

Expansion Compression Contacts for Thermoelectric Legs

Ordinarily regarded as disadvantageous, thermal-expansion mismatch would be turned to advantage.

NASA's Jet Propulsion Laboratory, Pasadena, California

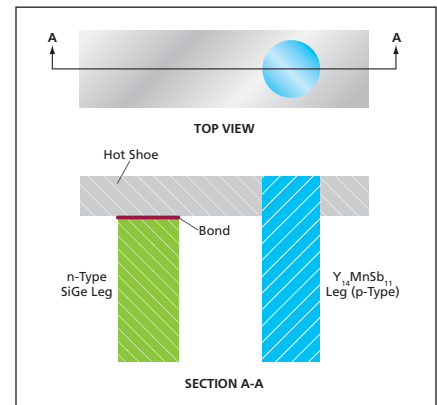
In a proposed alternative to previous approaches to making hot-shoe contacts to the legs of thermoelectric devices, one relies on differential thermal expansion to increase contact pressures for the purpose of reducing the electrical resistances of contacts as temperatures increase. The proposed approach is particularly applicable to thermoelectric devices containing p-type (positive-charge-carrier) legs made of a Zintl compound (specifically, $\text{Yb}_{14}\text{MnSb}_{11}$) and n-type (negative-charge-carrier) legs made of SiGe.

This combination of thermoelectric materials has been selected for further development, primarily on the basis of projected thermoelectric performance. However, it is problematic to integrate, into a practical thermoelectric device, legs made of these materials along with a metal or semiconductor hot shoe that is required to be in thermal and electrical contact with the legs. This is partly because of the thermal-expansion mismatch of these materials: The coefficient of thermal expansion (CTE) of SiGe is $4.5 \times 10^{-6} \text{ }^\circ\text{C}^{-1}$, while the CTE of $\text{Yb}_{14}\text{MnSb}_{11}$ is $20 \times 10^{-6} \text{ }^\circ\text{C}^{-1}$. Simply joining a $\text{Yb}_{14}\text{MnSb}_{11}$ and a SiGe leg to a common hot shoe could be expected to result in significant thermal stresses in either or both legs during operation.

Heretofore, such thermal stresses have been regarded as disadvantageous. In the proposed approach, stresses resulting from the CTE mismatch would be turned to advantage.

The figure depicts a thermoelectric unicouple according to the proposed approach. By use of established techniques, the n-type SiGe leg would be bonded to the hot shoe, which would be made of Si, Mo, or graphite. However, the $\text{Yb}_{14}\text{MnSb}_{11}$ leg would not be bonded to the hot shoe: instead, the $\text{Yb}_{14}\text{MnSb}_{11}$ leg would be inserted in a precisely fit hole in the hot shoe. The precision of the fit would be such that upon assembly at room temperature, the contact pressure between the hot shoe and the $\text{Yb}_{14}\text{MnSb}_{11}$ leg would be low. During heating up to a hot-shoe operating temperature of $1,000 \text{ }^\circ\text{C}$, the thermal expansion of the $\text{Yb}_{14}\text{MnSb}_{11}$ leg would exceed that of the hole by an amount that would increase the contact pressure to $>100 \text{ MPa}$. This pressure would suffice to keep the thermal and electrical contact resistances acceptably low.

Optionally, if the hot shoe were made of Si or Mo, the contact resistances could be made even lower by adding a thin, reactive layer of a metal at the in-



A Thermoelectric Unicouple as proposed would utilize thermal-expansion mismatch to obtain high contact pressure between the hot shoe and the $\text{Yb}_{14}\text{MnSb}_{11}$ leg.

terface between the $\text{Yb}_{14}\text{MnSb}_{11}$ leg and the hot shoe. Another option would be to taper the hole and the mating portion of the $\text{Yb}_{14}\text{MnSb}_{11}$ leg and to press-fit the leg and the hot shoe together at room temperature, thereby providing for maintenance of at least some pressure and prevention of separation during thermal cycling.

This work was done by Jeffrey Sakamoto of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-44896