The Independence of Isotropic Stress Evolution and Anisotropic Pattern Formation During Ion Bombardment of Silicon

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Abstract:

Ar^+ ion bombardment can lead to the formation of self-organized nano-ripple patterns on Si surface under certain ion irradiation conditions. There are some existing theoretical models that attribute the pattern formation to the development of surface stress. In this experiment, we observed the stress evolution of Si (100) wafers under low energy (250 and 500 eV) Ar^+ ion bombardment with a 60° incident angle at room temperature. This was within the regime of self-organized nanopatterning, and was investigated using the real time Multi-beam Optical Stress Sensor (MOSS) method. Our stress development is motivated by the recent results showing the independence of stress and the nano-ripple formation. However, these results showed a trace amount of impurities from the stainless steel (Fe, Cr and Ni) were co-deposited on the sample surface during the ion bombardment. In our experiment, samples were kept clean from any metal contamination during the ion bombardment. The surface compositions of two types of samples were measured by X-ray Photoelectron Spectroscopy (XPS).

Under clean bombardment conditions, stress was found to evolve isotropically in both the x- and y-directions, while post-bombardment Atomic Force Microscopy (AFM) revealed strictly anisotropic ripple patterns oriented parallel to the ion beam projection direction. This directional mismatch between stress evolution and surface patterning confirms their independence, and demonstrates that this independence is an intrinsic property of the ion bombardment process rather than an artifact of metal contamination. These findings suggest that stress-driven mechanisms alone are insufficient to explain nano-ripple formation, motivating further investigation into alternative mechanisms such as curvature-dependent erosion and ion-induced mass redistribution.