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He^+ Ions for 3D Imaging

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A theoretical model of He^+ ion imaging for acquisition of a stack of image slices with applications in 3D tomography previously showed that ion implantation accumulates with each image scan [1]. The accumulated ion implantation can result in damage to the target depending on image dose per slice and slice thickness. The imaging ion energy and incidence angle will also influence the accumulated ion implantation distribution for a specific target.

Here we continue the theoretical approach where it is assumed that slicing imparts no target damage and the He^+ ion implantation dose and distribution due to a scanning beam imaging each slice within the target volume is monitored. FIG. 1 shows a schematic diagram of the theoretical experimental setup. SRIM [2] is used to determine the initial ion distribution. In this theoretical experimental set up, the He^+ ion energy is 25 keV, the dose is 250 ions per pixel, the slice thickness is 20 nm, the incident angle is 0^o, and the target is Si. The imaging pixel size is assumed to be 10 nm and therefore, the total imaging dose per pixel is 3.2E14 ions/cm^2. Previous work showed no observable defects in Si at 32 keV He^+ doses of 1E15 ions/cm^2, amorphization of Si at 5E16 ions/cm^2, and nanobubble formation in Si at 5E17 ions/cm^2 [3]. The starting energy and dose per slice in this theoretical work is much less than that needed to initially amorphize Si.

FIG. 2 shows the He^+ ion dose distribution into the target volume after imaging the 1st, 5th, 10th, 15th, and 20th slice. Note that the initial peak concentration level and the projected range occur below the surface at ~ 250 nm and that the total ion range reaches a depth of ~ 400 nm. Since the slice thickness for this experiment is much less than the projected (and total) range, the accumulation and retention of ions within the volume as measured from each new surface created by the slicing occurs with the 2nd slice onward as shown in FIG. 2. Note that with each subsequent slice, part of the previous distribution 20 nm from the surface is removed, and the same imaging dose is added to the remaining distribution to create a new distribution which pushes the peak implantation concentration value towards the surface. In this case, steady state conditions are met when the peak concentration level reaches the surface, i.e., after the depth of the original distribution has been fully removed via the slicing process. Thus, after ~ 20 slices the distribution of ions will remain the same for each subsequent slice. This is analogous to the situation for steady state sputtering whereby an increase in dose merely recedes the surface, but does not change the implantation concentration distribution [5]. For the experimental conditions presented, the dose accumulation in the volume is less than that required to amorphize or form nanobubbles in Si and thus, this could provide for damage-free 3D imaging conditions.

References

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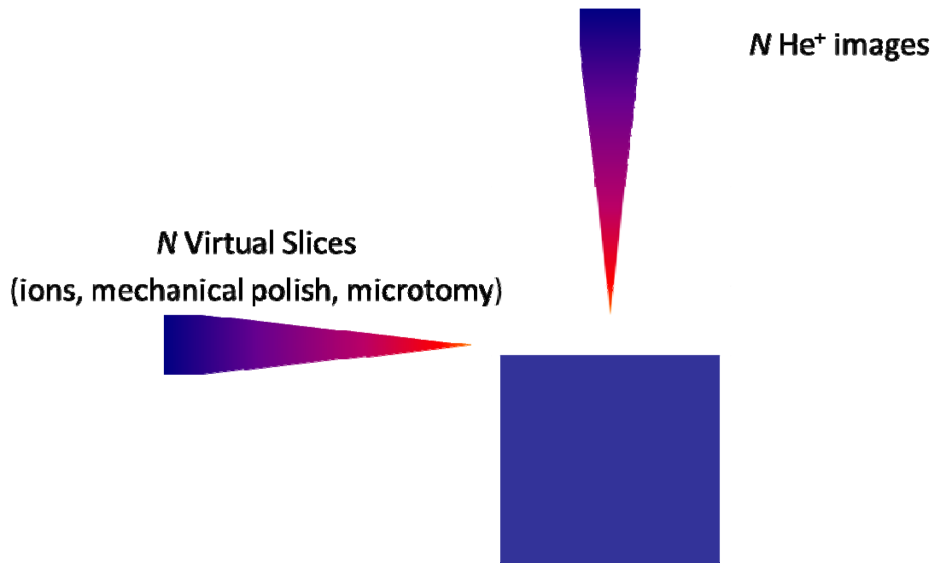

FIG 1. A schematic diagram of the theoretical experimental setup where a scanning He^+ beam collects an image after each slice.

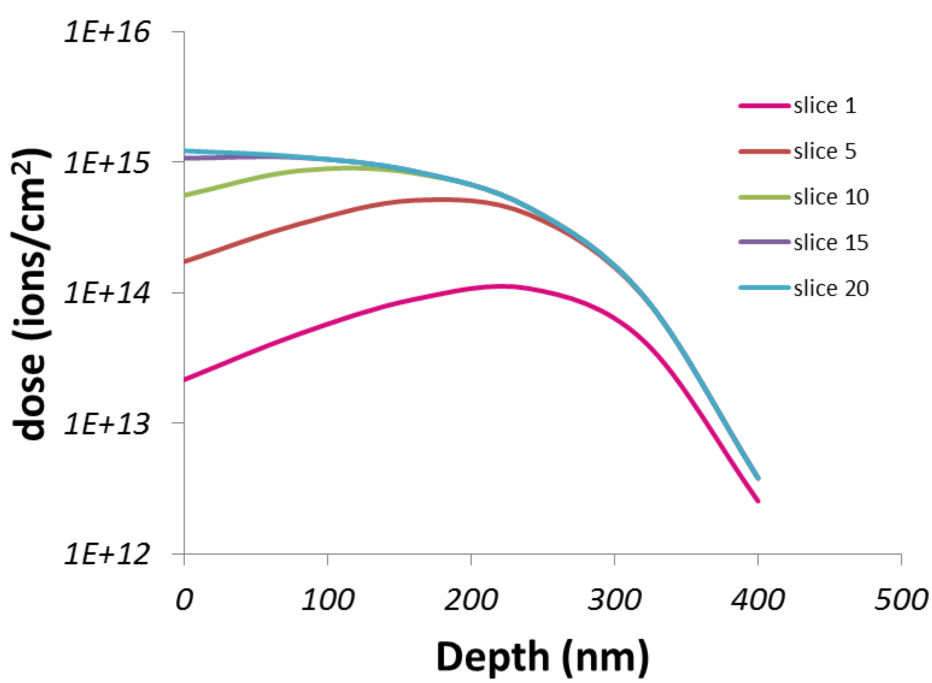

FIG. 2. The distribution of 25 keV He^+ ions into Si after 1,5,10,15, and 20 slices, with a starting dose per slice = 3.2E14 ions/cm^2. Each slice is 20 nm.

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