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Piezo-thermal probe array for high throughput applications

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Abstract

Microcantilevers are used in a number of applications including atomic-force microscopy (AFM). In this work, deflection-sensing elements along with heating elements are integrated onto micromachined cantilever arrays to increase sensitivity, and reduce complexity and cost. An array of probes with 5–10 nm gold ultrathin film sensors on silicon substrates for high throughput scanning probe microscopy is developed. The deflection sensitivity is 0.2 ppm/nm. Plots of the change in resistance of the sensing element with displacement are used to calibrate the probes and determine probe contact with the substrate. Topographical scans demonstrate high throughput and nanometer resolution. The heating elements are calibrated and the thermal coefficient of resistance (TCR) is 655 ppm/K. The melting temperature of a material is measured by locally heating the material with the heating element of the cantilever while monitoring the bending with the deflection sensing element. The melting point value measured with this method is in close agreement with the reported value in literature.

Keywords

- Microcantilevers;
- Scanning probe microscopy;
- Piezoresistive sensing;
- Parallel imaging;
- Elastography;
- Mechanical characterization;
- Melting point;
- High throughput

Figures and tables from this article:

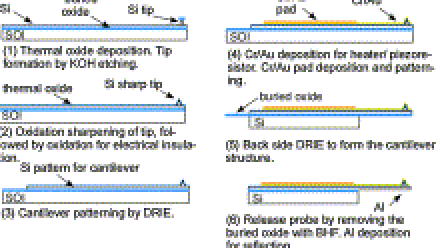

Fig. 1. Process flow for fabricating the probe array.

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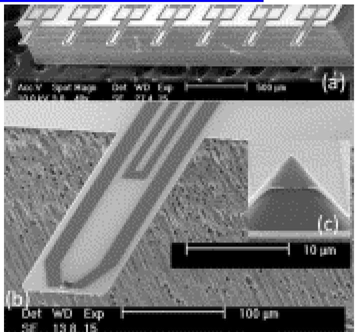

Fig. 2. (a) SEM of the probe array. (b) Individual cantilevers include two resistors, one over the tip serving as a localized heater/thermal sensor and a second closer to the base serving as a resistor for deflection sensing. Inset (c) SEM close-up of the tip.

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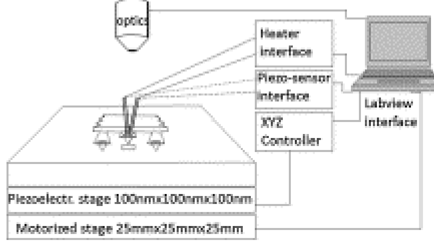

Fig. 3. The experimental set-up used to conduct these studies.

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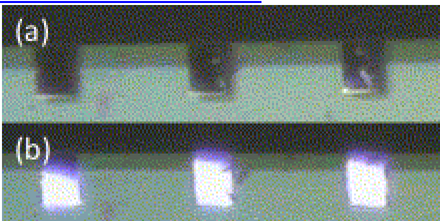

Fig. 4. Probes are monitored using an optical microscope to determine contact, which occurs when the reflection changes. Here, three probes are shown (a) before contact and (b) after contact.

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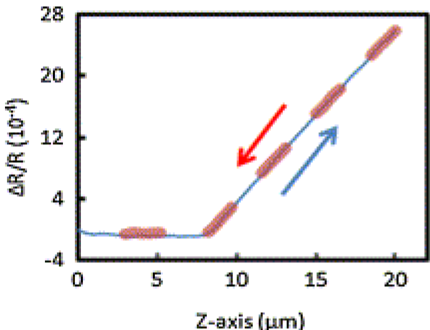

Fig. 5. Electrical monitoring of probe-sample contact and cantilever characterization is done using “force-curves” of a probe on a hard substrate such as glass. (For interpretation of the references to color in the text, the reader is referred to the web version of the article.)

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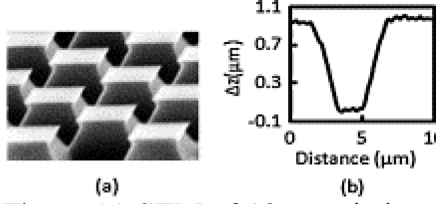

Fig. 6. (a) SEM of 10 μm pitch square grating with 1 μm height. (b) A high resolution 10 μm line scan. The probe moved in 0.2 μm steps in the *X* direction.

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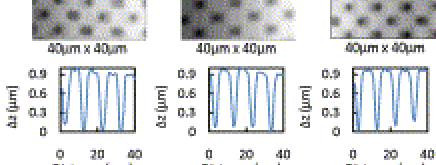

Fig. 7. A 40 μm × 40 μm area scan acquired by 3 different probes scanned over the 10 μm pitch square grating.

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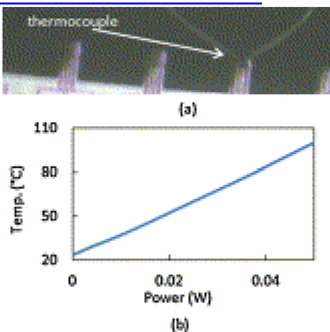

Fig. 8. (a) An optical image of a 12 μm thermocouple in contact with one of the probe tips of an array. The thermocouple is used to calibrate each heater. Each heater is heated gradually, while the current through the probe (*I*), the voltage (*V*) and the temperature at the tip are recorded. (b) The calibration curve of power vs. temperature from the measured data is very linear. From the resistance and temperature data the TCR is estimated to be approximately 655 ppm/K.

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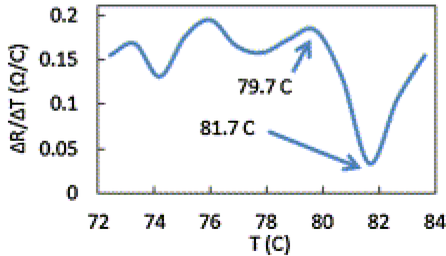

Fig. 9. The first order derivative of change in resistance with respect to temperature vs. temperature is shown with knee point at 79.7 °C. The *X*-axis represents the temperature of the heater and the *Y*-axis the change in resistance with temperature of the deflection sensing element.
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