BIMETALLIC BUCKLING DISK FOR THERMAL MANAGEMENT OF CHIP SCALE ATOMIC CLOCKS

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We report the first use of a bimetallic buckling disk as a thermal conduction switch. The disk is used to mechanically alter the thermal resistance of the package of a chip scale atomic clock. These bimetallic disks are used extensively in thermal switches to make or break an electrical connection, but not a thermal contact [1]. The switch is necessary to reduce the heating power of the clock, shown in figure 1 [2]. Two components in the clock, a vertical-cavity surface-emitting laser (VCSEL) and a cesium vapor cell, must be maintained at 70$\pm$0.1ºC even under an ambient temperature variation of 0ºC to 50ºC. To reduce heating power, the clock package needs to be well insulated to reach 70ºC by using a small amount of waste heat dissipated from the electronics when the ambient temperature is at 0ºC. However, when the ambient temperature is increased to 50^{o}C, the VCSEL and the Cs cell will overheat. To prevent overheating, a bimetallic disk is used as a passive component to make a mechanical contact and reduce the package's thermal resistance significantly in high temperatures.

The disk is made from two thin layers of dissimilar metals such as invar and brass and formed in to a sight dome shape. The large thermal mismatch between the two layers the disk cause it to deform with temperature change. At a certain temperature (depending on materials and extent of forming) the disk will buckle from convex to concave. This buckling event has been harnessed to make or break a thermal contact with the clock package. For example, when the outside temperature is low the disk will be snapped downward and will not be in contact with the inner package. When the outside temperature is high the disk will be snapped upward making physical contact with the inner portion of the package.

A thermal test vehicle has been developed to characterize a sample package with a bimetallic disk thermal conduction switch. The assembly is made from two FR-4 printed circuit boards with a separation of 900 μm for the thermal switch. To create the switch, between the two boards, a bimetallic snap disk, taken out of an Airpax 5003 thermal switch, is flexibly attached to the bottom board using a 300 μm thick ring of Dow Corning 3-6652 thermally conductive silicone. A 3 mm diameter, 300 μm thick pad of silicone is also attached to the bottom of the top board to create a soft contact pad for the disk. Resistors are attached to the top of the upper board to simulate the thermal properties of the clock's electronics.

The thermal test vehicle has been used to test the power needed to maintain one of the resistors at 69°C while the temperature at the base of the assembly was changed to simulate outside temperature variation. Three cases are presented for the temperature control of: 1) the center resistor in a vacuum package; 2) the center resistor in a regular package filled with air; and 3) the side resistor in a vacuum package. At 38^{o}C, the switch is snapped upward to reduce the thermal resistance. As a result, the heating power needed to maintain the same temperature is increased from 100 to 175 mW for Case 1. Such a significant change of the thermal resistance demonstrates the effectiveness of the novel thermal mechanical switch. However, the switch becomes less effective with air filling the gap, as in Case 2. More interestingly, the switch is not effective at all if the side resistor's temperature is to be controlled. The results of these tests have been verified using a FEA thermal-structural-contact model. According to our knowledge, such a bimetallic disk thermal conduction switch is reported for the first time.

References
[1] "Airpax Series 5003 Thermostat", Copyright 2000 Airpax Corporation, Cambridge, MD.
[2] "Thermal management of chip-scale atomic clock," Alex Laws, Richard Chang, Victor M. Bright and Y. C. Lee, ASME InterPACK, San Francisco, July 18-22, 2005.
Keywords: Bimetallic, Disk, Thermal