Seminar

Institute for Plasma Research

Title: Nanopatterns Formation by Low-Energy Ions: Experiment and Simulation

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Date: 16th May 2023 (Tuesday)

Time: 11.00 AM

Venue: Seminar hall, IPR

Join the Talk: Online

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Abstract: Interaction of low-energy ions with solid surfaces has the potential to produce self-organized nanoscale patterns over the surfaces leading to various potential applications, especially in magnetism, microelectronics, optical and in biomedical. Different types of patterns form after low energy ion irradiation such as nanoripples, nanodots, facets, holes etc. Recently, it has gathered substantial interest and has been the focus of studies, i.e., how such patterns evolve on the surface and their dependency on various experimental parameters (Ion Energy, Angle of Incidence, Fluence, material etc.). Despite the significant technological potential of this nanostructuring method, there is still inadequate understanding of the underlying physical processes.

The current study explores the formation of nanoscale triangular features riding over nanoripple patterns induced by low-energy (<1 keV) ion beams on *Si* and *Ge* surfaces. The evolution of these features under different ion beam parameters, including energy, fluence, and angle, was examined at both room temperature and elevated temperatures. The study found that the lateral growth of triangular features increased (95 – 350 nm) with ion fluence ($5 \times 10^{17} - 1.3 \times 10^{19}$ *ions/cm²*), while the base angle (ϕ) remained nearly constant (for 300eV ($\phi \sim 40^\circ$) and for 500 eV ($\phi \sim 45^\circ$)) [1]. Our experiment reveals that the base angle of triangular features increases gradually from 29˚ to 45˚ for the ion incident angle ranging from 60˚ to 70˚. Most importantly, the number of elevated triangles was observed to be greater than depressed triangles, and both lateral length and base angle decreased with increasing substrate temperature [2]. Similar findings were observed on *Ge* surfaces with *Xe* ion irradiation [3]. In numerical simulations, the influence of dispersion on the evolution of these triangular patterns in the modified Anisotropic Kuramoto-Sivashinsky (AKS) equation is studied, which includes an improved approximation to the sputtering yield. Numerical investigations of the equation of motion (EOM) reveal that the patterns coarsen for long times. It is observed that dispersion leads to formation of triangular regions which are in two forms: elevated triangles and depressed triangles, as observed experimentally. It has been found that dispersion is the important phenomena responsible for the formation of triangular structure over ripple patterns. For a strong dispersive coefficient (α) in EOM, highly ordered parallel-mode ripples form. The angle dependency is observed numerically in curvature-dependent coefficient and diffusion replicates the temperature-induced effect on patterns produced by low-energy ion beam. Finally, a study is carried out on a compound material (soda-lime glass) to observe pattern formation and understand their dynamics with respect to improved AKS equation. It is observed that there is transition of ripples to terraced topography when both ion fluence and ion energy is increased. This study is followed with application of making surface hydrophobic in nature by tuning ion beam parameters.

References:

[1] Emergence of triangular features on ion irradiated Silicon (100) surface
Sukriti Hans, Mukesh Ranjan, *Surface Science* 715 (**2022**) 121951.
[2] Temperature influence on the formation of triangular features superimposed on nanoripples produced by low-energy ion beam.
Sukriti Hans, Basanta Kumar Parida, Vivek Pachchigar, Sebin Augustine, Mahesh Saini, KP Sooraj, Mukesh Ranjan, *Surfaces and Interfaces* 28 (**2022**) 101619
[3] Dynamics of nanoscale triangular features on Ge surfaces
Sukriti Hans, Basanta Kumar Parida, Vivek Pachchigar, Sebin Augustine, KP Sooraj, Mukesh Ranjan, *Nanotechnology* 33 (**2022**) 405301.