Patterning of Non-Planar Diamond Anvils for High Pressure Materials Characterization via Electron Beam Lithography

D.S. Schulman
Department of Materials Science and Engineering, The Pennsylvania State University, University Park, PA 16802, email: dus36@psu.edu
C.M. Eichfeld, M. Labella III
Materials Research Institute, The Pennsylvania State University, University Park, PA 16802, e-mail: cme133@psu.edu
S. Das
Department of Engineering Science and Mechanics, The Pennsylvania State University, University Park, PA 16802
L. Zhang, R.M. Schmid
Raith America, 300 Jordan Rd. Troy, NY 12180
W.S.M.M. Ketelaars, A.C. Zonnevylle
Raith, De Dintel 27a, 5684PS Best, The Netherlands

Increasingly nanotechnology and MEMS applications require high resolution patterning of irregularly shaped non-planar substrates. Electron beam lithography (EBL) of planar substrates requires precise measurement of the sample to final lens distance to transfer the pattern correctly onto the surface. The in-situ laser height readings typically used are not compatible with non-planar samples with large height variation and instead require an accurate height map referenced to the coordinate system of the electron beam writer. The advanced external height mapping system with Confovis technology[1] integrated into the external alignment microscope of the Raith EBPG5200 e-beam writer permits efficient patterning over a 10mm height range, coupled with its fast Z drive.

This capability enables complex patterning for applications such as patterning electrodes on diamond anvil cells (DAC), which are used for electrical and optical characterization of materials at pressures >100GPa. The diamond anvils have a flat culet surface of 200µm to 1mm dia., electrical leads need to be patterned down the angled diamond face as shown in Figure 1. Traditionally these leads are pre-patterned, and samples simply are placed on the leads making poor contact. While adequate for resistance measurements, materials such as layered transition metal dichalcogenides (TMDs) require high quality evaporated contacts and ideally need to be electrostatically gated. The ability to deterministically transfer these materials with submicron precision coupled with non-planar electron beam lithography (EBL) allows high quality devices with submicron features to be fabricated on these diamond anvils

We present a non-planar EBL process to pattern diamond anvils and fabricate TMD devices with high quality evaporated contacts as outlined in Figure 1. First, the anvil is sputtered with a conformal Mo film and placed on a carrier wafer patterned with alignment markers. A height map is produced using the external height mapping system of the Raith EBPG5200 e-beam writer as shown in Figure 2a. Z-lift positions at every position during patterning can be obtained or inferred from this height map data. The pattern data is divided into zones of 20µm height change like shown in Figure 2b. This allows for improved write time, improved focus over the field and improved field stitching errors. The resist is then exposed, developed and the electrodes etched.

1. http://www.confovis.com/

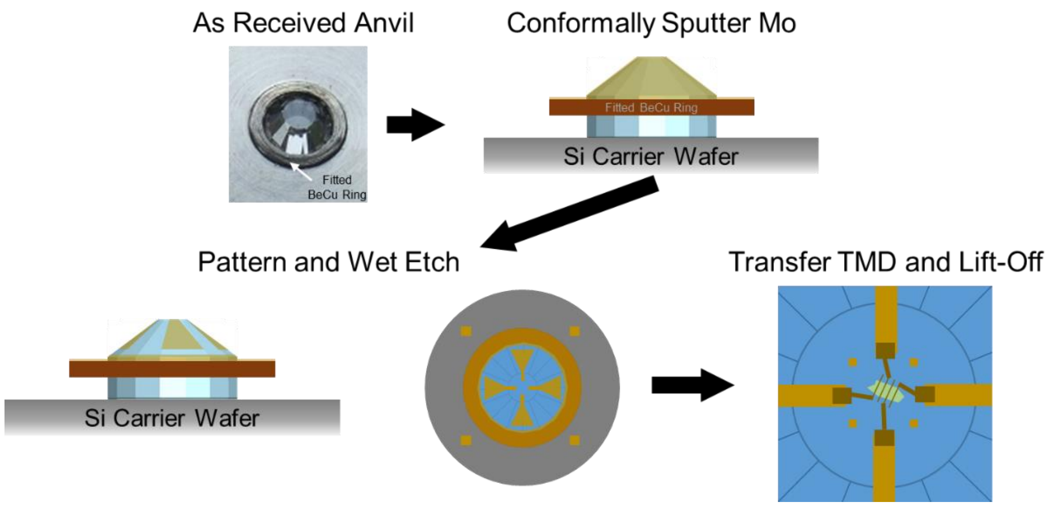

Figure 1: Diagram of the non-planar lithography process. First the diamond anvil, which is fitted into a BeCu ring, is mounted on a carrier wafer with pre-patterned alignment markers. 300nm of Mo/Au is then sputtered onto the diamond surface followed by spin coating of ZEP520A. The Raith EBPG5200 external height mapping system is used to create a height map of the sample relative to the carrier wafer alignment markers. The EBPG5200 with Z drive then exposes the resist on the sample. After developing, wet etching of the Mo/Au defines the electrical leads down the anvil sides. At this point, additional lithography steps are used to fabricate devices on the flat diamond anvil surface.

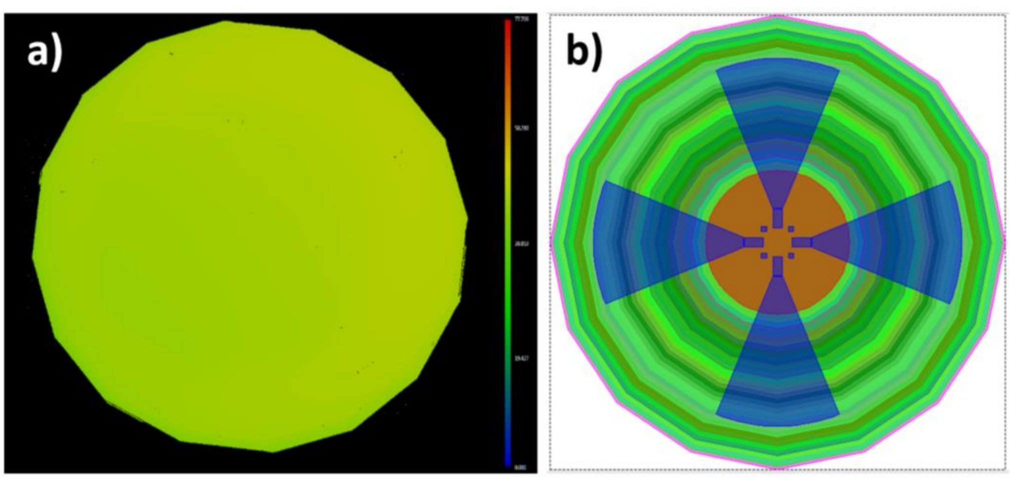

Figure 2: a) A heightmap of the top surface of the diamond anvil cell measured using the external alignment microscope of the Raith EBPG 5200 e-beam writer. This heightmap can be combined with data known about the diamond to create a full heightmap of the substrate. b) The pattern file is fractured into segments of 20um of height change. This allows for more efficient patterning and improves stitching of the pattern.