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Investigating post-fracture surfaces at the nanometer scale in the SmartcutTM technology

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Extended Abstract

Abstract

The ion implantation using high doses of light elements (H or He) in silicon substrates leads to the formation of a buried damaged layer which contains various crystalline defects ranging from point defects, vacancies/interstitials-hydrogen complexes and nanometric cavities filled with gas, named “platelets”. At the depth of maximum damage, the mechanical stress due to the strained Silicon lattice promotes the development of (100) platelets, parallel to the wafer surface [1]. Upon annealing, platelets grow via an Ostwald Ripening mechanism [2], which modifies their distribution inside Silicon. Eventually, coalescences among neighbours definitively set the opened surface and microcracks appear [3]. When the implanted substrate is bonded to another one, the latter acts as a stiffener and microcracks keep growing until a fracture propagates through the bonded structure. The SmartCutTM technology takes advantage of this effect to transfer a thin Silicon layer on top of an oxidized Silicon substrate, which yields the Silicon-on-insulator (SOI) [4]. Because advanced devices keep requiring better thickness uniformity of the thin transferred Silicon layer, an accurate assessment of the post-transfer roughness and its origin is of great interest. Especially, the ion implantation conditions are a key parameter that controls the distribution of platelets after implantation[5], and hence the post-transfer surface. In this paper, a simple model is proposed to describe the post-fracture surface thanks to a characterization performed usingAtomic Force Microscopy (AFM). Wafer implanted with several implantation conditions were bonded to a Silicon substrate (stiffener) and the whole structure was annealed until fracture occurred. Post-fracture surfaces were characterized by AFM in Peak-Force mode, using a super sharp probe (2 nm radius). The scans were then investigated through spectral analysis, using the 2D Power Spectral Density (PSD). The PSD signals were fitted with a simple three-parameter model which yields the size, height and width of equivalent surface patterns. The validity of this model was established on surfaces exhibiting patterns with various sizes and heights. The post-annealing topography shows remarkable terrace patterns on the surface, corresponding to the fracture path between neighbouring platelets. AFM has thus proven a relevant and sober tool - compared to Transmission Electron microscopy (TEM) - to characterize the implantation defects. The presented model accurately describes the relationship between the FT cut-off frequency and the characteristic size of surface patterns. Furthermore, it displays the impact of hydrogen fluence on both the density of platelets and their vertical distribution in the material. The key role of hydrogen concentration in the nucleation of platelets in Silicon [5] was therefore confirmed. Eventually, the third parameters describing the width of the platelets' edges was found to explain the slope of experimental PSD at high frequencies. This original work shed light on the mechanisms responsible for opening the surface at the nanometer scale in the SmartCutTM technology, which has both fundamental and industrial interest.

Keywords:

fracture SmartCut nanocracks coalescences Atomic Force Microscopy