Etching Fabrication of ‘Superthin’ Diamond Beam Position Monitors

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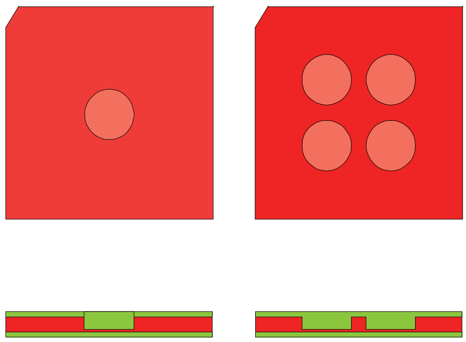
1. Objective/Context of the Project:

We will etch-thin diamond plates required for the fabrication of X-ray beam position monitors for synchrotron beamlines. 'Superthin’ membranes (≤10µm) of single crystal CVD diamond are required for these position sensitive detectors. We have demonstrated the successful performance of single crystal diamond plates to provide position noise <5nm using devices processed with discrete quadrant metal electrodes. Single crystal CVD grown diamond devices are made at present using ‘thick’ diamond substrate plates polished down to a minimum thickness of 40µm, but the development of a suitable dry etching process is required to further thin to membrane devices <10µm.

2. Description of Work Required

To solve the problem of fragility of thin diamond plates <40µm, we require the use of a masking process to restrict the area(s) of the etch thinning process to a 1~2mm central region of highly parallel plate diamonds, thus leaving a much thicker surrounding ‘window frame’ area. Such masked etch processing is not new, but there are technical issues to validate regarding mask erosion resistance and the avoidance of ‘grass’ or the spontaneous growth of ‘whiskers’ during processing. A further challenge is to ensure that the etching process maintains the initial plate thickness uniformity of thickness across say an 80% central area of the mask thinned region. The work will be undertaken as part of a 6 month stage by a Masters student at the ESRF. The project goals are described below, but a large part of the work will be to determine the most appropriate etching method and to optimize machine parameters.

Masked etch thinning of sample plates:
In the figure, green areas are those to be removed by ion etching. The starting plate size is ~3mm square and of thickness ~50µm (the vertical dimension shown is magnified x10 in the figures).
Goals are
i). 10µm initial etch removal on the entire (unmasked) bottom side of the plate,
ii) additional topside 35µm etching of topside masked region(s) to leave a plate with ‘window frame’ 40µm thick and central unmasked area(s) 5µm thick.



The size and shape of the superthinned areas (shown here as 1mm diameter circles) may be altered. The edge profiles of the superthinned areas are not critical, i.e. a vertical etch wall is not required.

Calibration of the rate of the etching process or in-situ monitoring of thickness is needed to obtain a final average thickness close (within +/-10%) to specification.

Challenges are:

i. Mask erosion. Ion milling or other plasma etching processes to several microns depth questions of the mask/diamond erosion rates, i.e. whether the mask will permit sufficient IBM etching before the mask itself is etched through. Fortunately, for this work, no precise mask features are required, and edge erosion of the mask outline is not critical (figure). Diamond or graphite shadow masks have previously been successfully used.

ii. Mask debris. The possibility of the mask erosion contaminating the diamond surface to be etched, resulting in non uniform etching features such as ‘grass’ or other features. This will not be acceptable, other than for possibly a few cosmetic defects.
iii. Previous work on deep >10µm deep etching using pure Ar milling resulted in samples showing occasional ‘whisker’ growths. The nature of this growth process is not understood. This is fortunately a limited occurrence but interferes with subsequent lithographic processing; it therefore reduces plate yield and must be controlled (ideally eliminated).
iv. Defect enhanced erosion. Chemically assisted etching (e.g. ArO) is attractive due to higher etch rates achievable but this usually results in preferential etching of local defects, either crystal structure in the diamond bulk else engendered by prior surface polish damage.
v. the etching process should result in smoothing of the initial scaife polished diamond surface (that will itself has a roughness ~1nm Ra). At least, the etching process should not deteriorate the measured rms roughness as measured (at ESRF) by profilometry and/or AFM over a lateral scale 1…100µm.