Seminar

Institute for Plasma Research

Title : Low energy ion beam nanopatterning of Co_xSi_{1-x} surfaces

Speaker: Dr. Basanta Kumar Parida
Indian Institute of Technology Ropar, Punjab

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Abstract:

Ion beam sputtering of a solid surface has the potential to create rich varieties of nanoscale periodic patterns by varying the beam parameters. This bottom-up approach of nanopatterning has been serving as an easy and low cost fabrication technique close to half a century. Nanoripples and nanodots are primarily found to form on most of the solids including semiconductors, metals, insulators, etc. due to ion irradiation. With a large number of experimental and theoretical work, this field has been a fascinating one for surface physics researchers. The nature of nanostructures formed on monoelemental and binary compound surfaces has motivated researchers due to their stark differences on these surfaces. This is due to the individual sputtering yield and diffusivity of elemental species in the binary compounds. However, experimental work on compound surfaces are less compared to theoretical findings. This work focuses on a binary compound containing Co and Si as the constituent elements. The binary compound has been sputter deposited on Si substrates. The morphologies of the as-grown samples and those irradiated under varying ion beam parameters are characterized by various surface sensitive techniques.

An experimental study of ion beam sputtered nanopatterning on CoxSi1-x surfaces has been conducted. Varieties of patterns formed have been explored with low energy Ar+ and Xe+ ions at different ion beam parameters. At oblique ion incidence and a constant ion fluence, varying the energy of ions between 500-1200 eV, a clear morphological transition has been observed where self-organized nanoscale ripples change to micro-scale ellipsoidal structures. The instabilities due to the differential diffusivities and sputtering yields are explored. Effect of individual ion species and their momentum transfers to substrates have been studied for a fixed fluence and different incident angles.

Ion beam induced well-ordered nanoripples aligned parallel to the ion beam direction are obtained using Ar+ ions at 500 eV at an oblique incidence of 67o within the irradiation time of 10-60 mins. Anisotropicity in electrical conduction properties for the patterned surface has been presented. Electrical measurements on the pristine and patterned surfaces show strong dependency on the patterning of the surface. Electrical conduction sets in above a threshold voltage (~5 V) which is required to overcome the trapping barrier as a result of anisotropic surface patterning. The surface resistance is found to be dependent on the ripple amplitude of the patterned surface.

Impact of initial stoichiometry of binary compound on surface nanostructure formation with low energy ion irradiation has been studied. Within a narrow window of stoichiometric variation, selforganized nanoripples have been observed and the ripple structures are well formed for stoichiometric ratios of 40:60 for Co:Si. Nanoscale ripples start growing for a concentration of about Co22Si78. The root mean square (rms) roughness shows an inverse coarsening trend in the ripple formation regime. The evolution of different morphologies has been corroborated from the behavior of power spectral densities (PSD). Correlation lengths are extracted from atomic force microscopy (AFM) images to corroborate the ripple formation region only within a specific stoichiometric range.

The effect of swinging of Co69Si31 binary compound during low energy ion beam irradiation has been explored. Stochastic nanoscale dots are observed at lower angles of swinging. Nanoscale cauliflower like structures are observed at higher angles. Linear growth trend in roughness is observed with increasing angle. With the increasing rotation speed of the azimuthal swing, the number density of the nanocauliflowers grows up. Finally, the thesis has been summarized with some future possibilities from an application point of view.

Keywords: Ion beam sputtering, binary compound, nanopatterns, atomic force microscopy, surface morphology