DIODE THERMOMETRY IN LABORATORY SCALE TEST FACILITIES

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ABSTRACT

A novel method of using miniature diodes for temperature measurements in laboratory scale test rigs has been developed. This method allows for small sub-millimeter sensors to be used, enabling spatially dense temperature measurements. This diode thermometry method allows for the use of custom printed circuit boards (PCB), simplifying the placement and connection of multiple sensors.

INTRODUCTION

Many laboratory test facilities used for heat transfer measurements require temperature measurements with a high spatial resolution. This can be achieved using techniques such IR or thermochromic liquid crystal thermography. These techniques can provide high resolution but require optical access, which can be a challenge in some facilities requiring mirrors or multiple cameras to view all the features of interest. Thermometry without optical access can be achieved using multiple thermocouples attached to a test article. However, this method requires accurate placement on many thermocouple beads, plus careful lead out of the cables. An alternative method is desirable which does not require optical access and allows for increased spatial resolution over what is practical with individually placed thermocouples.

Silicon diodes have been commonly used as general purpose temperature sensors in cryogenic applications, but can also be used at elevated temperatures, up to 500 K [1]. They can be found in small sub-milliliter packages, with commercial diodes being available at low cost, €0.25 each. The use of diodes over thermocouples removes the requirement for lead out wires to be made of thermocouple alloys and allows for the use of PCB for mounting and connecting the diodes. Custom PCB can be designed with a high spatial density of sensors whilst providing convenient lead out and electrical connection locations. The diodes are electrically and mechanically connected to a PCB using a reflow soldering process. During this process the components are pulled by surface tension into the correct placement, giving accurate spatial location of the sensors onto the PCB. The populated PCB can then be mounted onto an article under test diode side down, meaning no protrusions are present in the flow.

RESULTS AND DISCUSSION

A custom flexible PCB was designed to mount a single commercially available diode. A single diode was used as the first test case to allow for ease of construction and comparison with a thermocouple. The diode package used was 0.6 × 0.6 × 0.4 mm, which was mounted to a flexible polyimide PCB with dimensions 1.6 × 12 × 0.11 mm. The diode and PCB are shown in Figure 1, compared to a commercially available thermocouple made with 0.315 mm (30 SWG) wire and a bead diameter ~0.75 mm. The gold-plated pads are used to connect lead out wires to the PCB.

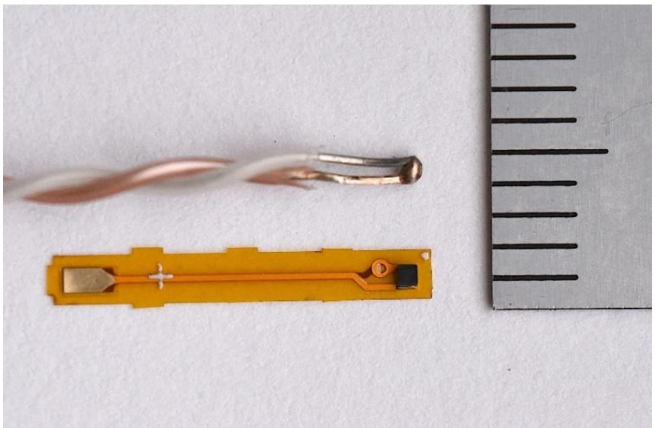

Figure 1. Single diode thermometer (bottom) compared to thermocouple (top), scale is in millimeters

The thermal time constant of the diode thermometer was measured, allowing for a temporal as well as spatial comparison to a thermocouple. The temperature sensitivity of the diode can also be determined, by measuring the diode voltage drop at varying temperatures with a constant supply current. The diode sensitivity should be very linear with a value around -2 mV/K.

The single diode PCB design will then be revised to create a high spatial density PCB, allowing the capability of high-density diode thermometry to be determined.

REFERENCES

[1] Temperature Sensor Selection Guide, Lake Shore Cryotronics
https://www.lakeshore.com/docs/default-source/product-downloads/literature/sensorsflipbook.pdf