Insights into Thermoelectric Materials: New Structures and Properties.

Paul Zschack, Argonne National Laboratory
Colby Heideman, Qiyin Lin, Ngoc Nguyen, Mary Smeller, Clay Mortensen, David C. Johnson , University of Oregon

Current national and international focus on green and clean energy has placed attention on both improved efficiency and on renewable sources of energy. Thermoelectric materials provide an attractive approach for waste heat recovery and for direct conversion of thermal energy to electrical power. Because they are highly reliable, have no moving parts, and may be scaled to small sizes for targeted applications, this class of material is also appealing for solid-state cooling applications. However, widespread use of thermoelectric materials for power generation and for cooling applications will require improvements of device efficiency. While there are a number of strategies for improving this efficiency, the largest gains have been achieved through optimizing the thermal properties. Layered materials fabricated with the Modulated Elemental Reactant (MER) technique have demonstrated extremely low thermal conductivity and therefore hold great promise for significantly improved thermoelectric performance. These thin-films and multilayers incorporate ordered stacking of 2D hexagonal sheets that are highly textured with [00L] along the surface normal and have random crystalline orientation in the plane parallel to the substrate. This unusual structure gives rise to extremely low thermal conductivity through enhanced interface scattering of phonons, and through the localization of lattice vibrations within the randomly distributed nano-crystalline domains. X-ray diffraction and imaging techniques at the Advanced Photon Source have been used to characterize these structures, and help identify a new strategy for improving thermoelectric materials performance.