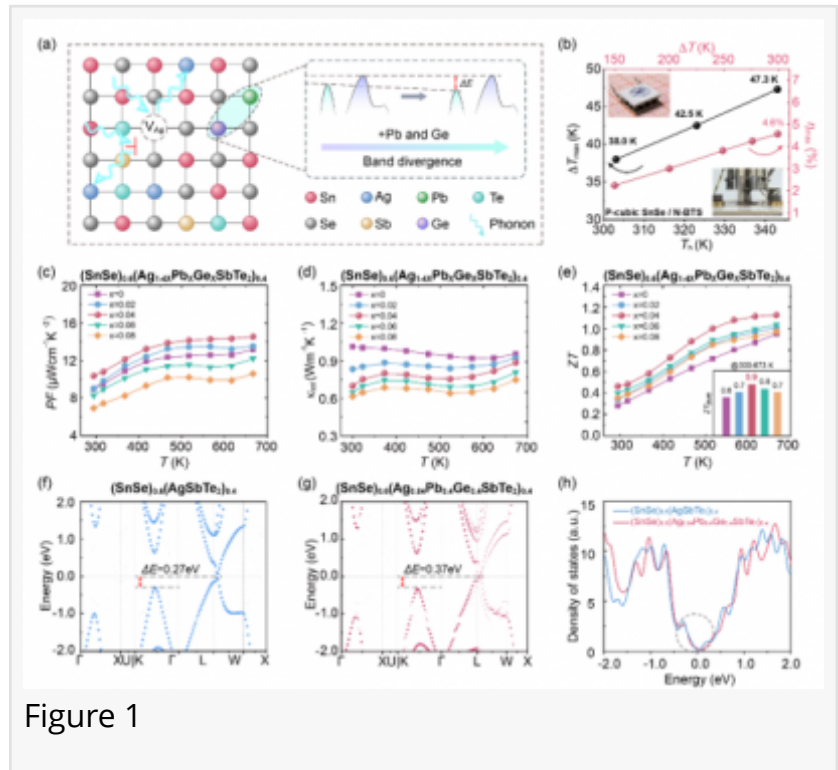


Efficient Power Generation and Cooling in Cubic Tin Selenide

FAYETTEVILLE, GA, UNITED STATES, September 4, 2026 /EINPresswire.com/ -- Thermoelectrics are regarded as potential materials in energy technology because they can enable direct and reversible conversion between heat and electricity. A new study advances this promise by redesigning polycrystalline tin selenide (SnSe), which is easier to manufacture than fragile single crystals but has historically shown limited room-temperature thermoelectric performance.

Thermoelectric technology relies on the Seebeck and Peltier effects, which enable the direct interconversion of heat and electricity. The conversion efficiency of a thermoelectric material is determined by the dimensionless figure of merit ZT , defined as $ZT = (S^2 \sigma / k) T$, where S , σ , k , and T represent the Seebeck coefficient, electrical conductivity, thermal conductivity, and temperature in kelvin. However, these thermoelectric parameters are strongly coupled with each other as a result of their mutual dependence on the dynamic carrier concentration n , which is usually limiting for thermoelectric optimization. Crystalline SnSe exhibits excellent thermoelectric potential, but its long fabrication cycle. Polycrystalline SnSe is more scalable, yet grain-boundary scattering and oxidation have restricted its performance. Given these challenges, further research on high-performance polycrystalline SnSe for cooling and power-generation applications is urgently needed.

In a study published in Originality, a research team led by Li-Dong Zhao from Beihang University reported "High-performance thermoelectric power generation and cooling realized in cubic polycrystalline SnSe" (<https://doi.org/10.1016/j.orig.2026.05.001>). The study addresses an important issue in SnSe thermoelectrics: How to achieve high device-level conversion efficiency and reliable device operation in polycrystalline SnSe. The team developed a non-equivalent



isoelectronic co-doping strategy using Pb and Ge at cation sites in polycrystalline SnSe with cubic structure, achieving excellent near-room-temperature thermoelectric performance as well as outstanding power-generation and cooling performance.

The key advance lies in a defect-engineering strategy that turns atomic-scale defects into beneficial features for performance enhancement. In cubic polycrystalline SnSe, substitutional doping with lead (Pb) and germanium (Ge) disrupts the cation balance and generates abundant cation vacancies. These vacancies further coalesce into micro-and nanoscale defect regions, forming hierarchical phonon-scattering centers that suppress phonon transport and reduce lattice thermal conductivity. Simultaneously, Pb/Ge co-doping reshapes the valence-band structure, increases band divergence, lowers the effective mass, and enhances carrier mobility by nearly fourfold. As a result, the cubic SnSe achieved a room-temperature ZT of ~ 0.5 and an average ZT (ZT_{ave}) of ~ 0.9 from 300 to 673 K. When paired with n-type bismuth telluride selenide ($Bi_2(Te,Se)_3$) in a full thermoelectric device, the optimized p-type cubic SnSe polycrystal delivered a maximum cooling temperature difference (ΔT_{max}) of ~ 47.3 K and a maximum conversion efficiency (η_{max}) of $\sim 4.6\%$. Moreover, the cubic polycrystalline SnSe exhibits isotropic transport behavior and higher hardness than pristine polycrystalline SnSe, which could make it easier to cut, polish, assemble, and integrate into thermoelectric devices.

These findings provide a new materials basis for near-room-temperature thermoelectric cooling and waste-heat power generation, and are expected to meet the needs of industrial equipment, electronic devices, and compact thermal-management systems for localized cooling, precise temperature control, and waste-heat recovery. Meanwhile, the study also shows that the synergistic design of band engineering and vacancy manipulation may offer new insights for polycrystalline thermoelectric materials to overcome the traditional trade-off between thermoelectric performance and mechanical durability.

References

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Lucy Wang

BioDesign Research

[email us here](#)

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