Laser Print Patterning of Planar Spiral Inductors

N. Klejwa, R. Misra, J. Provine, and R.T. Howe
Stanford University, Dept. of Electrical Eng. 420 Via Palou, Stanford, CA 94305
S.J. Klejwa
Magnetic Abrasive Technologies Inc., 11365 Sunrise Gold Circle,
Rancho Cordova, CA 95742

This abstract describes direct laser printing of thin-film polymer onto planar quartz substrates for use as an aluminum etch mask. Using this technique, we fabricated square planar spiral inductors 12x12mm with 2.5 to 5.5 turns producing series inductance Ls = 80 to 180nH and series resistance Rs = 15 to 23Ω. This technique is a low-cost, low temperature, rapid turn-around, maskless, resist-free, means of patterning large area metal layers with features as small as 200μm.

Metal on-chip spiral inductors used in RF applications have features much larger than CMOS transistors, but are fabricated using the same costly lithography steps [1]. Improved materials have allowed for high-Q passive elements, but still require expensive masks and multiple spin-bake-develop steps [2]. In contrast, this work demonstrates rapid printing of inductor patterns directly on a substrate.

Laser printer toner consists of particles approximately 10μm in size made from a mixture of polymer (styrene), dye (carbon), and magnetic material (Fe/Ni). A modified HP Laserjet III printer was used to pattern and deposit toner directly onto a 4" quartz wafer coated with a 500nm aluminum film. (*Fig.1*). After deposition, particles were fused to form a patterned layer which masks the wet etching of the underlying aluminum layer into patterned spiral inductors *(Fig.2)*. The maximum process temperature used is 100˚C to fuse the polymer particles. Removing the polymer layer in acetone produces completed inductors *(Fig.3)*.

Measured inductances are close to analytical expressions. A 12x12mm spiral inductor with 4.5 turns yields a low frequency inductance of 166nH *(Fig.4)* while the modified Wheeler formula for a square inductor yields 210nH [3], the difference attributable to variances in geometry and measurement parasitics. This technique has broad applicability to rapid prototyping and low-cost manufacturing of microelectronics. Work is underway to create metal strain gauges, thermo-resistors, and micro-heaters on a variety of substrates using this novel technique.

---

1 Ashby, K.B. et al. *Proc. Bipolar and BiCMOS Tech.,* 1994, pp. 179–182.
2 Mina, R-Z. et al. *IEDM '06*, Dec. 2006, pp.1-4, 11-13.
3 Mohan, S.S. et al. *J. Solid-State Circuits*, Oct. 1999, pp. 1419-24.

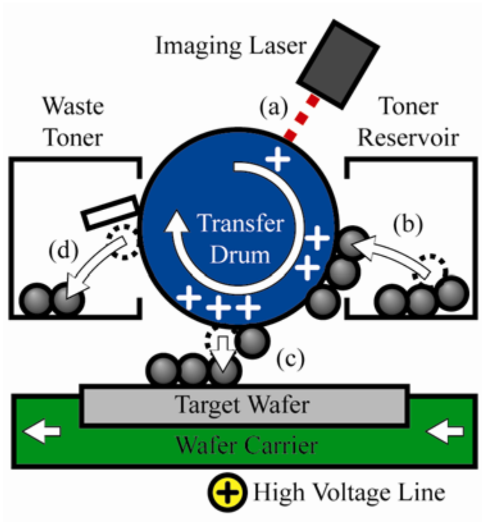

Fig 1: Polymer Printing Process: (a) Imaging laser creates charged pattern on transfer drum (b) Toner drawn from reservoir to charged regions of transfer drum (c) Toner transferred from transfer drum to wafer by high voltage line (d) Waste toner removed from transfer drum.

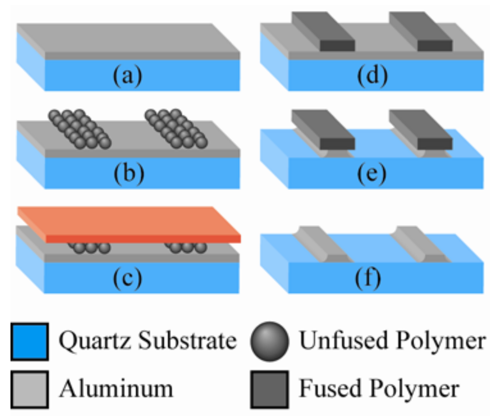

Fig 2: Inductor Fabrication Process: (a) Sputter 500 nm Al onto 4" quartz substrate (b) Print inductor pattern in polymer (c) Fuse polymer 5 min at 100C with 12 kPa pressure (d) Fused polymer etch mask (e) Wet etch Al (f) Remove polymer mask with acetone leaving completed metal inductors.

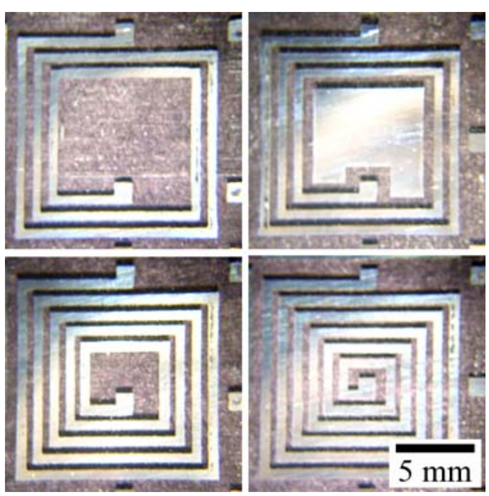

Fig 3: Finished Devices: Optical micrographs of completed inductors with outer dimensions 12x12mm.

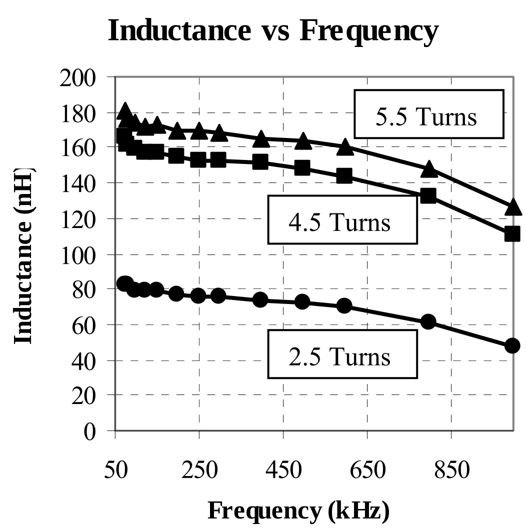

Fig 4: Inductor Performance: Inductance of 12x12mm spiral inductors with varying number of turns.