DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

There are many similarities between the structures for MJTCs and for integrated MFI-μpots formed according to this invention. The principal difference lies in the addition of thin film broadband resistors in series with the heater element to provide either single or multi-range integrated MFI-μpots having operational ranges of between 1 mV to 300 mV. An output voltage from the MFI-μpot is generated by the voltage drop across the resistor or resistors provided in series with the heater. Since the basic structure of the MJTC is thus somewhat simpler than that of a corresponding MFI-μpot, the former will be discussed first.

Experience in the manufacturing of semiconductor devices has led to the development of photolithographic techniques which enable the formation of extremely precise and regular geometries of thin film elements such as the heater elements, thermocouples, resistor elements and contact pads. Such techniques, spanning both thin film and thick film technologies, together with a planar structure for the devices, are found to satisfy the above-stated objects of this invention.

It is noted that the performance of the micropotentiometer will benefit from a low Thompson effect and a low Peltier effect. For this to be accomplished, the Thompson coefficient of the heater material should be small and the thermal couples used as part of the micropotentiometers should be disposed uniformly and symmetrically on opposite sides of the elongated heater element. To reduce the Peltier effect, the contact area between the heater and pads should be on a good heat sink. This is accomplished by placing the cold junctions of the thermocouple over a semiconductor substrate rather than over the aperture in the substrate.

Referring now to FIG. **1**, there is seen in perspective schematic form an assembly comprising the essential elements of an exemplary integrated MFI-μpot structure **100**. Both MJTCs and MFI-μpots according to this invention are formed on a dielectric substrate **102** having a planar upper or front surface **104** on which are to be formed a heater element **106**, pluralities of thermocouples, i.e., thermopiles, **108**, **110**, exemplary resistors **112**, **114**, and exemplary contact pads **116**, **118**, **120** and **122**. The substrate is most conveniently made of silicon or glass. A through opening **126** is formed in the substrate **102**, and has a membrane **124** at surface **104**. The heater element **106** and substantial portions of thermocouples **108** and **110** lie over the through aperture **126** as integrated parts of a multilayer membrane structure, as described below in greater detail.

It should be remembered that the structure illustrated in FIG. **1** is meant to be merely exemplary, i.e., only to facilitate an understanding of the relative dispositions of individual elements, without being limiting in other respects.

A preferred composition of the alloy used to form the heater element, available commercially as Evanohm TM, is as follows:

nickel: 75%
chromium: 20%
aluminum: 2.5%
copper: 2.5%

Other material with small temperature coefficient and Thompson coefficient can also be used. Suitable materials for forming thermocouples are: constantan (Cu and Ni) and chromel (10% Cr and 90% Ni) and many others.

Evanohm TM, constantan, etc. are suitable materials for forming the resistors for the MFI-μpots. Other known materials having suitable electrical resistivity may also be used.

The contact pads are preferably made of a highly conductive metal, e.g., aluminum, copper, or even gold if cost considerations are not limiting.

The materials employed to form the thermocouples, resistors, pads, etc., are preferably applied by sputtering. Other alternatives include evaporation of the selected materials or printing with ink containing the same. Any affordable and reliable known apparatus or technique for forming uniform thin films may be utilized. The preferred structure eventually includes an integrated plurality of films, including dielectric layers formed of materials such as SiO_2 and Si_3N_4, preferably applied by a known technique such as chemical vapor deposition, organic reduction, evaporation, plasma enhanced deposition, or sputtering.

One of the keys to forming the MFI-μpots according to the present invention is to produce low-stress, multilayer films. To do this, initially, a heat sink (not shown) is attached to the back of a silicon wafer **102** to keep it at close to room temperature. Selected materials for the heater element **106**, the thermocouples **108**, **110**, resistors **112**, **114**, assorted insulation layers and the contact pads **116–122** are then applied with the use of masks. If sputtering is used, the sputtering rate is kept low and is adjusted as needed to ensure that the resulting structure will have low residual stresses. Another adjustable parameter in the process of applying the selected layers is the distance between the target, i.e., source of the material to be deposited, and the substrate surface on which the material is to be deposited. The through opening 126 is initially formed by etching the silicon substrate 102 from its rear surface part way through the thickness thereof, with the residual thickness of silicon removed by etching only after the key elements, i.e., the heater element **106**, the thermocouples **108**, **110**, etc., are formed. This leaves a stress-free, stable, multifilm structure stretched over the through opening.

To minimize problems that would otherwise be generated during use of the finished device at the interface between the heated material of the heater element and the silicon surface contacted thereby and regions immediately surrounding the heater, the present invention thus employs a low-stress, multifilm, composite membrane which has both a high thermal efficiency and high mechanical stability. The SiO_3—Si_3N_4—SiO_2 sequence provides lower dielectric loss than Si_3N_4—SiO_2—Si_3N_4, and therefore better electrical performance of the heater, and reduces the risk of surface cracks due to defects: The preferred combination of steps to form the desired structural layers will now be described. Details of the various elements which cooperate to form various embodiments of the MFI-μpots follow.

As generally indicated in FIG. **1**, the heater element **106** is thermally isolated by its location on a thin dielectric membrane **124** which stretches across and over an opening **126** formed in silicon substrate **102**. The hot junctions of each thermopile **108**, **110** are disposed symmetrically in close thermal proximity to heater element **106**. The cold junctions of each of the thermocouples comprised within thermopiles **108**, **110** are, correspondingly, symmetrically disposed to be on a portion of the