Non-toxic earth-abundant copper sulfide thermoelectric materials

With the support by the National Natural Science Foundation of China, Prof. Chen Lidong and Shi Xun's laboratory at the State Key Laboratory of High Performance Ceramics and Superfine Microstructure, Shanghai Institute of Ceramics, Chinese Academy of Sciences, reported high thermoelectric performance in non-toxic earth-abundant $Cu_{2-x}S$ ($x<0.05$), wich was published in *Advanced Materials* (2014, 26: 3974—3978).

Thermoelectric materials can directly realize green electricity under a large temperature gradiant. Industrial application requires large-scale low cost, environmentally benign, and non-toxic high performance thermoelectric materials. However, current state-of-the-art thermoelectric materials are usually composed of expensive, scarce, or toxic heavy elements such as Pb, Te, Bi, Ge, Co, Sb, etc. Sulfide is one of the most interesting candidates. Along the concept of 'phonon-liquid electron-crystal', copper suflide ($Cu_{2-x}S$) has been found to possess abnormal electrical and thermal transport properties. The strucutre of $Cu_{2-x}S$ has two sublattices: one rigid sulfide sublattice and one liquid-like copper sublattice. This quite special configuration ensures the smooth electron transfer in rigid sublattices; meanwhile, heat phonons are strongly scattered by liquid-like copper ions. In addtion, the liquid sublattice also strongly diminishes heat capacity of lattice vibrations to below the Dulong-Petit value due to the extraordinarily damped transverse phonons. Overall, the extremely low thermal conductivity in copper sulfides gives them the advantage to acquire ultrahigh thermoelectric performance. Copper sulfides are expected to attract great attention within the waste heat recovery industry for their unique combination of elements that are low-cost, non-toxic, and earth-abundant.

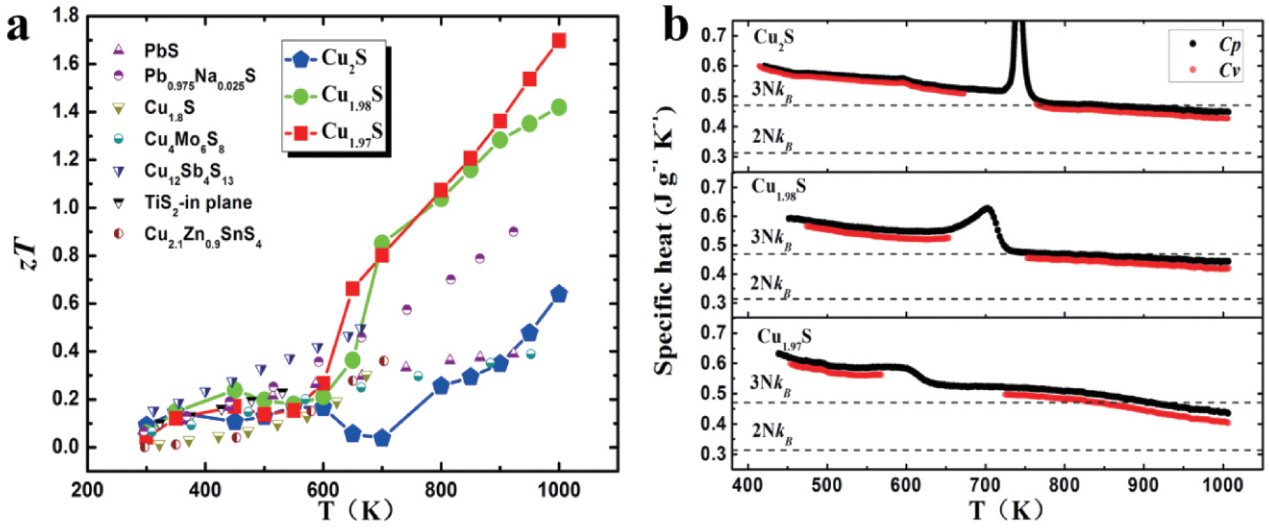

Figure Thermoelectric performance of copper sulfide and its liquid-like specific heat. a, Temperature dependence of the dimensionless thermoelectric figure of merit (zT) of $Cu_{2-x}S$ and other sulfide compounds taken from the references. b, Temperature dependence of heat capacity of $Cu_{2-x}S$ at constant pressure (C_p) and volume (C_V) between 450 and 1000 K.