Nanofabrication of Sharp Diamond Tips by E-beam Lithography and ICP-RIE

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Diamond AFM probes provide the hardest tips for scanning probe microscopy on the market, benefitting of diamond's exceptional hardness, low adhesion force and low wear properties. Arrays of sharp diamond tips, such as field emission arrays, or structures for micro abrasive polishing are so far batch fabricated by two methods: (1) coating silicon tips with diamond films [1], or (2) molding diamond in pits etched in a sacrificial substrate, bonding the sacrificial substrate to another substrate or electrodepositing a handling chip, followed by dissolving the sacrificial substrate [2]. While the first method results in tips having their radius limited by the thickness of the coating diamond, the second implies a costly bonding and release process, as well as difficulties in thoroughly filling high aspect ratio apex of molding grooves with diamond at the nanoscale. Here we explore the fabrication feasibility of sharp diamond tips by direct etching, using ultrananocrystalline diamond (UNCD®, [3]) as a starting material, and a cap-precursor-mask scheme (Fig.1) for reactive ion etching of diamond, similar to some Si tips fabrication methods [4].

The challenge in this process is that the control and fine tuning of the etching anisotropy of UNCD must be sufficient for generating high aspect ratio tips, but also have the necessary isotropy to provide underetching of the precursor cap and sharpening of the delineated diamond tip. We explored the etching rate, selectivity (UNCD versus SiO_2 cap etching) and etching anisotropy of the O_2-SF_6 ICP plasma in a range of O_2/SF_6 flow ratios, RIE/ICP power ratios, and substrate temperatures (from -100 ^oC to 400 ^oC). Various shape of tips – conical, pyramidal, star-shaped (Fig.2)– were produced with 30 keV e-beam lithography and ICP-RIE, with tip radii down to ~25 nm. Further evaluation and optimization is in progress for reproducibility and scaling to large arrays of probes and wafer-scale processing.

References

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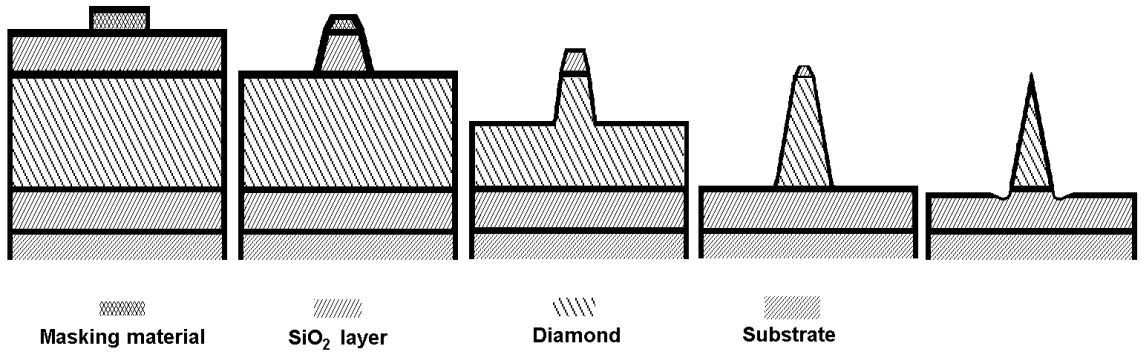

Fig. 1. Fabrication of UNCD tips by direct ICP-RIE etching starting from a SiO_2-capped precursor.

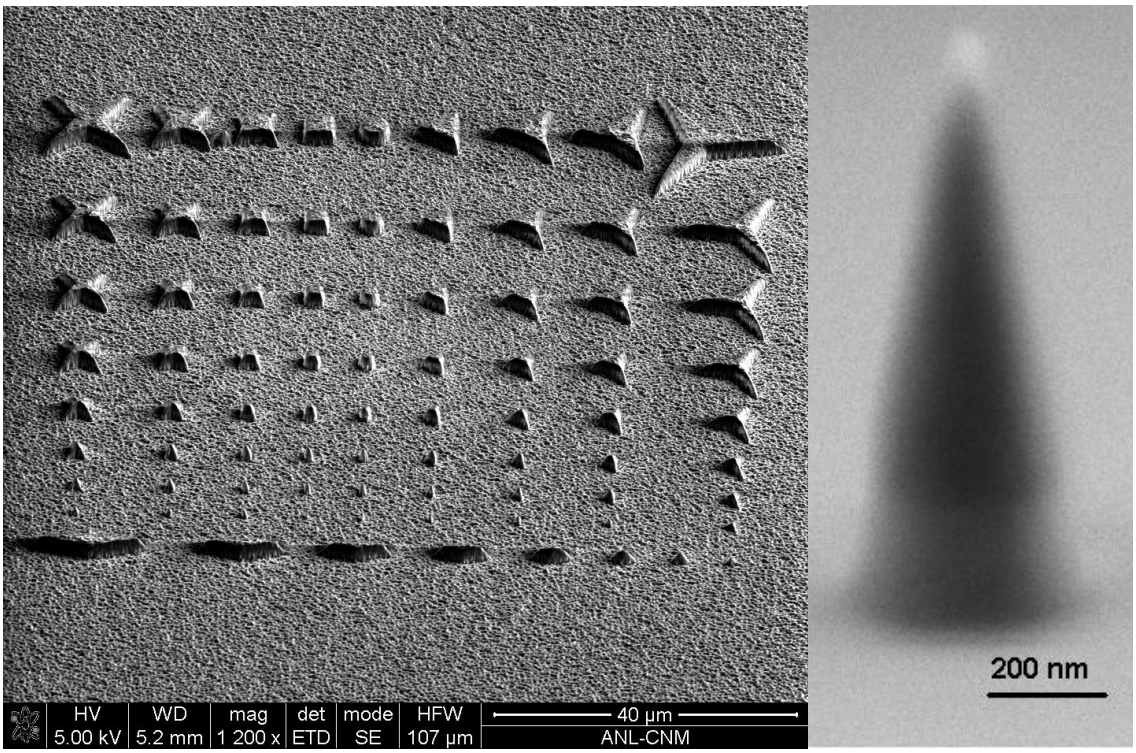

Fig. 2. Various shapes and sizes of UNCD tips on a test pattern and image of an ultra-sharp UNCD tip produced by direct etching.