Micromachined stylus ion traps through high aspect ratio lithography and electrochemical deposition

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Electrochemical fabrication offers unique advantages for nano/microfabrication. Precise control of deposition sites and thicknesses in addition to 3-D stacking of materials allows significant challenges to be solved through electrodeposition that are beyond the capabilities of standard silicon methods or conventional machining techniques.

Increasing optical access to trapped ions allows enhanced measurement and reduction of anomalous motional heating. Maiwald, et al.[1] has recently designed a stylus ion trap that significantly increases the percentage of solid angle in which optical and physical access is achieved. Traditional machining technologies are unable to realize these structures due to minimum feature size, while silicon processes such as physical vapor deposition and etching techniques are unable to efficiently reach the necessary thicknesses of these designs. In this work we have developed a fabrication process through thick multi-layer electrochemical deposition in order to realize wafer level fabrication of three-dimensional stylus ion traps.

Progress in studying various material and/or surface treatments to improve the performance of ion traps is hindered by the long turn-around times required to design, fabricate, set up, and conduct measurements. As opposed to serial fabrication, we have combined photolithography and electrodeposition to simplify construction of stylus ion traps while allowing a variety of trap geometries to be batch processed on a wafer level manufacturing scale.

High aspect ratio photolithography as well as LIGA techniques have been developed and compared as successful methods for thick multi-layer metal stacking, allowing wafer scale throughput of three-dimensional stylus ion traps. A schematic of the designed structure is shown in Figure 1 consisting of a ground plane, center ring, split RF biasing ring, and four compensation posts for DC biasing. Each of these structures is 150µm tall with a minimum width of 40µm. An asymmetric potential is generated through a RF bias applied to the split cylinder concentric cylinders and the DC bias on the center ring and four compensation posts minimizing the motion of the trapped ion. The ground plane is comprised of 2.5µm electroformed Au with isolated connections to each of the four compensations posts, as well as outside and inside concentric cylinders. A two layer process is utilized to form the ground plane and the trap geometry through aligned photolithography and electrochemical deposition of gold. A top-down optical microscope image as well as two SEM images of fabricated traps are shown in Figure 2. With these electroformed stylus ion traps a Mg^{25} ion was trapped within 65µm of the trap with lifetimes on the order of 2 hours.

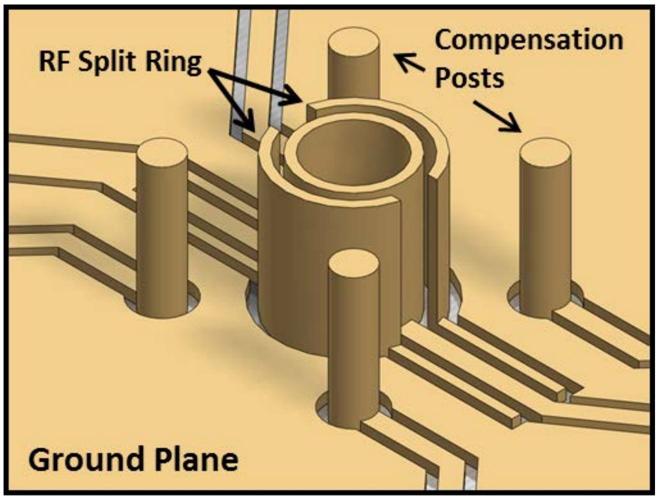

Figure 1: Schematic of designed stylus trap showing center ground ring, split RF biasing ring, with four outer compensation posts. Ground plane is comprised of 2.5μm electroformed gold with isolated lead outs to biasing bond pads. Posts and ring features are 150 μm electroformed gold.

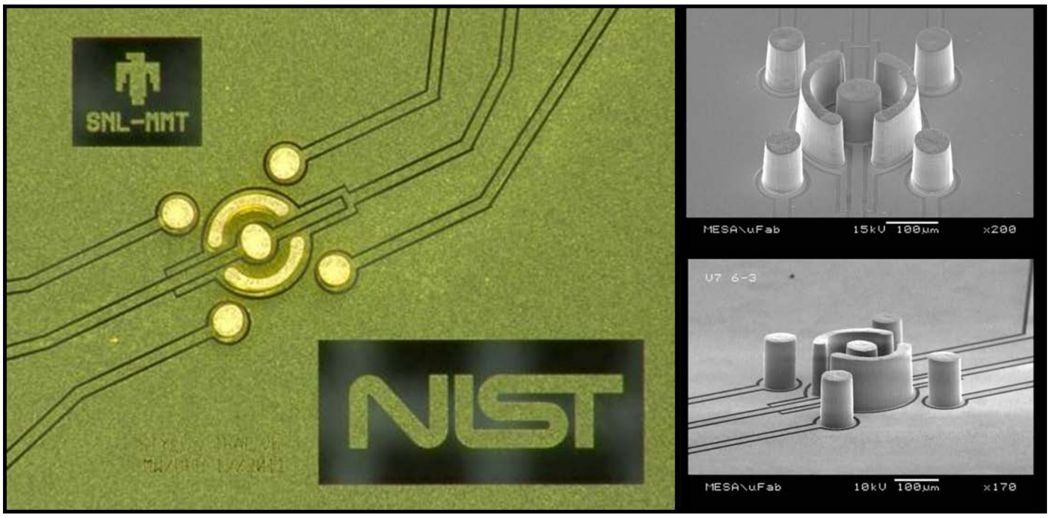

Figure 2: Optical microscope image (left) and angled SEM images (right) of electroformed 150μm tall stylus ion traps.

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1. Maiwald, R., Dietrich, L., Britton, J., Bergquist, J. C., Leuchs, G., and Wineland, D., "Stylus ion trap for enhanced access and sensing." Nature Physics, 1311, 2009.