INTEGRATED SHEAR STRESS/TEMPERATURE MICROMACHINED SENSORS

A final report submitted to
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1.) Accomplishments

During this project we were able to design and initiate the fabrication of an integrated Micro ElectroMechanical Systems (MEMS)-based shear stress/ temperature sensor for flow control applications. The following items represent a brief summary of the completed activities during this project:

Sensor Design

The shear-stress sensor design consists of a large aspect ratio thin film of platinum patterned on a silicon-nitride diaphragm that is stretched over a vacuum cavity. This design maximizes directional sensitivity and minimizes conduction losses. Specifically, the shear stress sensor device structure consists of a 1500 Å-thick x 4 μm-wide x 200 μm-long platinum sensing element on top of a 1500 Å-thick silicon nitride membrane which seals a 200 μm-diameter and 10 μm-deep vacuum cavity (see Figure 1). Two gold leads at each end of the sensing element permits 4-point probe characterization exclusive of the effects of the biasing circuitry. Titanium serves as an adhesion layer for the leads and sensing element. The temperature sensor design will be identical except that a winding resistor to increase the sensor resistance to over 1 kΩ will replace the 1500 Å-thick x 4 μm -wide x 200 μm-long platinum film resistor.

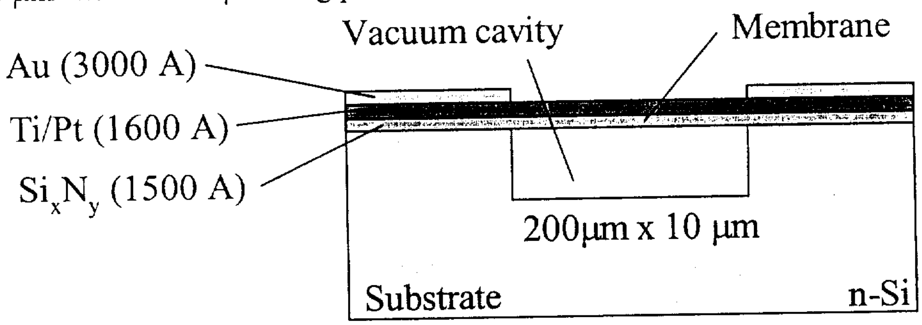

Figure 1: Cross-sectional schematic of the thermal shear stress sensor.

Microfabrication

A wafer-bond, thin-back process is currently being used to fabricate the shear-stress and temperature sensors (Figure 2). The process begins with two p-type <100> single-polished silicon wafers. Cavities are etched via DRIE in the handle wafer followed by growth of 7000 Å of thermal oxide as a bonding layer. The membrane material, 1500 Å of silicon-rich silicon nitride, is deposited on the device wafer and polished via CMP in preparation for bonding (A). The wafers are bonded in 100% O2 ambient and annealed at 1100 oC for one hour. A vacuum is formed within the cavities during the anneal as O2 is consumed by the growth of SiO2. The handle wafer is protected and the device wafer is thinned back to the silicon nitride using 20% KOH at 60 °C (B). The sensing element and leads are patterned via image reversal lithography and titanium, platinum, and gold are realized via E-beam deposition. The sensing element and leads are realized via lift-off and the gold is etched from the sensing element using a KI wet etch (C). This novel process produces devices with known material properties and strict geometry control (thickness and diameter), which is crucial for fabricating high-sensitivity sensors. The use of a platinum sensing element in the thermal shear-stress sensor offers the following advantages over polycrystalline silicon: the thermal coefficient of platinum is larger than that of polycrystalline silicon and platinum is a metal which does not possess grain boundaries. Therefore, a platinum-based shear-stress sensor will be more sensitive and possess a lower noise floor than a polysilicon sensor.

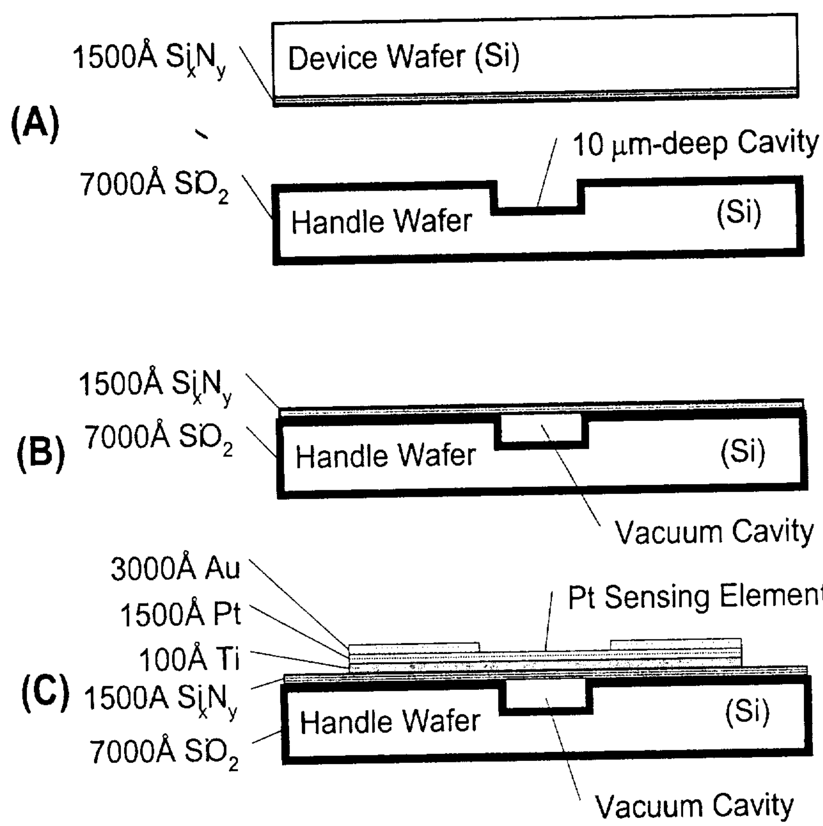

Figure 2: Cross-sectional schematic of the sensor fabrication sequence.

The a schematic of die layout is shown in Figure 3 and the specifics of the die design are as follows:

- Four-lead connection
- Die Size = 4.0 mm by 2.4 mm
- R(shear) = ~ 200 Ω, 1500 Å thick platinum element
- R(temp) = ~ 2000 Ω, 1500 Å thick platinum element
- ID Cavity = 200 µm (10 µm deep), 1500 Å thick Si_xNi_y seal
- Contact Pad Size = 100 µm by 100 µm
- Line Width = 40 µm

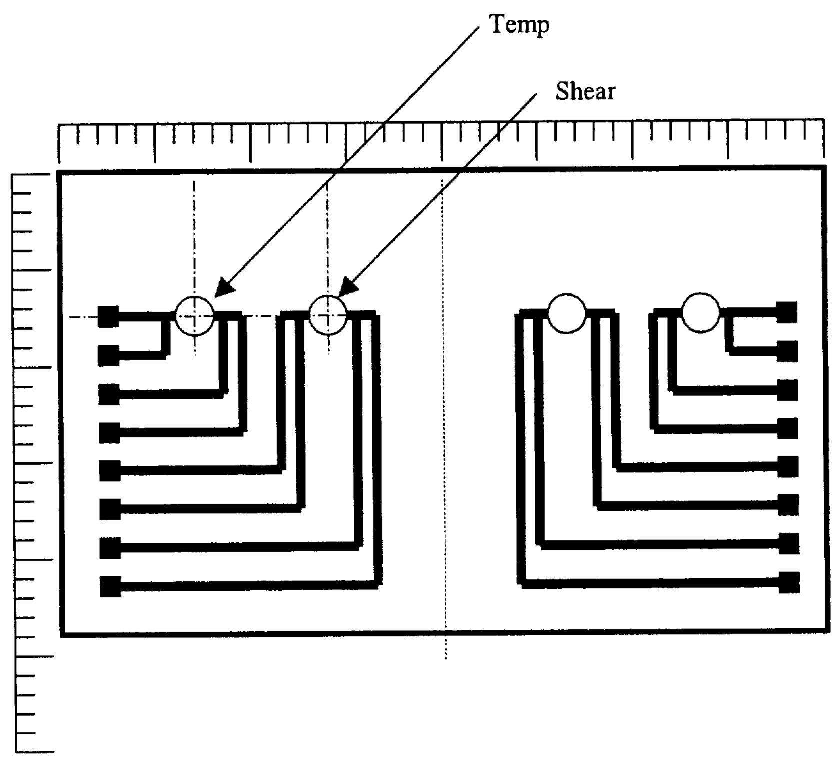

Figure 3: Schematic of the sensor die.

2.) Ongoing Work

The devices are currently being fabricated at MIT. Unfortunately, unforeseen equipment failures at MIT have greatly delayed the completion of the fabrication.

Once these devices are fabricated, a novel dynamic calibration technique will be used to simultaneously determine the frequency response of the thermal sensors.