Materials

Vaporizable Scaffolds for Fabricating Thermoelectric Modules

Thermoelectric legs would be separated by precise gaps.

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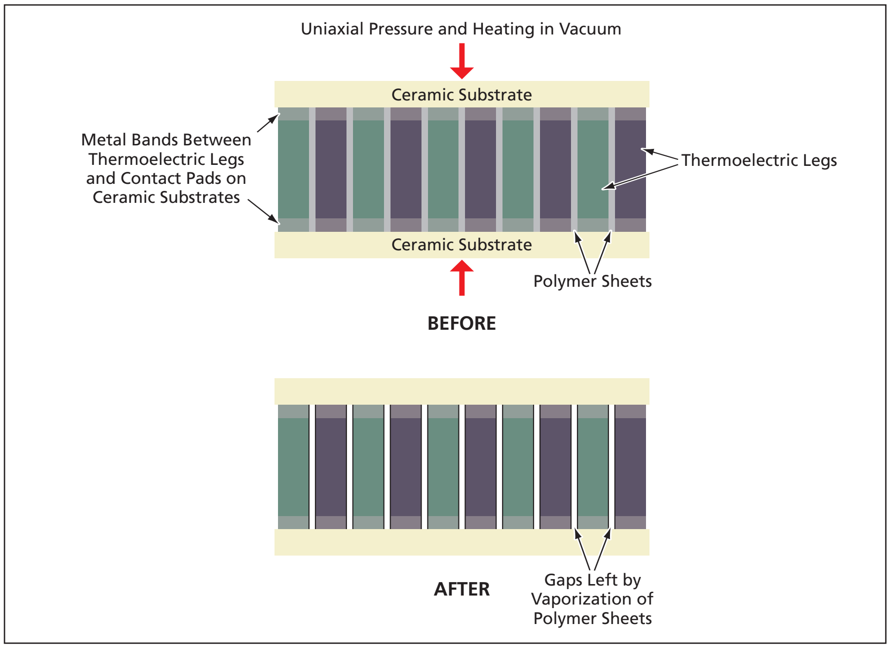
A process for fabricating thermoelectric modules with vacuum gaps separating the thermoelectric legs has been conceived, and the feasibility of some essential parts of the process has been demonstrated. The vacuum gaps are needed to electrically insulate the legs from each other. The process involves the use of scaffolding in the form of sheets of a polymer to temporarily separate the legs by the desired distance, which is typically about 0.5 mm. During a bonding subprocess that would take place in a partial vacuum at an elevated temperature, the polymer would be vaporized, thereby creating the vacuum gaps. If desired, the gaps could later be filled with an aerogel for thermal insulation and to suppress sublimation of thermoelectric material, as described in "Aerogels for Thermal Insulation of Thermoelectric Devices" (NPO-40630), *NASA Tech Briefs*, Vol. 30, No. 7 (July, 2006), page 50.

A simple thermoelectric module would typically include thermoelectric legs stacked perpendicularly between metal contact pads on two ceramic substrates (see figure). As the design of the thermoelectric module and the fabrication process are now envisioned, the metal contact pads on the ceramic substrates would be coated with a suitable bonding metal (most likely, titanium), and the thermoelectric legs would be terminated in a possibly different bonding metal (most likely, molybdenum). Prior to stacking of the thermoelectric pads between the metal pads on the ceramic substrates, the polymer sheets would be bonded to the appropriate sides of the thermoelectric legs. After stacking, the resulting sandwich structure would be subjected to uniaxial pressure during heating in a partial vacuum to a temperature greater than 700 °C. The heating would bond the metal pads on the legs to the metal pads on the substrates and would vaporize the polymer sheets. The uniaxial pressure would hold the legs in place until bonding and vaporization were complete.



A **Single Thermoelectric Module** containing a small number of legs is shown here for simplicity to facilitate understanding of the process described in the text. In an economically practical version of the process, multiple modules would be stacked in a more-complex, checkerboardlike arrangement during bonding and vaporization of the polymer sheets.

Ideally, the polymer chosen for use in this process should be sufficiently rigid to enforce dimensional stability of the gaps and should vaporize at a temperature low enough that it does not undergo pyrolysis. (Pyrolysis would create an undesired electrically conductive carbonaceous residue.) Poly(α-methylstyrene) [PAMS] has been selected as a promising candidate. PAMS is considered to be rigid, and, in a partial vacuum of 10^{-6} torr (≈1.3×10^{-4} Pa), it vaporizes in the temperature range of 250 to 400 °C, without pyrolizing.

Initially, the primary concern raised by vaporization of polymer scaffolding was that polymer-vapor residue might interfere with the bonding of the thermoelectric legs to the metal pads on the ceramic substrates. In an experiment to investigate the likelihood of such interference, a mockup comprising two molybdenum legs separated by a PAMS sheet in contact with a titanium plate was placed under uniaxial pressure and heated to a temperature of 950 °C in a partial vacuum of 10^{-6} torr. Strong, uniform bonds were made between the molybdenum legs and the titanium plate, demonstrating that the PAMS vapor did not interfere with bonding.

This work was done by Jeffrey Sakamoto, Shiao-pin Yen, Jean-Pierre Fleurial, and Jong-Ah Paik of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

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