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Intermittent Ion Beam Sputtering with Temperature Variation for Controlled Nanopatterning of Silicon Surfaces

Self-organized nanopattern formation on solid surfaces through low-energy ion beam sputtering has emerged as a versatile technique for nanoscale surface engineering. While continuous ion irradiation has been extensively investigated [1–6], the effects of intermittent (pulsed) ion exposure, particularly when coupled with controlled substrate temperature variation, remain comparatively less explored [7].
In this study, we examine the evolution of nanoscale surface morphologies on silicon (Si) subjected to low-energy (500 eV) Ar^+ ion irradiation applied in an intermittent (pulsed) mode, while maintaining a constant total fluence. The substrate temperature is systematically varied during the intermittent sputtering process to assess its influence on surface pattern development. The ion beam, incident at an oblique angle of 67°, promotes the formation of anisotropic triangular features riding on nanoripples.
The investigation focuses on understanding how ON/OFF sputtering cycles, in conjunction with thermal modulation, affect the ordering, orientation, and roughness of the resulting nanopatterns. The results indicate that intermittent irradiation enhances morphological control by enabling surface relaxation and adatom diffusion during the OFF phases, while temperature variation facilitates stress relaxation and structural stabilization.
These findings are expected to provide deeper insight into the thermally assisted evolution of surface morphologies under non-continuous ion bombardment, establishing a novel pathway for achieving high-precision nanoscale patterning. The outcomes will contribute to the development of advanced fabrication techniques for applications in optics, sensing, and nanoelectronics [8-9], while also contributing to the refinement of continuum theoretical models describing surface dynamics under dynamic ion irradiation.
Keywords: Ion Beam Irradiation, Intermittent Sputtering, Nanopattern Formation, Temperature-Dependent Morphology, Atomic Force Microscopy

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