Three-Dimensional Microlithography System

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Seventeen years ago, LLNL created a unique quasi-3-D laser direct writing tool, called laser pantography, to fabricate metal interconnects on multichip modules. We also created a suite of processes for deposition, etching, and lithographic patterning of 3-D surfaces. In addition to the multichip modules for which the system was created, this tool and the associated deposition and etching processes allowed us to make unique mm- and sub-mm-scale parts such as RF inductors, diamond anvils with electrode structures, NMR microcoils, micromotor stators, and magnetic relays.

Project Goals

In this project we have addressed the fundamental limitations of the laser pantography tool: because of the original mulitchip module application and limitations in the CAD/CAM systems of the time, the configuration could not support out-of-plane patterns more complicated than straight lines of fixed length parallel to the z-axis. Also, the workstation and interface hardware was out-of-date, using an operating system no longer supported.

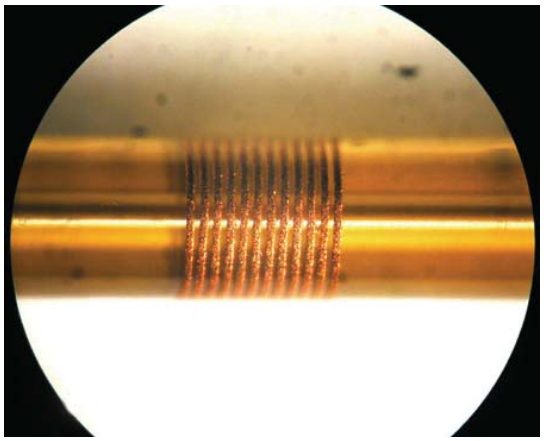

Figure 1. 12-turn copper coil patterned on 360-μm-diameter capillary.

Another limitation was that motors could not be started at exactly the same time. To use a simple example, this meant that diagonal lines in the x-y plane were executed as stair steps. Modern motor control systems allow simultaneous movement of multiple stages so that smooth diagonals, ovals, and other shapes can be drawn.

FY2004 Accomplishments and Results

We have assembled a modern, fully 3-D, sub-μm-accuracy motion system driven by a commercial CAD/CAM package. This 3-D microlithography system (3D MLS) functions as both a lathe and a five-axis milling machine, each using the focused laser as the "cutting tool," to expose photoresist.

The upgrade of the 3D MLS involved the replacement of the original custom hardware and software with a standard motion-control hardware package, together with commercially available 3-D CAD/CAM software, licensed to LLNL. The new software outputs standard G-code, which the new hardware executes in the same fashion as a five-axis CNC milling machine.

A true 3-D MLS is our final product. It is a unique capability, and is expected to generate considerable interest and support. It dramatically increases our 3-D patterning

capability, making it applicable to surfaces and structures that could not be patterned previously. As technology demonstrations, we have patterned helices and racetrack coils on < 400-μm-diameter cylindrical surfaces (for NMR and MRI applications) and simple periodic structures on spherical or elliptical surfaces of radius of order 1 mm (for NIF physics targets).

We have installed new motion-control hardware, including a Pentium computer, a Delta Tau microprocessor control card, motor amplifiers and motor controllers for up to eight degrees of freedom. A 3-D CAD/CAM package was installed, and initial handshaking software linking it to the motion-control hardware was put in place. Also, x-, y- and z-translation stages (existing equipment) were installed and wired. Requirements for high-precision theta in x and z axes were ascertained, and stages with sufficient speed and precision were purchased and installed. An initial version of a Visual Basic GUI front end for the PC was written. We also assembled a new optical system with versatility as well as minimum feature size under various motions. Improvements in the optical system have produced a "cut size" of 2 μm with thin resist.

Creating fixtures for various workpieces is also a significant issue when precise knowledge of the exact position of the part is required. For example, we have made significant progress in handling and manipulating 240-μm-diameter flexible tubes on which NMR coils are fabricated. We are now confident of our ability to fabricate 100-μm-diameter NMR tubes for DOE and DHS in the coming year.

Figures 1 to 3 are examples of our work.

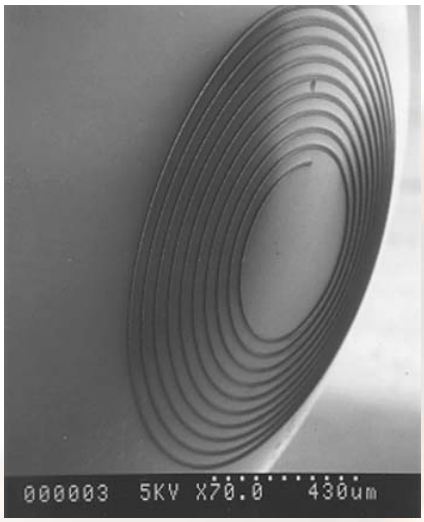

Figure 2. Spiral pattern with 6-µm line width on 1-mm-diameter sphere.

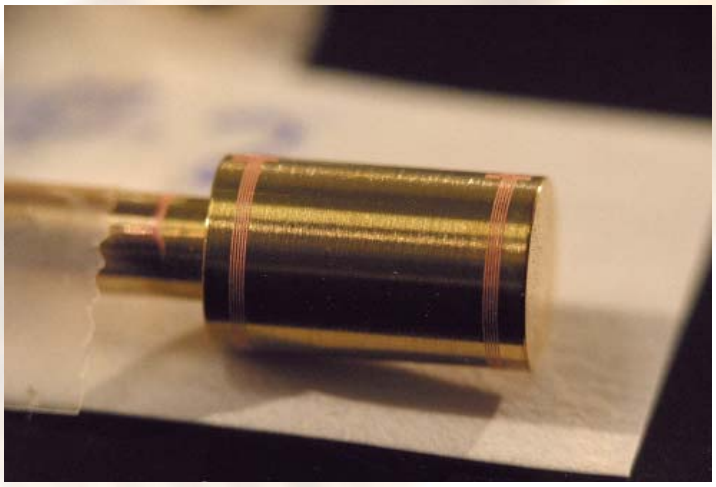

Figure 3. 6-mm-OD brass mandrel patterned with copper to simulate "Hohlraum" heater wires.