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IMPROVED HIGH-CURRENT THIN-FILM MULTIJUNCTION THERMAL CONVERTERS

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Abstract

We report on the fabrication of new thin-film multijunction thermal converters suitable for the measurement of current and new, simpler multiconverter modules that are much easier to manufacture than previous multiconverter modules.

Introduction

The NIST reference standards for ac-dc difference of current are thermoelements (TEs) rated from 2.5 mA to 20 A. For ranges up to 250 mA, the TEs are vacuum enclosures with a single thermocouple attached to the midpoint of a short, relatively straight heater by an insulating bead. The converters rated at 250 mA and above contain temperature compensation, heat sinks attached to the heaters, and low-inductance current-return paths. The highest current units have tubular heaters to reduce skin effect. This construction provides a reasonably low reactance and moderate skin effect. The output emfs of these devices are generally from about 7 mV to 12 mV at their rated input current.

Although traditional TEs in the current range of 250 mA and below have small ac-dc differences which are reasonably independent of frequency, higher current, conventional TEs may exhibit large errors from skin effect in the heater and lack of suitable thermal lagging or compensation. The specially constructed high-current TEs in use at NIST are no longer commercially available and attempts to rebuild failing units have been only partially successful. Current shunts can be used, but they present more problems from stray impedances to ground, thermal drift, and exhibit greater errors from skin effect at 20 kHz and above.

To replace these converters, we reported previously the fabrication of thin-film multijunction thermal converters (FMJTCs) and the assembly of high-current modules containing four or more FMJTCs [1,2]. This paper reports on the fabrication of improved, second generation FMJTCs and on the manufacture of simpler, multiconverter modules. We also present preliminary results for the prototype units.

Fabrication of new high-current FMJTCs

The first generation high-current FMJTCs were generally successful; however, the FMJTCs had time constants of only a few milliseconds resulting in significant ac-dc differences at frequencies below 1 kHz. The new, second generation FMJTCs are fabricated using a Deep Reactive Ion Etching (DRIE) process [3]. This process facilitates the production of an obelisk of silicon beneath the FMJTC heater resulting in an increased time constant and a reduction of low-frequency ac-dc differences by more than an order of magnitude at 10 Hz [3]. In addition, the new FMJTCs can be mounted in evacuated packages, further increasing the time constant as well as the output emf. The first such package has retained its vacuum for about 9 months.

New Multiconverter Modules

The new multiconverter modules are based on a double-sided printed circuit board with the chips symmetrically spaced around a circle. Current enters the board at the center of one face and fans out along radial tracks to the heaters of the FMJTCs. Current returns to the center of the opposite face of the circuit board on tracks immediately under the input leads to form a minimum loop area. The thermocouple outputs are connected by circular tracks having a nearly symmetric return path, again to minimize the loop area. The boards presently in use have provision for eight converters. Figure 1 shows a photograph of a circuit board populated with four converters. Although the module design reported in the previous paper worked satisfactorily from an electrical perspective, it contained many machined parts and was difficult to assemble. Since the design of the new module is based on a mass-produced circuit board, it is much less expensive to make and is readily assembled. In the same manner as the earlier module and a type of coaxial shunt designed at NIST [4], the new module has coaxial input and output connectors to permit insertion in a coaxial line.

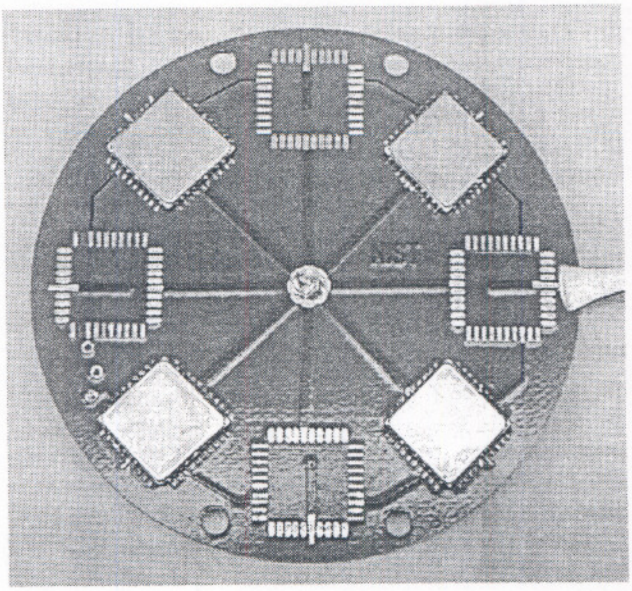

Figure. 1 Photograph of a module circuit board populated with four converters. The packages are 12 mm on a side.

Results and Future Plans

Results of ac-dc difference measurements on four individual FMJTC chips and on the multiconverter module are shown in Table 1. Type A uncertainties are 2 μA/A or less for all these measurements. Uncertainties for the standards are presently undergoing review but are estimated to be 7 μA/A and 24 μA/A for 1 kHz and 100 kHz, respectively, at 50 mA; and 11 μA/A and 32 μA/A for 1 kHz and 100 kHz, respectively, at 200 mA (k=2).

Design and fabrication are underway for the production of these new converters with heaters rated up to 1 A permitting module currents above 5 A with its full complement of eight FMJTCs.

Acknowledgement

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References

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Table 1. Measured ac-dc differences for four FMJTCs with nominally rated 50 mA heaters and a multiconverter module populated with the same four chips.

FMJTC Serial Number	Applied Current mA	Output Emf mV	Ac-dc Difference (μA/A) 20 Hz	1 kHz	20 kHz	50 kHz	100 kHz
56B4	40	23		-8			-13
56B6	40	24	-20	-8	-6	-5	-16
56D2	40	21		-8			-14
56E6	40	26	-19	-8		-5	-15
Module	200	104	-12	-10	-8	-14	-35