Efficient, stable thermoelectric module based on high-performance liquid-like materials

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Based on high-performance liquid-like materials, scientists from the Shanghai Institute of Ceramics of the Chinese Academy of Sciences and Northwestern University in the U.S. fabricated a $Cu_2Se/Yb_{0.3}Co_4Sb_{12}$

thermoelectric module with eight n-type Ni/Ti/$Yb_{0.3}Co_4Sb_{12}$ legs and eight p-type Ni/Mo/Cu_2Se legs.

Their strategy goes beyond the normal design of TE modules based on traditional TE materials, thus realizing a high energy conversion efficiency of 9.1 percent and excellent service stability. The study was published in *Joule*.

The usual design of thermoelectric modules based on traditional materials only needs to realize high efficiency or high-power output through optimizing the geometry and interfaces of material legs. However, liquid-like ions present a new challenge and service stability must be included in the design of thermoelectric modules based on liquid-like materials.

During service, the voltage across liquid-like materials (V_a) is directly related to the ratio of the cross-sectional areas of the p- and n-legs (A_p/A_n). If the liquid-like material is p-type, the larger A_p/A_n will lead to a smaller V_a and consequently better stability during service.

In this study, scientists developed two kinds of TE modules based on liquid-like materials. They chose Cu_2Se and $Cu_{1.97}S$ for the p-type legs and selected $Yb_{0.3}Co_4Sb_{12}$-filled skutterudite for the n-type legs. The results showed that the $Cu_{1.97}S/Yb_{0.3}Co_4Sb_{12}$ TE module is not stable during service, while the $Cu_2Se/Yb_{0.3}Co_4Sb_{12}$ TE module is quite stable when A_p/A_n is higher than four.

Three-dimensional numerical analysis showed that high energy conversion efficiency requires that A_p/A_n be between two and eight. Thus, A_p/A_n values between four and eight are required to simultaneously maximize conversion efficiency and achieve good stability.

The scientists realized a maximum energy conversion efficiency of 9.1

percent for the $Cu_2Se/Yb_{0.3}Co_4Sb_{12}$ thermoelectric module, a record-high energy conversion efficiency among high-temperature thermoelectric modules. The long-term aging test confirmed the good stability of the module.

This strategy can also be used to design new TE modules based on other liquid-like materials such as Ag_9GaSe_6 and Zn_4Sb_3.

Thermoelectric technology can realize direct conversion between heat and electricity. Due to the advantages of no noise, no moving parts, and high reliability, it has attracted great attention as an alternative way to very efficiently utilize energy.

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