TITLE: SEMICONDUCTOR SURFACE NANOPATTERNING BY LOW ENERGY ION BEAM SPUTTERING

Abstract

We have studied low energy Ar\(^+\) ion beam induced pattern formation on Si(100), Ge(100) and GaAs(100) substrates. For Si surfaces, the role of ion incidence angle, ion sputtering time, ion energy, ion current density, substrate rotation and substrate temperature are investigated. Due to 500 eV Ar\(^+\) ion sputtering, Si surfaces show parallel and perpendicular mode ripples for incidence angles 55°-70° and 80°-85° respectively for fluence 1\times10^{18} \text{ cm}^{-2}. The parallel to perpendicular mode pattern transition occurs at 75° where irregular mound structures are appeared. The temporal evolution of Si surfaces during oblique incidence (65°) 500 eV Ar\(^+\) ion beam sputtering at room temperature show well-ordered ripple nanopatterns at low ion fluences which are superimposed by long-wavelength corrugation at intermediate and high fluences. But at substrate temperature 450°C, the ripples are orthogonally rotated after a certain time of sputtering. The time evolution of surface structures at grazing incidence (75°) 500 eV Ar\(^+\) ion sputtering show dot-like structures for initial sputtering which gradually grow and evolve to cone/needle-like structures, pointing towards the beam direction. After fluence 1.5\times10^{18} \text{ cm}^{-2}, the erosion dynamics follow super-rough scaling behaviour with the set of exponents \(\alpha = 1.6 \pm 0.1\), \(\beta = 0.99 \pm 0.03\), \(\alpha_{\text{local}} = 1\) and \(\beta_{\text{local}} = 0.63 \pm 0.05\). A fixed substrate rotation of 5 rpm during 500 eV Ar\(^+\) ion beam sputtering results hexagonally ordered at 75° for fluence 1\times10^{18} \text{ cm}^{-2}. The TEM study of the dot microstructure shows that the dots are crystalline and are not induced by metal contaminants. The pattern formation on Ge surfaces has been investigated for 30 eV Ar\(^+\) ion irradiation at normal incidence and at elevated temperatures for fluence 1\times10^{19} \text{ cm}^{-2}. Within 225°C to 400°C, the grown patterns resemble to the checkerboard patterns of alternating mounds and pits. The results support a growth model that incorporates the effects of diffusion-bias and slope selection. For GaAs(001) surfaces, the pattern formation have been studied for 30 eV and 1 keV Ar\(^+\) ion bombardment at elevated temperatures. For both cases, the ripple patterns are formed with its ridges along the \(<1\bar{1}0>\) direction but for the second case, the ripples are perfectly parallel and defect free. For 30 eV ion sputtering, the pattern formation is driven by Ehrlich–Schwoebel barrier and for 1 keV ion sputtering, a coupled continuum equations, involving height and compositional variations and plugged with the diffusion bias, can reproduce remarkably well experimental results.