Formation of surface nanostructures on rutile (TiO_2): comparative study of low-energy cluster ion and high-energy monoatomic ion impact

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The formation of nanostructures on rutile (TiO_2) surfaces formed after the implantation of kiloelectronvolt-energy Ar^{+}_{n} cluster ions and megaelectronvolt- to gigaelectronvolt-energy multiply charged heavy ions (I^{q+}, Ta^{q+} and U^{q+}) is studied. Despite the differences in stopping and energy transfer mechanisms between the kiloelectronvolt-energy cluster ions and megaelectronvolt-energy monoatomic ions, their impacts lead to a similar type of surface damage, namely craters. For the cluster ion implantation the craters are caused by the multiple-collision effect (dominated by nuclear stopping) and the high density of energy and momentum transferred to the target, while for the case of megaelectronvolt multiply charged ions the craters are probably formed due to the Coulomb explosion and fast energy transfer caused by the electronic stopping. At ion energies in the gigaelectronvolt range, nanosize protrusions, so-called hillocks, are observed on the surface. It is suggested that electronic stopping leads to the formation of continuous tracks and the transferred energy is high enough to melt the material along the whole projectile path. Elastic rebound of the tension between the molten and solid state phases leads to liquid flow, expansion and quenching of the melt, thus forming the hillocks. Atomic force microscopy measurements carried out under different environmental conditions (temperature and atmosphere) suggest that the damaged material at the nanosize impact spots has very different water affinity properties (higher hydrophilicity or water adsorption) compared with the non-irradiated rutile surface.