MULTILAYER THIN FILM MULTIJUNCTION INTEGRATED MICROPOTENTIOMETERS

FIELD OF THE INVENTION

This invention relates to multilayer, thin film, integrated micropotentiometers (MFI-μpots) suitable for use as primary and secondary calibration standards and for the measurement of ac and RF voltage, with the MFI-μpots used to measure and produce low voltages over a broad frequency range. More particularly, this invention relates to MFI-μpots which offer performance over very broad ranges of frequency, voltage and output-emf, with low ac-dc and RF-dc differences, in a form suitable for low cost mass production for inclusion in a variety of instruments.

BACKGROUND OF THE PRIOR ART

The addition of one or more previously formed resistors in series with the heater element of a thermal converter forms a micropotentiometer. The highest performance thermal converters are multijunction thermal converters (MJTCs).

Micropotentiometers are very precise standards for determining a low voltage output over a wide range of frequencies for ac-dc and RF-dc applications. To meet this need, integrated μpots require physical ruggedness, ability to withstand stresses associated with thermal cycling and in-use exposure to a wide range of temperatures locally, and an error-free structure, e.g., minimization of capacitances or inductances developed between the heater and thermopiles and/or the contact pads.

The best combination for structural elements for forming MJTCs and the output resistors required for the corresponding μpots includes: low stress sandwich-type multifilm membranes; low stress metal films for forming the heater element, thermopiles, contact-pads, and the like; minimization of capacitances between heater and thermopiles or between contact pads by precise definition of form and structure; a coaxial design, use of a relatively thick film nonmagnetic mounting substrate to support a chip containing thinner films constituting the heater element, thermopiles, resistors and contact pads; optional provision of guard thermocouples at both ends of each thermopile; and careful selection of materials so that, for example, the resistance heaters have a very low thermal coefficient of resistance and Thompson effect. The present invention incorporates such features in novel and highly reliable structures.

These and other related objects of this invention are described more fully hereinbelow, as are structural details of the preferred embodiments of this invention and methods of forming the same. Persons of ordinary skill in the art, upon understanding the following disclosure and the accompanying drawing figures may consider implementing obvious modifications and variations of this invention, and the claims appended hereto are intended to comprehend such variations of the explicitly disclosed embodiments.

SUMMARY OF THE INVENTION

A principal object of the present invention is to provide highly compact, low-cost, easy to manufacture, rugged, low stress, micropotentiometers (MFI-μpots) to measure and produce low ac voltages, at frequencies ranging from low audio frequencies to 1 GHz.

Yet another object of this invention is to provide low-cost, highly reliable, mechanically stable, low current MFI-μpots, including either a single or a bifilar or a trifilar heater element on a composite, stress-balanced, thin-film membrane, with low electrical capacitances and inductances between adjacent elements of the structure.

A related further object of this invention is to provide rugged, accurate, low stress multifilm, low-cost, MFI-μpots for precise measurement of low voltages and currents across a broad frequency range extending from low audio frequencies to 1 GHz, comprising thermocouples disposed about a precisely formed heater element electrically insulated therefrom. A related further object of this invention is to provide output resistors on the chip and a method for forming the above-described type MFI-μpot structures to provide the desired precise measurement capabilities.

These and other objects of this invention are realized by providing an integrated micropotentiometer formed on a substrate with a through aperture. A membrane is arranged over the through aperture and comprises a first layer of SiO_2, a second layer of Si_3N_4 and a third layer of SiO_2. A heater element is provided on the membrane over the aperture. A first plurality of serially-connected thin-film thermocouples are formed on one side of the heater and have their hot junctions formed over the aperture and their cold junctions formed over the semiconductor substrate outside of the aperture. A second set of serially-connected thin-film thermocouples is formed on the opposite side of the heater to that of the first plurality. The hot junctions of the second plurality are formed over the aperture and the cold junctions are formed over the semiconductor substrate. A plurality of resistor elements located on the chip are coupled in series at one end of the heater element and at least one possible current return path is arranged parallel to the heater element.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective schematic view of an exemplary integrated MFI-μpot constructed according to the general principles of this invention.

FIG. 2 is a plan view of a first preferred embodiment of a MFI-μpot including a plurality of thin-film resistors which enable a multi-range operation.

FIG. 3 is another embodiment of a MFI-μpot according to this invention, comprising a plurality of thin-film output resistors and electrical contact pads coupled with an outside return current path to provide multi-range operation.

FIG. 4 is yet another embodiment of a MFI-μpot wherein the return current path is disposed between the hot junctions of adjacent thermopiles.

FIG. 5 is yet another embodiment of a MFI-μpot which is a modification of the embodiment illustrated in FIG. 4.

FIG. 6 is a trifilar MFI-μpot provided with a trifilar geometry containing a pair of symmetrically disposed current return paths parallel to a single linear elongate heater element and between the hot junctions of adjacent thermopiles.

FIG. 7 is a transverse cross-sectional view of the MFI-μpot illustrated in FIG. 3 at Section X—X therein.