Application of Tetrahedrite and Magnesium Silicide in a Novel Thermoelectric Unicouple to Generate Electricity from Industrial Waste Heat

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Thermoelectric (TE) generators are devices that use a temperature gradient to generate electricity (Seebeck Effect). Widespread usage of TEGs is limited due to high material costs. In this research, a novel TE material combination was explored to reduce costs for industrial waste heat recovery. Tetrahedrite, a naturally occurring p-type mineral, has been found with a zT (TE figure of merit) of 0.95 at 720 Kelvin; to this day, its complementary n-type compound has not been realized. Magnesium Silicide, a non-toxic n-type compound that exhibits a zT of 1.3 at 750 Kelvin, was found to be compatible with tetrahedrite. A unicouple composed of one n-type $Mg_2(Si_{0.4}Sn_{0.6})$ leg and one p-type $Cu_{11.5}Ni_{0.5}Sb_4S_{13}$ leg was fabricated by performing chemical-mechanical planarization to reduce topography of the legs, metallizing the TE materials with SEM gold sputtering, and insulating the system with Al_2O_3 ceramic substrates. Procedures to test this unicouple included exposing it to temperatures ranging from 350-750 Kelvin, measuring the temperature difference using a thermocouple, and collecting data about its voltage, resistance, and amperage to draw conclusions about its overall efficiency. Results show that this novel unicouple can generate up to 140 mV, which is comparable to state-of-the-art Bi_2Te_3 unicouples, for a bulk material cost that is 60 times lower. Power output was calculated to be 1.3 W for a 120-couple module operating at ~700 Kelvin. Theoretical calculations also indicate superior performance to commercial TEGs, with a maximum efficiency of 16%. This design paves way for a new sector of research using TE junctions with dissimilar materials and presents opportunities for increased efficiency in automobiles, industrial factories, and coal power plants.

Awards Won:

First Award of $5,000

Intel ISEF Best of Category Award of $5,000