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This Quarterly report describes the techniques used to measure the thermal coefficient of expansion and the emissivity of Cadmium Telluride. It presents some results found using these techniques. The report also describes a gradient layer calorimeter that will be used to measure the specific heat of semiconductor materials at high temperatures.

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PERIOD: JUNE 10 TO SEPTEMBER 10, 1983

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I. INTRODUCTION

Geoscience has been contracted to measure some of the thermal properties of certain semiconductor materials. The semiconductors involved include mercury telluride, cadmium telluride and gallium arsenide. The properties to be measured are: 1) thermal conductivity, 2) specific heat, 3) expansion coefficient, 4) heat of fusion and 5) emissivity. These properties are to be measured over a range of environmental conditions.

This Quarterly report presents expansion coefficient and emissivity measurements that were made on cadmium telluride during this period. Also discussed are additional measurement efforts which are currently underway.

II. CURRENT PROPERTY MEASUREMENTS ON CADMIUM TELLURIDE

During this period the thermal coefficient of expansion and the gray body emissivity for CdTe were measured. It would have been possible to make property measurements for other semiconductor materials if samples had been available (Geoscience has been having difficulty in procuring test materials from industry).

A. Thermal Coefficient of Expansion

The thermal expansion coefficient was measured using a quartz dilatometer as outlined in the previous Quarterly report (GLM-322). Data were taken from room temperature to about 410°F. In this temperature range, the expansion coefficient was found to be 1.09 x 10^{-6} in/in°F (1.96 m/mK). The expansion observed over this temperature range was linear.

B. Gray Body Emissivity

Several measurements have been made of the gray body emissivity of a 2" x 2" x 1/4" slab of CdTe. An alternate method of measuring this parameter than proposed previously was utilized in this instance as only one test sample was successfully prepared. The emissivity method described in the last Quarterly report required two test slabs whereas the current method to be described below requires only a single slab.

The slab of CdTe (containing a laterally drilled thermocouple hole to the center) was positioned on top of a calibrated heat flux sensor which in turn was located on a surface heater that generated the heat flux flowing through the system (see Figure 1). This matrix was also insulated thermally at the sides and the bottom.

The steady state heat loss from the surface of the CdTe test sample is composed of natural convection to the surrounding air and thermal radiation to the surrounding environment. It is noted in Figure 1 that the environmental radiant temperature is in essence defined by a mean surface temperature of a horizontal panel spaced some distance above the test apparatus. The equation describing the energy exchange is,

$$\frac{q}{A} = h_{cv}\left(t_s - t_a\right) + h_{r_p}\,\epsilon\left(t_s - t_{mr}\right) \qquad (1)$$

where,

$\frac{q}{A}$, total heat flux from test surface

h_{cv} , natural convection conductance of surface

t_s , surface temperature

t_a , ambient air temperature

h_{r_p} , Planckian radiation conductance of surface

ϵ , gray body emissivity

t_{mr} , mean radiant temperature

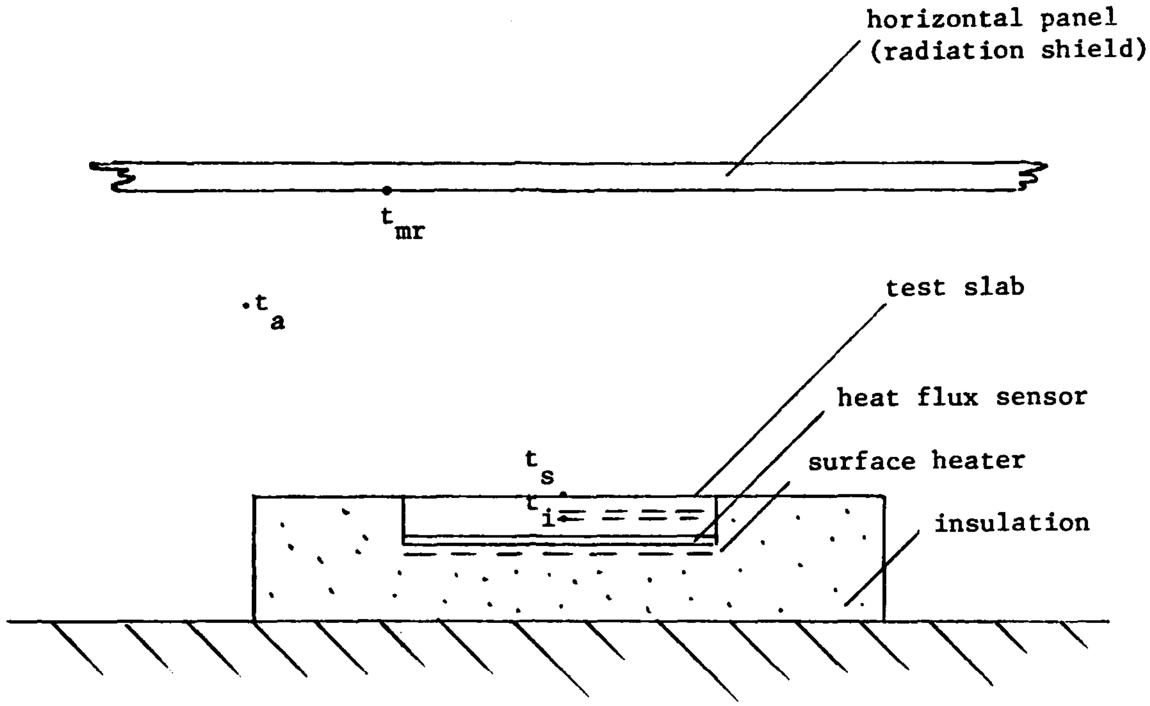

Figure 1. Schematic diagram showing the single slab emissivity test system.

Although one can predict the convective conductance, h_{cv}, from fundamental natural convection theory, the accuracy is probably no better than about 10 - 15 percent for the specific geometry involved; therefore, it is best to determine the convective conductance by experiment, as follows. First use a test sample that has a Planckian surface, (or one that has a known, high emissivity). Under these conditions, the convective heat loss can be determined by subtracting the known radiation heat loss for the Planckian surface for the surface and mean radiant temperatures involved from the total heat loss through the circuit (as determined by the heat flux sensor); thus, the convective conductance is established.

The emissivity of the CdTe sample can then be determined for the same surface temperature, air and mean radiant temperatures so that the convective conductance (which is dependent on these temperatures) will have the same value as in the Planckian test. The resulting gray body emissivity (based on three separate measurements) was 0.79 over the temperature range of 120 to 200°F.

III. HIGH TEMPERATURE GRADIENT LAYER CALORIMETER

A gradient layer calorimeter having the inside dimensions, 1" diameter by 3" long, was designed and fabricated for use at higher temperatures than the one that was previously used at Geoscience to make the specific heat measurements. This new calorimeter, shown in Figure 2 with a test capsule, can also be used to measure heats of fusion for materials whose melting temperatures lie below 1500°F (in addition to specific heat determinations of semiconductor materials in the high temperature region). The calorimeter is constructed of mullite and the thermoelectric materials are Chromel-Alumel.

The calorimeter is calibrated by placing a small electric heater inside the device; upon dividing the measured electric heat generated by the generated millivolt output of the calorimeter thermopile at steady state, the calibration constant for the device is established.

Some specific heat runs using this calorimeter have been made on both CdTe and copper. As an accurate calibration for the calorimeter has not yet been obtained (because of a calibration heater problem), the preliminary specific heat results (which fall in reasonable ranges) are only approximate at this time.

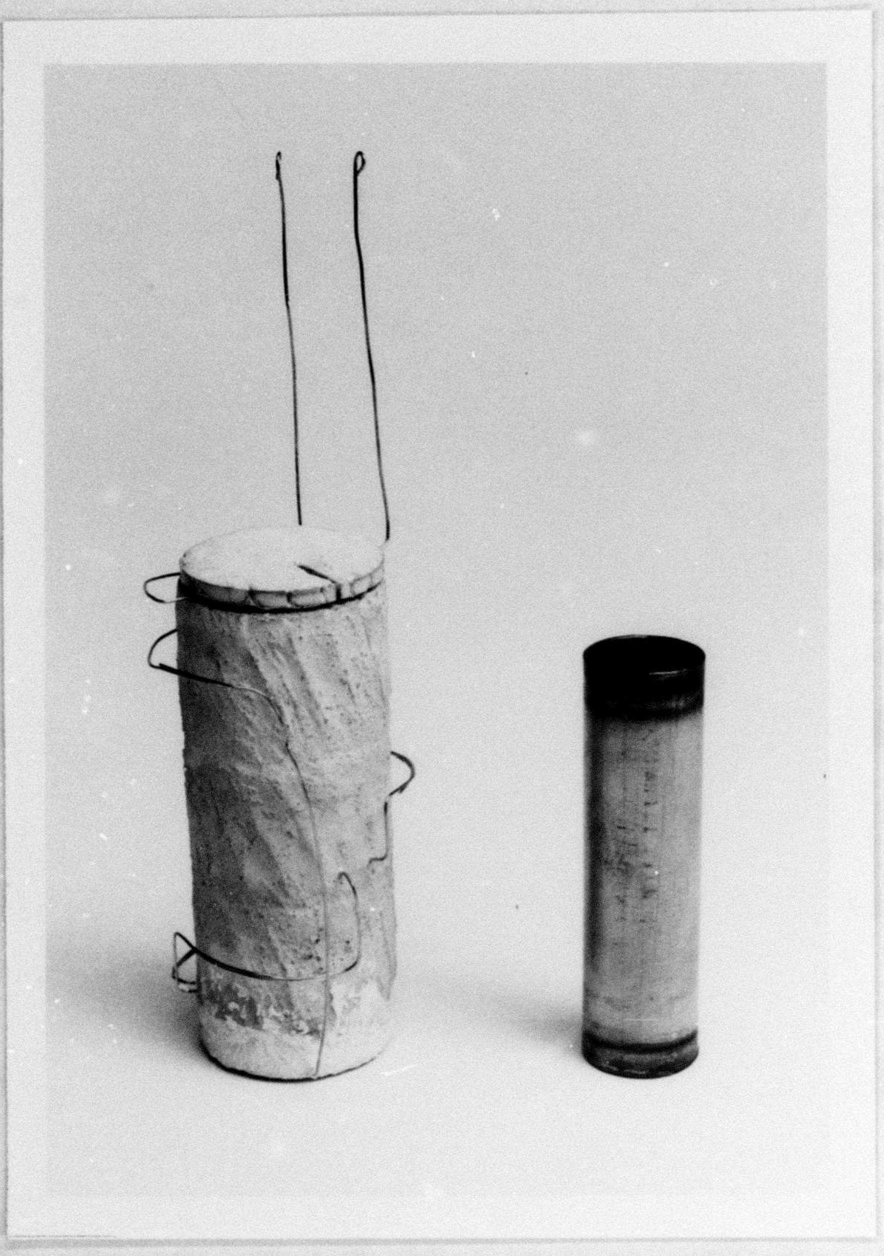

Figure 2. Photograph of the high temperature calorimeter and a test capsule.

IV. WORK CURRENTLY IN PROCESS

The three main efforts currently being pursued relate to 1) the procurement of additional semiconductor materials for measurement, 2) further work on the high temperature calorimeter and 3) high temperature emissivity measurement.

Attempts are being made to procure both mercury telluride and gallium arsenide materials to make property measurements.

The high temperature calorimeter is undergoing further calibration and modification so that high temperature specific heats can be determined.

A heater system which has been fabricated, is to be used in a hard vacuum system to measure high temperature emissivities.