

Laser Direct-Write of Metal Patterns for Interconnects and Antennas

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ABSTRACT

The use of direct-write techniques in the design and manufacture of interconnects and antennas offers some unique advantages for the development of next generation commercial and defense microelectronic systems. Using a laser forward transfer technique, we have demonstrated the ability to rapidly prototype devices. and how this technique may influence current and future sensor applications.

Keywords: Laser Direct-Write, Laser Micromachining, Laser Forward Transfer, Conformal Antennas.

1. INTRODUCTION

Current trends for developing advanced electronic and sensor systems place great emphasis in achieving performance levels generally associated with integrated circuits. This requires further miniaturization, while enhancing the functionality and reliability of existing components. It also requires new strategies in order to eliminate the long lead times required for the fabrication of prototypes and evaluation of new materials and designs. Blah, blah, blah.

Give a brief background to what do we mean by direct-write techniques. Reference Dave Nagel's chapter in the DW book. Point to Figure 1 as a schematic comparing photolithographic processes with direct-write processes.

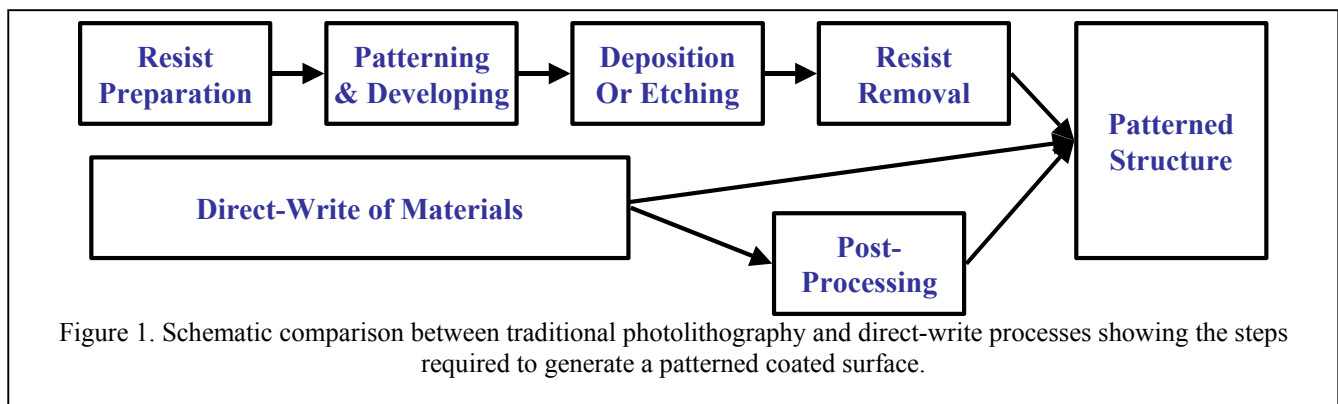


Figure 1. Schematic comparison between traditional photolithography and direct-write processes showing the steps required to generate a patterned coated surface.

Direct-write technologies do not compete with photolithography for size and scale, but rather add a complementary tool for specific applications requiring rapid turnaround and/or pattern iteration, conformal patterning, or for modeling difficult circuits².

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Need a brief overview of laser direct-write. Explain both its subtractive (micromachining) and additive (laser forward transfer modes).

Then talk about laser direct-writing of metal lines and the generation of 3D patterns.

Then talk about the use of 3-D metal patterns for conformal antennas.

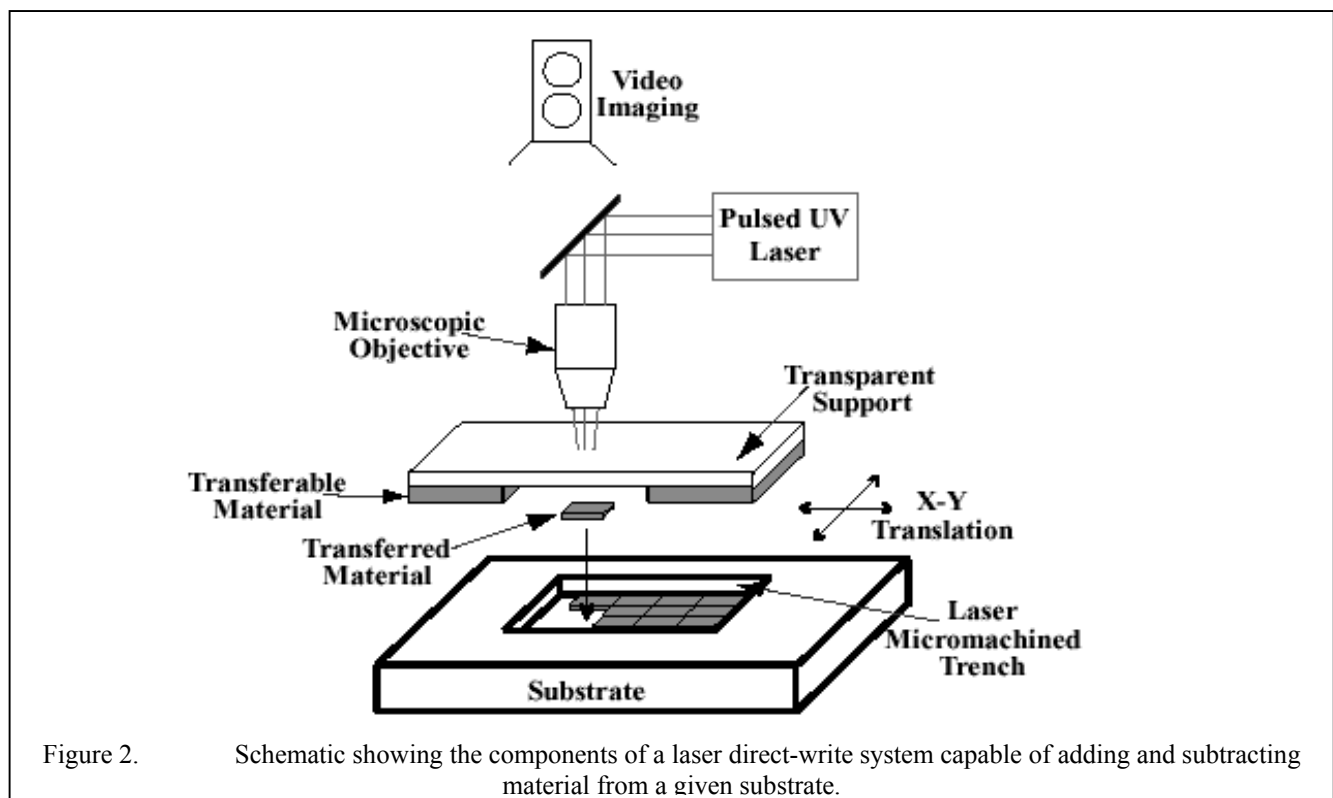
Conformal antennas were originally developed for military applications where their aerodynamic and covert properties played key roles. The thin, unobtrusive nature of these antennas makes them ideally suited for relatively small platforms such as unmanned vehicles and portable or hand-held systems. The fabrication of antennas for such applications, however, pose major challenges to currently available materials and manufacturing techniques.

Direct-Write processes circumvent these challenges by making possible the fabrication of novel conformal antenna structures. Direct-write techniques have demonstrated their impact in the fabrication of mesoscopic electronic [Pique SPIE 1999], sensor [Pique SPIE 2002] and power generation [Arnold ???] components for next generation microelectronic systems

In this paper, the use of a laser direct-write process will be described for the deposition of metal patterns on various substrates (polyimide and glass) and examples of the various types of structures that can be generated over conformal surfaces will be presented. Finally, we will show how the laser direct-write technique can be used to fabricate novel conformal miniature antennas.

2. EXPERIMENTAL

The laser micromachining experimental setup is shown in figure 2. The pulsed UV laser source for these experiments is a Nd:YVO₄ laser (Spectra Physics) operating at 355 nm with a frequency of 10 KHz and a pulse duration of 30 ns. The laser pulse passes through a series of focusing optics and a UV microscope objective before reaching the sample which is mounted on a vacuum chuck. The nominal laser spot size in this setup is 25 μm in diameter. All the samples are irradiated at energies ranging from 3-30 μJ per pulse (~2-20 J/cm²) with internal laser fluctuations of +/-5% as measured by an energy-meter (Ophir Nova) monitoring the laser pulse energy during the experiment.



The spot-to-spot translation distance is controlled by an x-y motion control system (Aerotech D500) with a maximum x velocity of 115 mm/s and y velocity of 100 mm/s. An acousto-optic modulator (NEOS) is used to fix the dwell time between subsequent laser pulses. For all the experiments shown here, the time between pulses is 10 ms to allow for efficient stage operation and avoid cumulative heating effects. Inline video imagery enables sample alignment as well as real time monitoring of the micromachining process.

In the present study polyimide (110 μm thick DuPont Kapton™ Type H) samples are irradiated at varying translation distances and laser energies. Substrates are cleaned with acetone and ethanol prior to laser micromachining. Using a laser spot 25 μm -wide, square frames 500 μm x 500 μm are machined on these polyimide substrates with translation distances ranging from 1 μm to 40 μm . All experiments are performed at room temperature and ambient pressure where it has been shown that atmospheric conditions have no measurable influence on pulsed UV laser micromachining of polyimide.[Branon, 1985]

The same apparatus is used to deposit conductive silver lines using a laser forward transfer direct-write technique described elsewhere.[Chrisey, 2000; Pique, 1999] A commercially available screen printing silver ink (Paralec Inc.) is spread in a 10 μm thick layer on a borosilicate blank that is then mounted above the machined substrate. The laser interacts with the ink and causes a forward transfer of material that lands on the waiting substrate 100 μm below. For deposition, the spot size is increased to 120 μm giving us a decreased laser fluence of $\sim 0.6 \text{ J/cm}^2$. Conformal deposition over a variety of surface structures is easily obtained. Following deposition, the transferred ink is dried in an oven at 150 $^\circ\text{C}$ for 5 minutes.

Surface characterization measurements are performed on samples after laser irradiation and after laser deposition without any additional substrate cleaning to preserve the surface structure. Depth and surface roughness measurements are performed using a profilometer (Tencor Instruments P-10) with a 2 μm stylus tip. Measurements of machined features are sampled over a fixed distance of 450 μm on one side of the machined frame. In all cases, the same side of the frame is used to prevent errors associated with starting and stopping or asymmetric spot geometries. Scanning electron microscopy (LEO 1550) is performed to further investigate surface features in polyimide after laser irradiation.

3. RESULTS AND DISCUSSION

3.1 Metal lines

Figure 3(a) shows an optical micrograph from a pair of silver lines that were deposited inside trenches with steps that were laser machined on polyimide. The steps were generated by adjusting the translation distance at fixed laser energy of 30 μJ . Afterwards, using the laser direct-write process, we conformally deposited silver over the length of the trench and over the step, producing a layer that is on average 10 μm thick above the bottom laser machined trench. This can be seen from the profilometer scan results taken along the trench before and after the silver layer was deposited as shown on figure 3(b). As the scan shows, the silver deposited layer uniformly covers the step and the surface of the trench.

Figure 3. (a) Optical micrograph of silver lines deposited on trenches on polyimide substrates by laser direct-write.

It is worth noting that the resistivities calculated for the silver lines made by laser direct-write are of the same magnitude as the resistivities present on solder materials used for circuit boards. Furthermore, the laser direct-write process offers the unique ability to deposit the metal patterns over conformal surfaces with very uniform thickness, which becomes very important for making metal interconnects in 3D geometries such as vias, across layers and for connecting components to a circuit board.

3.2 Antennas

The ability to laser direct-write metal patterns can be used for the fabrication of antenna structures.

4. SUMMARY

Need a summary paragraph (use for abstract as well)

5. ACKNOWLEDGEMENTS

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