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Photon Emission Induced by keV Ions Transmitted Through Single-Crystalline Si Membranes

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Ions penetrating matter cause a number of different electronic excitations in the material and in the projectile itself. The investigation of ion induced photon emission contributes to a better understanding of the exact processes taking place. We investigate the photons emitted upon transmission of keV He and Ne ions through thin single-crystalline Si membranes. The measurements were recorded with pulsed ion beams at the Time-of-Flight Medium Energy Ion Scattering (ToF-MEIS) setup at Uppsala University, which enables us to study processes with a time-resolution better than one ns. As the number of ions included in a single ion pulse is statistically well below one, we were able to perform coincidence measurements i.e. we can directly link a photon to the deexcited ion recorded up to a few 100 ns later. These coincidence measurements were performed for randomized and channeled ion trajectories while separating the charges of the transmitted ions. Our results show that the photon emission is constant for any angle relative to the surface normal if photons emitted at the rear surface of the membrane are measured. In contrast, photon emission is drastically reduced and angular dependent if the front surface is investigated instead. We can show that the behavior on the rear surface is due to the absolute majority of the recorded photons being created by electronic deexcitations of the transmitted projectile behind the surface. Therefore, for He projectiles, detection of the 2+ charge state is suppressed if the coincidence condition is applied. The excited projectiles are found to travel up to several centimeters from the surface of the sample before deexcitation. For He ions, the probability that an ion exiting in a specific charge state emits a photon remains independent of the crystal orientation. We conclude that the same processes which determine the charge state of the transmitted projectile also determine if and how the transmitted projectile is excited.

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