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Single Crystal SiC Microhotplate Conductometric Chemical Sensor Arrays

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This presentation reports the development and performance of a robust, single crystal silicon carbide microhotplate chemical sensor platform with integrated conductometric semiconducting metal oxide (SMO) films.

Microhotplates are miniature (typically ~100µm on a side) micromachined devices with integrated heaters, temperature sensors and film resistance sensors. With their low power consumption, millisecond thermal response times and small size (allowing compact microsensor arrays), microhotplates are versatile chemical sensor platforms [1] and powerful materials deposition and characterization tools [2].

When fabricated from single crystal silicon carbide, the mechanical support, heater and sensor functions can all be implemented within patterned, alternately doped SiC layers, thereby eliminating the need for multi-layers of dielectrics, metal traces and electrical contacts in the "hot zone". The simplified monolithic SiC design remediates two common microhotplate degradation mechanisms: stress-induced micro-cracking of the SMO gas sensitive films caused by thermal cycling of the CTE mismatched multi-layer structure, and interfacial reactions between the layers, particularly at the metal contacts. As a result, SiC microhotplates may be stably heated to ~1000°C in air, and above 1200°C in inert or reducing environments.

The 2x2 silicon carbide microhotplate arrays were fabricated from n-type 6H-SiC substrates having 1.0 µm thick p-type and n-type SiC epilayers. The epilayers were patterned by ECR RIE, and the wafers were then photo-electrochemically micromachined in HF using highly selective p-n junction etch-stops [3,4] to form tethered, under-etched microhotplate structures as shown in figure 1a. Each of the four tethers supports two conductive n-SiC traces: one for ohmic heating and the other to provide electrical contacts to the temperature or film resistance sensors on the hotplate. The symmetrical orientation of the four tethers and the high thermal conductivity of SiC allows uniform heating of the hotplate (Figure 1b). Microhotplate temperature is determined from the resistivity of a portion of the heater trace on the microhotplate, which is measured in a 4-point probe configuration. Resistance and other electrical properties of films deposited on the microhotplate surface are measured by a pair of inter-digitated n-SiC electrodes.

The microhotplates have been selectively coated with a variety of SMO films by self-lithographic chemical vapor deposition (SLCVD), as shown, for example, by the tungsten trioxide coated microhotplates in figure 3.

The design, fabrication and characterization of the microhotplates, and their performance as conductometric chemical sensor arrays when coated with a variety of SMO films, will be presented.

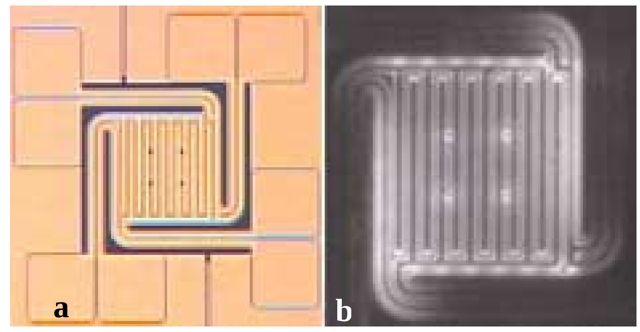

Figure 1. Left: Optical micrograph of a 100µm × 100µm × 2µm thick SiC microhotplate after photo-electrochemical micromachining. The microhotplate consists of patterned and underetched p- and n-SiC layers supported by four tethers. Right: IR image of the microhotplate heated to 650 °C. The temperature is uniform across the microhotplate and falls almost linearly along the length of the tethers to the ambient temperature of the substrate.

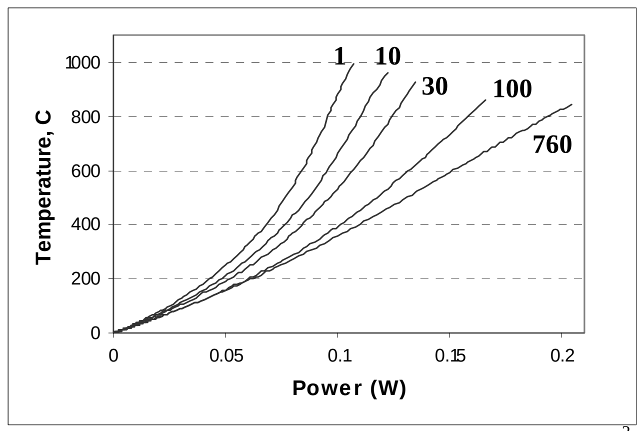

Figure 2. Temperature-power plots for a $100 \mu m^2$ microhotplate in air at various pressures.

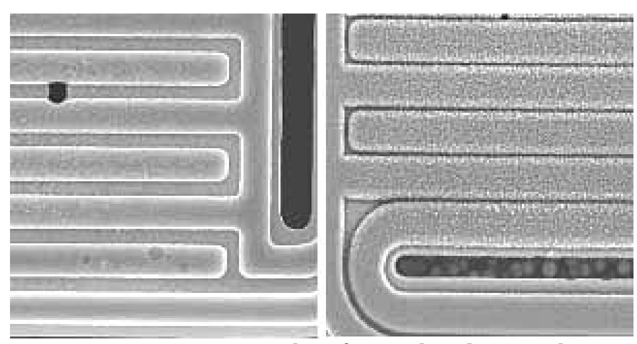

Figure 3. SEM micrographs of microhotplates with WO_3 films deposited by self-lithographic CVD onto 400°C microhotplates, using a $W(CO)_6$ precursor and O_2 mixture at 200 torr, after 1 minute (left) and 4 minutes (right).

1. S. Semancik, R, Cavicchi, "Kinetically Controlled Chemical Sensing using Micromachined Structures", *Acc. Chem. Res.*, **31**, 1998, p.279
2. R. Cavicchi, S. Semancik, F. Dimeo Jr., C. Taylor, "Use of Microhotplates in the Controlled Growth and Characterization of Metal Oxides for Chemical Sensing", *J. Electroceramics*, **9**, 2002, p.155
3. R. Mlcak, H.L. Tuller, "Electrochemical Etching Process," US Patent # 5,338,416, Aug. 16, 1994.
4. R. Mlcak, "Electrochemical Etching Process," US Patent # 6,511,915, January 28, 2003.