Ion Multi-Beam Nanopatterning for Photonic Applications: experiments and simulations, including study of precursor gas induced etching and deposition

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Sputtering and gas-assisted etching/deposition by focused ion beams are presently used, e.g., for integrated circuits modification, rapid prototyping of photonic structures and photomask repair. With the development of tools providing massively parallel focused ion beams[1] higher throughput will be possible, and new applications will emerge.
Using the CHARPAN – Charged Particle Nanopatterning Tool[1,2] resistless 10 keV Argon ion multi-beam kinetic sputtering has been performed on Si wafer surfaces realizing examples of photonic structures with depth of 100 nm and 250nm, respectively. Examples are shown in Fig 1.
Using the IonShaper®[3] simulation software, which takes into account sputtering and redeposition effects to the 2nd order, an excellent agreement between theory and experiment has been obtained as shown in Fig 2a, but only when using IMSIL[4] instead of SRIM for the sputtering and ion reflection inputs (Fig 2b).
With precursor gas assisted etching or deposition there is the possibility to achieve high aspect ratio structures (Fig 3). It can be observed that deposited pillars are broader than the ion beam[5]. This effect can be explained by the range of the recoils in the pillar[6]. Fig 3 shows simulations, using a new recoils-based algorithm, for gas-assisted etching and deposition when using different ions and energies for blur conditions achievable with the CHARPAN Tool. Experiments will be conducted with a newly developed gas injection system for the CHARPAN tool.

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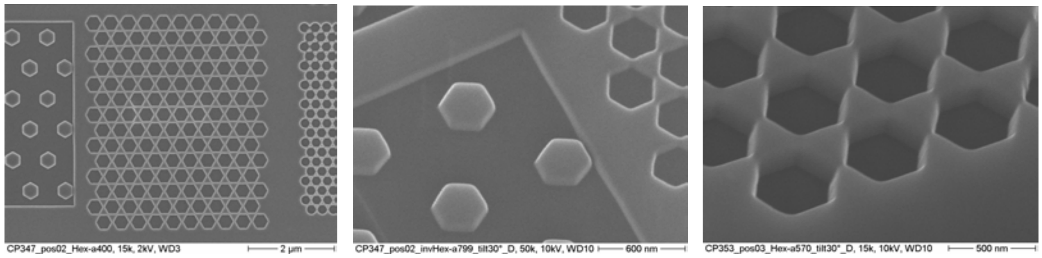

Fig 1: Examples of photonic structures realized with resistless 10 keV Argon ion multi-beam sputtering

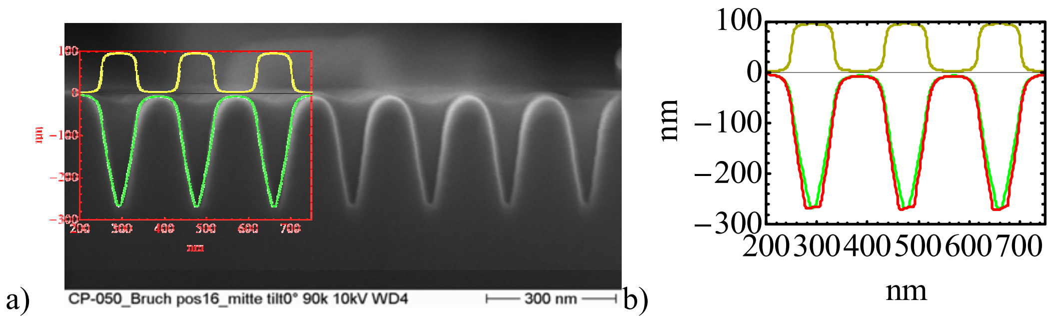

Fig 2: a) Comparison between IonShaper® simulations and 10 keV Ar^+ multi-beam sputtering of Si (top: assumed ion beam intensity profile for the simulation); b) Comparison of IonShaper® simulations when using IMSIL (green) and SRIM (red) inputs, (top: assumed ion beam intensity profile)

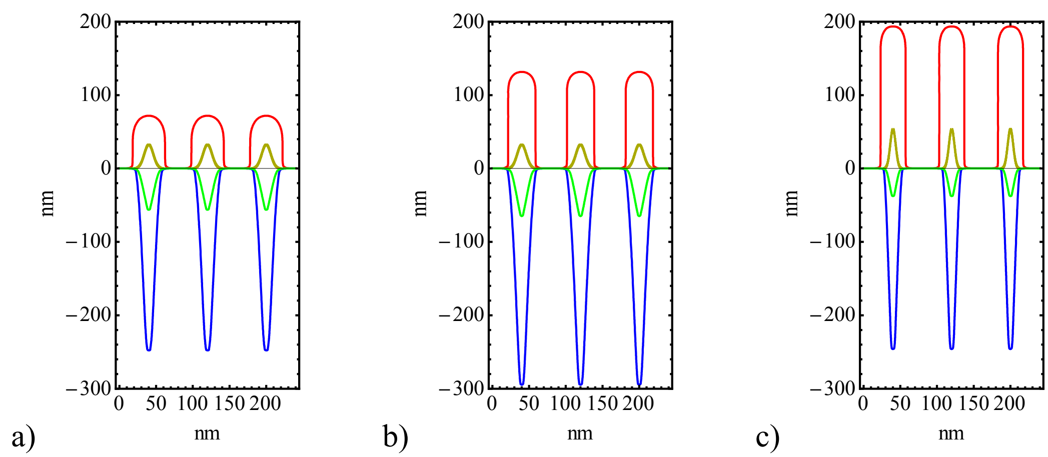

Fig 3: a) Comparison of IonShaper® simulations sputtering (green), precursor gas assisted etching (blue) and deposition (red) for 10 keV Ar^+ with 14 nm FWHM blur (yellow: ion beam intensity profile); b) for 10 keV Xe^+ with 14 nm FWHM blur, c) for 20 keV Xe^+ with 8 nm FWHM blur.