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Vinothkumar Lourdhusamy, Immanuel Paulraj and Chia-Jyi Liu*

Department of Physics, National Changhua University of Education, Changhua 500, Taiwan

High-Performance Thermoelectric Generators Utilizing Nanostructured Cu2Se0.96Te0.04-xIx/Cu2O Composites: An Investigation of Output Characteristics for Waste Heat Conversion

Abstract: A thermoelectric power generator (TEG) converts waste heat into electricity. In this study, we synthesized polycrystalline nanostructured $Cu_2Se_{0.96}Te_{0.04-x}I_x/Cu_2O$ composites (where x = 0, 0.01, 0.02, and 0.03) using an energy-efficient synthesis method conducted at room temperature. The $Cu_2Se_{0.96}Te_{0.02}I_{0.02}/Cu_2O$ and $Cu_2Se_{0.96}Te_{0.04}/Cu_2O$ composites showed promising thermoelectric performance, with zT values of 0.33 and 0.48, respectively, at 550 K. The temperature-dependent behavior of zT for both the p-leg and n-leg components of the TEG device was also calculated. To evaluate the practical performance of these materials, a TEG was fabricated using six pairs of p-type $Cu_2Se_{0.96}Te_{0.02}I_{0.02}/Cu_2O$ and n-type $InSb_{0.94}Bi_{0.06}$ modules. The current-voltage (I-V) characteristics of the TEG revealed a linear relationship between voltage and current, with the voltage increasing as the temperature difference (ΔT) increased. The maximum output voltage was measured as 0.115 V at ΔT = 120 K. Additionally, the effect of load resistance on output voltage was examined, showing that the output voltage increased with ΔT. The electrical output power of the TEG was measured as a function of output current, and the maximum power output was calculated using the equation 1:

$$P_{max} = \frac{E^2 R_{Load}}{(R_{internal} + R_{Load})^2}$$

where E is the output voltage, RLoad is the load resistance, and Rinternal is the internal resistance. The results showed that maximum power was obtained when the internal resistance matched the load resistance. The power output increased from 0.0081 μW at ΔT = 5 K to 10.64 μW at ΔT = 120 K. The TEG's performance was measured using a specialized setup that allowed precise control over temperature gradients and load resistance, providing detailed data for optimizing future thermoelectric devices. These findings emphasize the importance of resistance matching to enhance TEG efficiency.

Keywords: Thermoelectric Generator; Composites; Temperature difference; Power density

Biography: Dr. Vinothkumar Lourdhusamy is a physicist specializing in thermoelectric materials, with a focus on energy-efficient technologies for waste heat harvesting. He holds a Ph.D. in Physics from National Changhua University of Education, Taiwan, and an M.Sc. from Karunya University, India. His research aims to enhance thermoelectric properties for power generation, with several high-impact publications in top journals like ACS, JALCOM, and CEJ. A member of the Phi Tau Phi Honor Society, Dr. Vinothkumar has gained teaching experience and regularly participates in international conferences, demonstrating his commitment to advancing physics and sustainable energy solutions.

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