Nano-structuring of CaF_2 surfaces by slow highly charged ions: simulation and experiment

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Synopsis The impact of individual slow highly charged ions (HCI) on insulators can create nano-scale surface modifications. We present recent experimental results on nano-hillock and etch pit formation on CaF_2, where the appearance of surface modifications is observed only above a threshold projectile potential and kinetic energy depending on the type of damage. A proof-of-principle molecular dynamics simulation offers insights into the early stages of damage formation.

We investigate surface modifications on calcium fluoride (CaF_2) due to the impact of individual slow highly charged ions.

A systematic study of surface modifications [1] observed by atomic force microscopy reveals that two different types of surface modifications can be created on CaF_2, namely “nano-hillocks” and “etch pits” where the latter are only visible after a suitable etchant has been applied to the irradiated surface.

The creation of hillocks and etch pits is strongly dependent on the potential and kinetic energy of the impinging projectiles (Fig. 1, left). For low energies, no surface modifications are found while for larger energies only etch pits but no hillocks are observed. For even larger potential energy, hillocks are observed. They can be turned into etch pits upon application of the etchant. These results suggest the existence of two different thresholds for nano-hillock and etch-pit creation.

To understand the origin of these two thresholds [2], we model surface restructuring by HCI impact in a three-step model based on the scenario that the primary energy transfer from the HCI to the electronic system and subsequently to the lattice proceeds on a shorter time scale than the ensuing atomic rearrangements and structural changes. We discuss how the primary energy transfer leads to strong local heating near the impact point and follow the evolution of the heated region with a proof-of-principle classical molecular dynamics simulation (Fig. 1, right). Assuming that the main driving force for surface modifications is heating and subsequent melting near the impact point of the HCI, we observe two thresholds linked to hillock and etch pit formation in agreement with experiment.

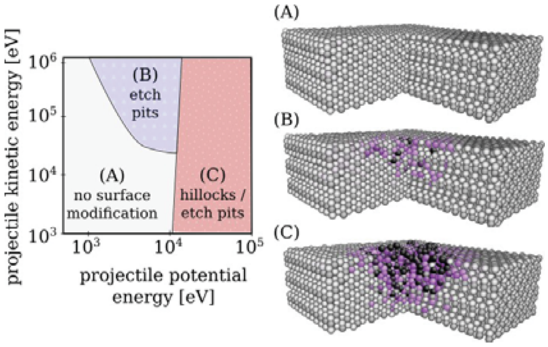

Figure 1. Left: Experimental results showing the dependence of surface modifications on projectile parameters [1]. **Right:** Simulation results corresponding to unperturbed surface (A), etch pits (B), and hillock formation and etch pits (C) [2]. The color scale indicates dislocations.

References

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