to measure temperature in some applications.

Foundry processes that use metals other than aluminum, e.g., tungsten, will allow other metals to be used in the devices of the present invention and will provide micro-hotplates than can operate at much higher temperatures.

For clarity, the wire connections to each of the leads of the micro-hotplates has not been shown. However, in use, the chip supporting one or more micro-hotplates is mounted on a ceramic chip carrier, having conventional connections between the chip and carrier leads accomplished using gold wirebonds.

The size of the initial micro-hotplate that was designed was 200 micrometers on a side. However this initial size is certainly not limiting since it is clear that other sizes could be chosen. In this regard, the present inventors have successfully designed and fabricated similar layouts to produce devices in a range of 50 micrometers to 800 micrometers.

No limitations have yet been encountered which limit the large end size at which a device can be made. However, small devices less than 50 micrometers may not be desirable since good thermal isolation may not be achieved.

Once the device is designed using CAD software, the file can be saved for future use. Since the devices of the present invention are manufactured using standard CMOS processes, conventional circuits can be added for temperature control and sensing and communication according to known techniques. It is noted that other silicon foundry processes are available such as BICMOS, BIPOLAR, etc. and that this methodology is also compatible with those processes.

While the device of the present invention is designed by making use of standard CMOS compatible micromachine processes, CMOS foundries do not currently offer the additional post-fabrication etching step required to form the suspended membrane or microbridge structure of the present invention. Therefore, this step is carried out after the CMOS fabrication process. This method of providing suspended membranes or microbridges has been shown to provide good thermal isolation in other devices (M. Parameswaran et al, "Micromachined Thermal Radiation Emitter from a Commercial CMOS Process", *IEEE Electron Device Letters*, Vol. 12, No. 2 (1991), pages 57–60).

After the designs are fabricated, the completed chips are subjected to a post-fabrication etch procedure to complete the fabrication of the device. In the post-fabrication etch a mixture of ethylenediamine-pyrocatechol-water-pyrazin (EDP, Transene Company) is utilized to form an etch pit **18** (FIG. **6**) beneath at least the central portion **3** of the membrane or microbridge **2**. EDP can be mixed in-house as reported in the literature (Jaeggi et al, "Thermoelectric AC Power Sensor by CMOS Technology", *IEEE Electron Device Letters*, Vol. 13, No. 7 (1992), page 366).

In the post-fabrication etch procedure used in the present invention aluminum hydroxide (AlOH) was added to the EDP in order to limit the attack of the EDP on exposed aluminum surfaces. The mixture was heated in a reflux container to 97° C. and the devices were etched for approximately 1 hour 15 minutes. After this step the fabrication is complete and the devices can be packaged and tested.

According to one embodiment, electroplating and electroless plating have been utilized to deposit barrier materials such as nickel and copper on exposed aluminum contact pads and on exposed silicon regions in order to protect these layers from the echant and to increase the operable temperature range of the device. This plating can be performed selectively on the contact pads, or the exposed silicon regions, or both utilizing maskless deposition techniques.

Thermal isolation which is provided for by the etching beneath the membrane or microbridge is necessary in order to heat the surface to elevated temperatures (in the range of ambient to over 1000° C.) at power levels that are compatible with IC-based applications (less than 100 mW per heater).

Thermal response time and power requirements of the device may be controlled by limiting or increasing the number and size of the legs **4** and the various electrical leads on the legs. In general, higher thermal conducting paths (more and/or shorter legs and more and/or larger electrical leads) will provide a faster response time (on the order of one microsecond or less) at a higher power requirement. Fewer legs and less electrical leads will provide a lower power requirement, but a slower response time.

Devices have been fabricated which have a response time of about 1 millisecond and require 10 mW of power to attain a temperature of 500° C.

The present inventors are not aware of any other methodologies which can be used to manufacture micro-hotplates with monolithic circuits using conventional foundry processes. Accordingly, the device of the present invention has advantages over other similar known devices in that it can be manufactured using commercial foundries and does not require any additional masking steps for the post-fabrication step. Other devices that may be similar are fabricated in accordance with custom processes which utilize materials layers that are different and not compatible with commercial foundry processes. Moreover, suspended membranes are created by etching from the back side of the wafer or chip utilizing additional masking steps. By being able to fabricate the devices of the present invention in a commercial foundry environment, the devices have the advantages of lower cost, fast fabrication, easy customization, fast technology transfer, and VLSI circuit compatibility.

The micro-hotplate devices of the present invention can be utilized to heat materials, while sensing electrical properties of the materials. Moreover, it is possible to deposit interactive material layers on the micro-hotplates, for use in environmental sensing such as gas sensing in exhaust emissions, in-situ process control where a material can be processed locally at some desired temperature, and process monitoring. For environmental sensing, such as gas sensing, an additional material layer can be deposited on the micro-hotplate and the temperature of this material can then be controlled with the monolithic electronics such as temperature controller and computer interface. For process monitoring application, the devices of the present invention can be used, for example, as a way of sensing the resistivity of a material as it is deposited and adjusting the temperature of the micro-hotplate(s) to compensate for errors in real time. Other uses for the micro-hotplates will be apparent to those skilled in the art.

Although the present invention has been described with reference to particular means, materials and embodiments, from the foregoing description, one skilled in the art can easily ascertain the essential characteristics of the present invention and various changes and modifications may be made to adapt the various uses and characteristics without departing from the spirit and scope of the present invention as described by the claims which follow.

What is claimed is:

1. A micro-hotplate device which comprises:

a support substrate;

a microbridge structure formed on said support substrate, said microbridge structure having a suspended portion;