

## COMBINATORIAL MULTI LEVEL MOLD INSERTS USING X-RAY LITHOGRAPHY

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### ABSTRACT

In the recent times, researchers in micro-electro-mechanical-systems (MEMS) are showing immense interest in developing mold inserts with complex, multi level, 3-dimensional and varying high aspect ratio (HAR) microstructures especially for micro fluidic applications and/or applications involving micro spectrometers, fiber optic wave guides, micro reactors, micro chips and sensors and actuators [1]. Multi level mold inserts have been fabricated using X-ray lithography and/or electroforming, hot embossing, micro milling, drilling [2-5]. However, the aspect ratio was limited to 15. The objective of the present research is to develop a process combining micro milling with LIGA to produce the complex multilevel microstructures with dimensions down to 10  $\mu\text{m}$  and aspect ratios greater than 20.

A schematic overview of the process is shown in the fig 1. Owing to ease of machining and selective etching of nickel, copper [6,7] was selected as the substrate. Micro-milling is performed on the substrates to incorporate multi level microstructures with different depths ranging from 50 to 300  $\mu\text{m}$ . Using proper adhesion layer, poly-methyl-metacrylate (PMMA) was bonded to milled substrates. The deep X-ray lithography was performed after passively aligning the substrate to the X-ray mask using the

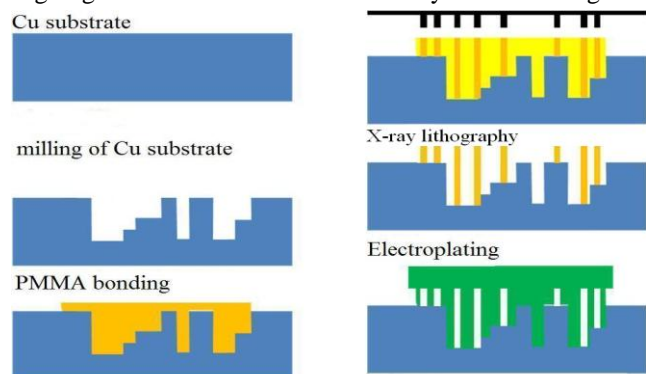


Fig 1: Overview of the process.

corresponding alignment marks micro-milled on substrates and the X-ray mask. Subsequently, the exposed PMMA was developed and metallic microstructures were fabricated by electroplating nickel. In order to make the mold inserts, the microstructures will be over-plated and the copper substrate will be removed by selective etching.

In order to explore the possibilities and limits of high aspect ratio microstructures fabrication on a pre structured substrate, mask with several test structures and 6 fields was used, Fig. 2. The dimensions of the fabricated microstructures were ranging from 10  $\mu\text{m}$  to 200  $\mu\text{m}$  and heights up to 500  $\mu\text{m}$ . Each type of design was replicated

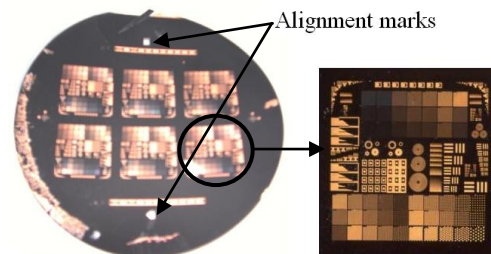


Fig 2: X-ray mask with test patterns

several times within the unit cell to test repeatability and obtain statistical information. In this research a limited number of structures were chosen for in-depth metrology and structure analysis to demonstrate the capability of combinatorial process for high aspect ratio ( $> 20$ ) micro structures. The design pattern shown in Fig. 2, contains grating structures (Fig. 3) for pattern accuracy of the teeth, finger structures (Figs. 4) to compare tall and small structures exposed to same dosage, post arrays (Fig. 4) with different post shape for verticality and straightness with varying depth, different shapes including spirals and gears are used. Exposure experiments were conducted on XRLM1 and XRLM2 beam lines at CAMD/LSU using the DEX02 and DEX01 scanner, respectively. Different substrates (Si and Cu) with varying resist thicknesses (ranging from 200

to 650 microns) were exposed, developed and inspected to determine patterning accuracy, aspect ratio limits, process issues, and structural defects. Pattern transfer was

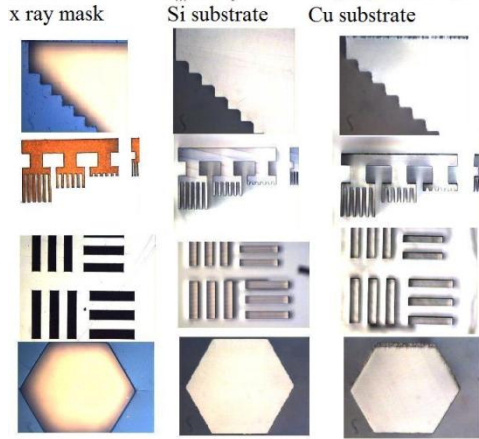


Fig 3: Microscopic images of substrate

adequately transferred to the substrates as can be seen in fig 3.

The chances of survival of posts were higher with lower dosage and longer development times which was demonstrated by using different dosages (bottom dose ranging from 2500 to 3500 J/cm<sup>2</sup>) on to the substrate. The HAR microstructures that received high dosage got washed

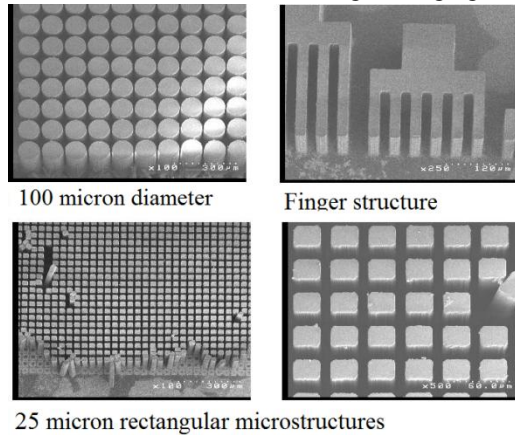


Fig 4: SEM images of patterned structures

off during the development process. Larger structures with lower aspect ratio were observed to adhere well to the substrate as can be seen in fig 4. Efforts are also made to find the maximum aspect ratio attainable using negative resist as well as positive resists which will be discussed in the presentation.

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