Micropotentiometers **1100** and **1200**, in FIGS. **4** and **5** respectively, illustrate other variations of the same basic concept, except that in both of these embodiments the return path is disposed between the hot junctions of their respective thermopiles disposed on opposite sides of the central linear elongate heater. The various corresponding elements are numbered consistently with comparable elements in the various embodiments described earlier in greater detail.

The MFI-μpot **1300**, illustrated in FIG. **6**, differs from those previously described in that it has a symmetry along the axis of the single linear elongate heater element, with two parallel symmetrically disposed current paths between the hot junctions of thermopiles **1308** and **1310**. It should be appreciated that although the electrical resistances are shown in different sizes in the various figures, the figures are themselves not necessarily drawn to scale and the electrical resistance values depend only in part on the physical size of the resistances and also depend on the resistivity of the material employed to form the various output resistors.

For high frequency type micropotentiometers, or those having coaxial or bifilar heating arrangements, contact pads for the heater should be made as small as possible in order to eliminate capacitive current. The contact pads should be in the range of $50 \times 50\ \mu m^2$ to $400 \times 400\ \mu m^2$. These types of micropotentiometers are usually characterized by heaters having a length from 20 μm to 8000 μm, a width of 1 μm to 1200 μm and a length to width ratio of 4 to 800. With high current type micropotentiometers heater contact pad size is not critical. The heater size for such devices typically range between a length of 20 μm to 8000 μm, a width of 10 μm to 6000 μm and a length to width ratio of 0.1 to 10.

FIG. 7 is a cross-sectional view at Section X—X in FIG. **3**. It is provided merely to emphasize that the various resistors are formed as integrated parts of the multilayer membrane structure disposed over the through opening in the dielectric substrate.

In disposing return current paths between the hot junctions of the thermocouples, it must be kept in mind that there are two types of coupling of ac into the thermocouples which are to be avoided. One is capacitive coupling. This can be reduced by careful disposition of the elements, e.g., by disposition of the heater element and the hot junctions over the through opening through the dielectric substrate, whereby the individual capacitances and capacitive coupling can be minimized.

It should also be appreciated that in devices like the MFI-μpots just described, the current return path is essentially at ground potential so that it has a shielding effect to the thermocouples so that there is actually less direct capacitance to the thermocouple.

The other type of coupling in the thermocouples is inductive in nature. To minimize this, for low frequency applications, one may use something like a bifilar or trifilar heater. Note, in particular, that with MFI-μpot **1300** (see FIG. **6**) the return current leaving the heater splits and returns symmetrically between the heater and the adjacent thermopiles so that there is a more even and better cancelling of the inductance and, therefore, less inductive coupling into the thermocouples. The key, to the extent possible, is to ensure that there is comparable reactance (and not just resistance or inductance) of the structure on both sides of the heater element.

In the present invention, because of the highly precise techniques employed, the various geometries can be made very accurately. Thus, for example, one can separate the hot junctions of the thermocouples from the adjacent edge of the heater element by 50 μm exactly, on both sides and all along the heater edges. Furthermore, all the lines corresponding to the various elements and adjacent thermocouples can be made very straight, to a much higher degree than was possible in the prior art with the use of fine wires.

The term "trifilar" may be used for the type of structure illustrated in FIG. **6** for MFI-μpot **1300**, i.e., a structure in which an ac or dc flow through a central heater and flow back in the opposite direction through two symmetrically disposed return paths. Generally, however, the MFI-μpot which has the most ranges on it has just one current path between the hot junctions of the thermopiles, namely through the single linear heater element. Examples of these may be seen in FIGS. 3, 4, and 5.

It should also be appreciated that there is a significant difference between the "potential leads", i.e. the leads for monitoring the voltage across the output resistors, and the "current carrying leads", namely the leads which bring in and take away current to the heater element and resistors. Reactance in the current carrying leads and in the potential leads is critically important to the MFI-μpot performance. Note that in the described structures the interconnecting leads between adjacent output resistors can be made as short as 2 to 200 μm. One cannot produce interconnecting leads like these unless they are actually fabricated as part of the structure, and with precise photolithographic techniques this is relatively easy in accordance with the present invention. The reactance errors due to such interconnecting leads are relatively large in ordinary multi-range μpots which are made from discrete components. However, with the present invention, such reactance errors are virtually eliminated.

In this disclosure, there are shown and described only the preferred embodiments of the invention, but, as aforementioned, it is to be understood that the invention is capable of use in various other combinations and environments and is capable of changes or modifications within the scope of the inventive concept as expressed herein.

What is claimed is:

1. An integrated micropotentiometer, comprising:

a substrate formed of a predetermined thickness of a dielectric material, having a front surface and a rear surface with a through aperture of predetermined shape and size formed therebetween;

a first layer of SiO_2, formed on the front surface of the substrate to extend over the through aperture in the substrate;

a first layer of Si_3N_4, formed on the first layer of SiO_2, to also extend over the through aperture in the substrate;

a second layer of SiO_2, formed on the first layer of Si_3N_4 so as to also extend over the through aperture in the substrate and to provide a mounting surface;

a layer of an electrically resistive material provided on the mounting surface to form a thin elongate heater element having two longitudinal parallel sides and first and second ends, the heater element being shaped and sized to be entirely contained within a periphery of the through aperture in the substrate as defined at the front surface of the substrate in the lateral direction and to extend beyond