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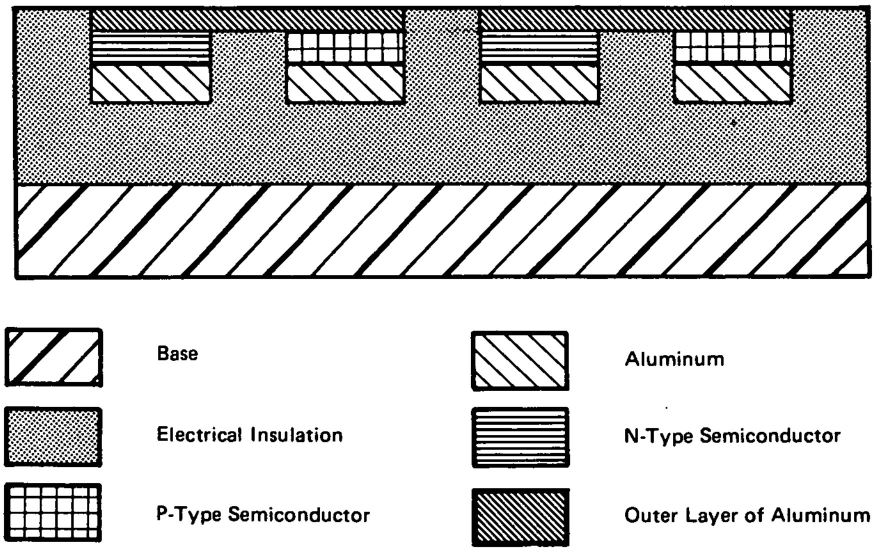
Thin Film Thermoelectric Devices as Thermal Control Coatings: A Study



Thin-Film Thermoelectric Device

The problem:

Thermal control coatings are used to control the heat absorbed or reflected by a surface. They help regulate the temperature of spacecraft cabins, but may also be useful in other enclosures in extreme temperature environments, or as heat shields. Most thermal control coatings are passive and are chosen for their reflectance or absorbance, which cannot be controlled. Passive coatings are also subject to degradation by radiation and contamination.

The solution:

A thin film of thermoelectric devices is not easily degraded and can be used to vary the heat absorbed by a surface.

How it's done:

Thermoelectric devices are constructed by connecting n- and p-type semiconductor bar materials through a good electrical conductor to form a single heat transfer element (see figure). These elements may be connected in series or parallel based upon the desired electrical and heat transfer factors, with the circuit ends in contact with the electrical energy source. As current flows through the entire device, the metal conductors will either heat or cool, depending upon the direction of the current flow. In addition, if the opposite metal ends of thermoelectric devices are exposed to a temperature gradient, current will flow from one semiconductor bar through an external circuit into a second bar, and the circuit will act as a generator.

These phenomena are the result of the interaction of three thermoelectric parameters: the Peltier effect which states that as current is driven across the junction of two metals, the contact either heats or cools depending upon the direction of current flow; the Thomson effect which states that when different parts of the

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same metallic conductor are maintained at different temperatures, a potential difference may be observed in the conductor; and the Seebeck effect which states that if two wires of dissimilar metal are joined at their ends, and these ends are maintained at different temperatures, a current may be observed in the wires of the circuit. These effects are utilized in the design of a thermal control coating that serves as a versatile means for controlling the heat absorbed and radiated by a surface.

Selection of the semiconductor materials to be used is based upon a term called "figure of merit". It is related to the thermoelectric power, conductivity, and resistivity of the material. Based upon present-day technology, it appears that bismuth telluride (Bi_2Te_3) compounds, when suitably doped, offer the maximum "figure of merit".

The optimal ratio of n- to p-type semiconductor and film thickness can be calculated. The proper choice has a significant effect on the efficiency of the coating. The coating could be deposited on a mechanically attachable surface or directly on a metal surface. Two forms of deposition are discussed briefly: (1) the flash evaporation method in which individual grains of semiconductor material are sublimated, and (2) the close-spaced method which employs a chemical transport agent.

Notes:

1. The following documentation may be obtained from:
   National Technical Information Service
   Springfield, Virginia 22151
   Single document price $3.00
   (or microfiche $0.95)

   Reference: TMX-64570 (N71-19733) "The Application of Thermoelectric Devices as Spacecraft Thermal Control Coatings"
2. Technical questions may be directed to:
   Technology Utilization Officer
   Marshall Space Flight Center
   Code A&PS-TU
   Marshall Space Flight Center, Alabama 35812
   Reference: B73-10153

Patent status:

NASA has decided not to apply for a patent.

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