Scaling analysis of AFM images for roughness evolution during oxidation of splitted SOI wafers

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Surface roughening of thin SOI film is undesirable and can lead to degraded performance of various discrete electronic devices. This is especially true as the dimensions of advanced thin-film devices continue to shrink. Hydrogen implanted silicon layers have been successfully used for ultra thin SOI production by method named Dele-Cut technology. The main advantage of this technology is a high quality thermal buried oxide (BOX) under top silicon layer [1]. If the bonding interface lies between SOI and BOX contrary to Smart Cut [2], the flatness of this interface can be extremely high as initial one for the surface of silicon wafer. The flatness of top surface of SOI film is another important parameter for ultra thin SOI structures. It depends on the method of SOI preparation and thinning procedure.

The aim of the effort was understanding of the surface morphology evolution, its change during thinning, and ultimately exacting control over the surface and interface roughness. We present an experimental investigation of the surface evolution and scaling of SOI thin film surfaces during production and thinning, studied by AFM (Fig.1). . Structural measurements of interfaces were carried out using high-resolution and transmission electron microscopy (HRTEM) cross section.

The initial thickness of silicon top layer (d_{Si}) was 600 or 200 nm. Silicon film of SOI structures were reduced to the final thickness by layer-by-layer oxidation at 1000^{o}C in an atmosphere of dry oxygen and oxide removal by diluted HF dip. Oxidation of SOI was done step-by-step in wet and dry and only in dry oxygen atmosphere at 1000^{o}C for ≥200 nm and ≤100 nm oxidized Si film thickness respectively and atomic force microscopy (AFM).

We have shown that oxidation is really smooth and slowdown at the SOI thickness less than 10 nm following oxidation induced defect and stress generation. We investigated the thickness effect on the surface morphology of thinned SOI films. We also studied the dynamic evolution of surface morphology with oxidation at an elevated temperature. It was shown that during thinning the SOI surface evolves according to a power law and experienced a smoothing transition after the film thinning to a critical thickness. Secondly, we obtain that static roughness exponent a and lateral correlation length L_c are found to be $\alpha = 0{,}7\pm0.1$ and $L_c = 0.9$ µm and 1.5 µm for initial and oxidized SOI wafers (Fig.2).. Layer-by-layer oxidation allows to obtain RMS surface roughness (R_q) close to 0.5 nm. There is a strong transition in roughness exponent to $\alpha = 0{,}4\pm0.1$ and $L_c > 10$ µm due to interface diffusion and SOI layer thinning below 50 nm.

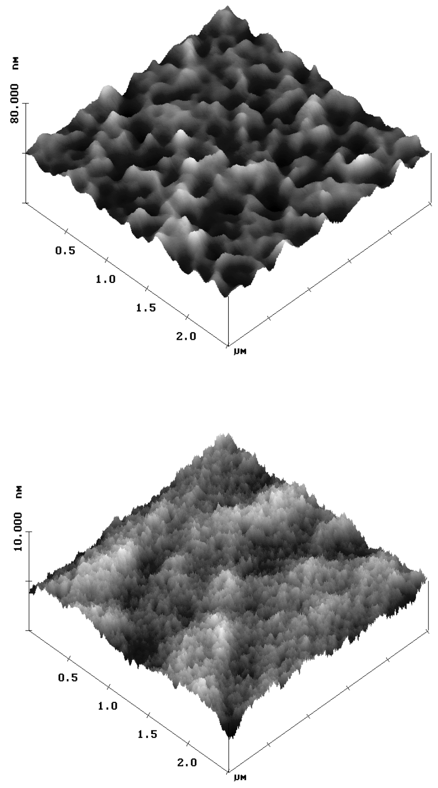

FIG. 1. AFM images of a thick SOI film (330 nm-top, R_q =3.4 nm) and after layer by layer oxidation and removal of thermal surface oxide in thin SOI film (19 nm –bottom, R_q =0.4 nm). The scale bar is in nm.

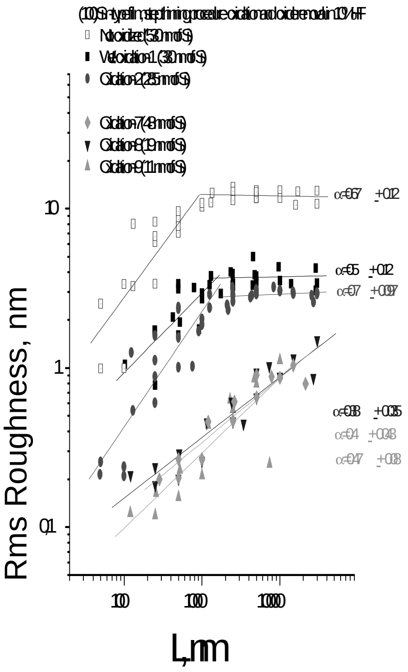

FIG. 2. Static roughness exponent ζ and lateral correlation length L_c for initial, oxidized and ultrathin SOI wafers

c3Nk

References

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[2] M. Bruel. Electron. Lett. 31, 1201 (1995).