Surface nanostructuring of CaF$_2$(111) by irradiation with slow highly charged ions

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ABSTRACT
We have investigated the surface of CaF$_2$(111) single crystals after irradiation with slow highly charged ions (HCI). Scanning force microscopy (SFM) reveals the creation of ion-induced surface nano-hillocks. These hillocks appear at a well-defined potential energy threshold of about 14 keV. Estimations of the energy density deposited suggest that the threshold is linked to a solid-liquid phase transition ("melting") on the nanoscale. With increasing potential energy, both the basal diameter and the height of the hillocks increase, while no clear dependence of these parameters on the kinetic energy of the ion is observed. The present results reveal a remarkable similarity between this predominantly potential energy driven process and track formation by the thermal spike of swift (GeV) heavy ions.

SCENARIO
Slow highly charged ions (1) form „hollow atoms“ in front of a target surface, leading to substantial electron emission [1]. Upon impact, their large potential energy is deposited mainly into the electronic subsystem (blue) of the target. In this respect, the interaction is closer related to swift heavy ion irradiation (3), which is dominated by electronic stopping, than to slower heavy ion irradiation (2) with dominant nuclear stopping (red). Using slow HCI, the interaction is limited to the surface of the target, eliminating the problem of radiation damage to the bulk.

SWIFT HEAVY ION TRACKS

An extension of the inelastic thermal spike model [5] to the case of slow HCIs calculates the energy transferred to target atoms via phonon coupling of the hot electrons produced by the HCI impact [6]. The model calculations show that the observed thresholds for hillocks formation are correlated to the phase transitions of melting and sublimation.

References

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in the bulk of various ionic fluoride single crystals [5], e.g. CaF$_2$, accompanied by hillock-like nanostructures protruding from the surface.

preliminary results at very low projectile velocity

At the Two Source Facility at FZD in Rossendorf, HCIs from an EBIT were decelerated to energies as low as 150 eV/q. Similar nanostructures are observed in this velocity regime, where the kinetic energy of the HCIs is much less than their potential energy.