



## Mo/Ti Diffusion Bonding for Making Thermoelectric Devices

Bonds are mechanically and chemically stable at operating temperatures near 700 °C.

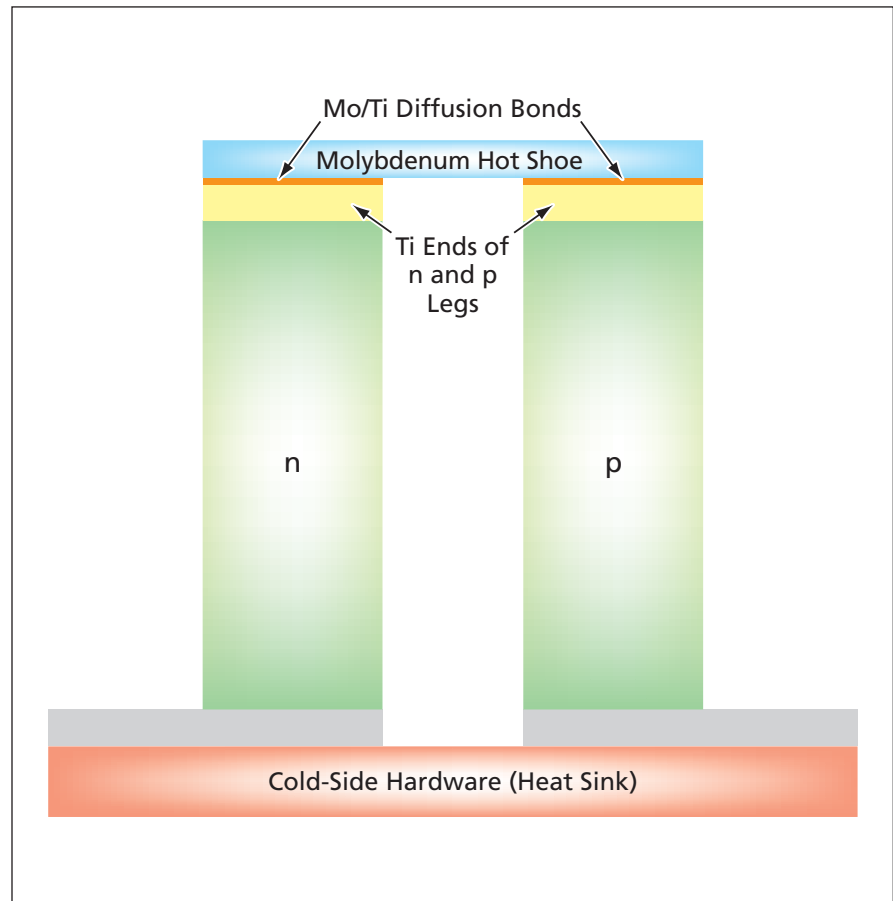
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An all-solid-state diffusion bonding process that exploits the eutectoid reaction between molybdenum and titanium has been developed for use in fabricating thermoelectric devices based on skutterudite compounds. In essence, the process is one of heating a flat piece of pure titanium in contact with a flat piece of pure molybdenum to a temperature of about 700 °C while pushing the pieces together with a slight pressure [a few psi (of the order of 10 kPa)]. The process exploits the energy of mixing of these two metals to form a strong bond between them. These two metals were selected partly because the bonds formed between them are free of brittle intermetallic phases and are mechanically and chemically stable at high temperatures.

The process is a solution of the problem of bonding hot-side metallic interconnections (denoted “hot shoes” in thermoelectric jargon) to titanium-terminated skutterudite n and p legs during the course of fabrication of a unicouple, which is the basic unit cell of a thermoelectric device (see figure). The hot-side operating temperature required for a skutterudite thermoelectric device is 700 °C. This temperature precludes the use of brazing to attach the hot shoe; because brazing compounds melt at lower temperatures, the hot shoe would become detached during operation. Moreover, the decomposition temperature of one of the skutterudite compounds is 762 °C; this places an upper limit on the temperature used in bonding the hot shoe.

Molybdenum was selected as the interconnection metal because the eutectoid reaction between it and the titanium at the ends of the p and n legs has characteristics that are well suited for this application. In addition to being suitable for use in the present bonding process, molybdenum has high electrical and thermal conductivity and excellent thermal stability — characteristics that are desired for hot shoes of thermoelectric devices.

The process takes advantage of the chemical potential energy of mixing be-



A **Molybdenum Hot Shoe** is bonded to the titanium tips of the p and n skutterudite legs of a thermoelectric unicouple.

tween molybdenum and titanium. These metals have a strong affinity for each other. They are almost completely soluble in each other and remain in the solid state at temperatures above the eutectoid temperature of 695 °C. As a result, bonds formed by interdiffusion of molybdenum and titanium are mechanically stable at and well above the original bonding temperature of about 700 °C. Inasmuch as the bonds are made at approximately the operating temperature, thermomechanical stresses associated with differences in thermal expansion are minimized.

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