MASKLESS LITHOGRAPHY BY PATTERNED HEATING OF PHOTORESIST USING ULTRA-COMPLIANT THERMAL PROBE ARRAYS

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With increasing costs of photomasks, maskless lithography is of interest as an avenue for re-configurable manufacturing. This paper describes the use of a micromachined array of ultra-compliant probes with polyimide shanks and embedded thin-film heaters (Fig.1) to induce ***spatially localized thermal cross-linking*** in AZ 5214 E, a widely available photoresist. The technique of localized heating, recently investigated using lasers[1], is similar to traditional image reversal[2], except that instead of patterning the UV exposure, the post-exposure bake is spatially localized. This contrasts with other methods of scanning probe lithography such as nano-indentation[3,4], dip pen patterning[5], and charge manipulation[6], and represents the only use of a heated tip to catalyze a localized chemical reaction. In this approach, pixel sizes can be controlled by the probe temperature and velocity. Using 20-30 mW power and 2-60 sec residence times, probes with 400 nm tip diameter were used to pattern pixels with diameters ranging in size from 400-2000 nm. Resolution can be improved to the sub-100 nm range by using sharper probe tips and thinner resists.

The probe arrays which enable this technology are fabricated by a low-cost micromachining process in which a thin film metal bolometer is sandwiched between two insulating layers of polyimide[7]. The metal film is molded into an anisotropically wet-etched notch in the Si substrate to form the scanning tip. The probe is then released from the substrate, flipped out over the die edge, and held in place by a thermo-compression bond by a thin film of Au. Probes fabricated from rigid materials[8] such as Si or Si_xN_y require a force feedback on each tip to prevent damage to soft samples. The use of ultra-compliant polyimide cantilevers permits the probes to operate in contact mode (for superior thermal contact) without mechanical feedback to control the contact force, and makes scaling to large arrays practical. This is potentially a low-cost approach to maskless lithography for rapid prototyping and re-configurable manufacturing.

References

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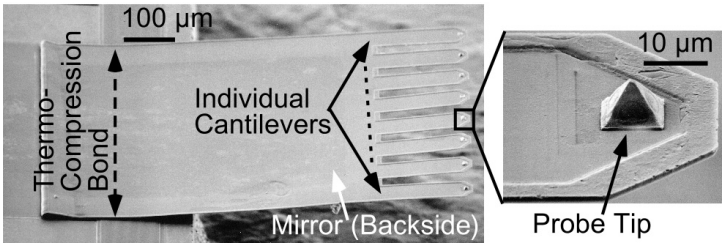

Fig. 1: SEM image of micromachined 8-probe array. Thin film resistors integrated on each cantilever allow each tip to be heated independently. Ultracompliant cantilevers fabricated from polyimide offer low contact force even without mechanical feedback.

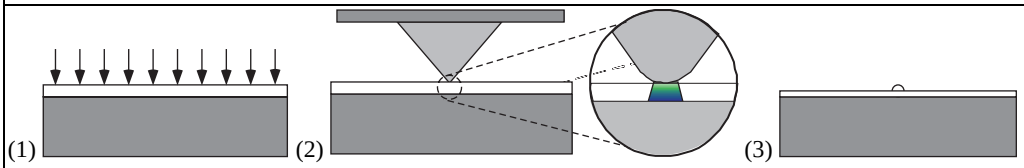

Fig. 2: Process flow for maskless thermal lithography. (1) Flood exposure of a wafer spin coated with a thermally cross-linkable photoresist. (2) Patterned baking with microprobes. Spatially localized thermal cross-linking occurs under the heated probe tip (inset) as a result of the flood exposed photoactive compounds (PACs) and elevated temperatures. (3) The insoluble cross-linked region remains after development in a standard TMAH-based developer.

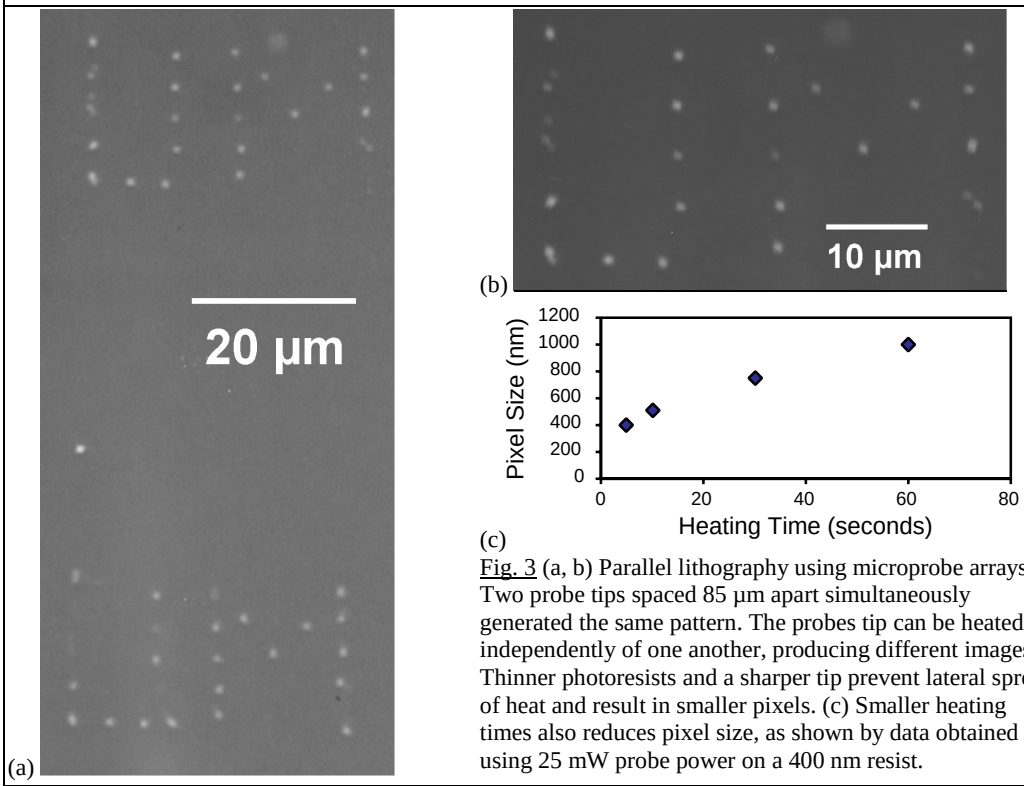

Fig. 3 (a, b) Parallel lithography using microprobe arrays. Two probe tips spaced 85 µm apart simultaneously generated the same pattern. The probes tip can be heated independently of one another, producing different images. Thinner photoresists and a sharper tip prevent lateral spread of heat and result in smaller pixels. (c) Smaller heating times also reduces pixel size, as shown by data obtained using 25 mW probe power on a 400 nm resist.