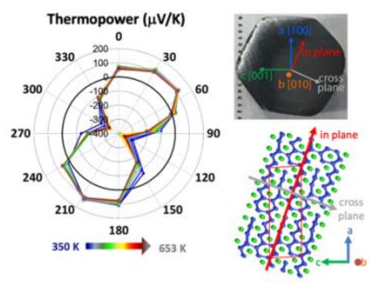

Figure 2**.** Thermopower polar plot of Re_4Si_7 measured from 350–650 K at different orientations along the *ac*-plane. 0^o corresponds to the *a* [100] direction and the crystal is in the same orientation as the crystal cross-section and crystal structure shown on the right.

[1] Y. Wang; K. G. Koster; A. M. Ochs; M. R. Scudder; J. P. Heremans; W. Windl; J. E. Goldberger, *J. Am. Chem. Soc.* **142**, 2812-2822(2020).
[2] B. He; Y. Wang; M. Q. Arguilla; N. D. Cultrara; M. R. Scudder; J. E. Goldberger; W. Windl; J. P. Heremans, *Nat. Mater*. **18**, 568-572(2019).
[3] K. G. Koster; Z. Deng; C. E. Moore; J. P. Heremans; W. Windl; J. E. Goldberger, *Chemistry of Materials* **35**, 4228-4234(2023).
[4] R. A. Nelson; Z. Deng; A. M. Ochs; K. G. Koster; C. T. Irvine; J. P. Heremans; W. Windl; J. E. Goldberger, *Mater. Horiz.* **10**, 3740-3748 (2023).
[5] A. M. Ochs; P. Gorai; Y. Wang; M. R. Scudder; K. Koster; C. E. Moore; V. Stevanovic; J. P. Heremans; W. Windl; E. S. Toberer; J. E. Goldberger, *Chem. Mater.* **33**, 946-951(2021).

+ Author for correspondence: Goldberger.4@osu.edu