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Sputtering of cryogenic films of hydrogen by keV ions: Thickness dependence and surface morphology.

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The solid hydrogen isotopes are the most volatile solids which exist in equilibrium with vacuum. For bombardment with 10 keV hydrogen ions the sputtering yield of these solids ranges from 200 D_2/ion for the less volatile solid deuterium up to 1000 H_2/ion for the most volatile solid, solid hydrogen [1]. The sputtering of thick films takes places via non-radiative electronic transitions which eventually liberate energy for ejection of the sputtered molecules.
Sputtering data for solid hydrogen have been obtained at the experimental setup at CERN [2,3] and sputtering data for solid hydrogen and deuterium at the setup Risø [2]. In both setups the films were deposited on a metal substrate kept at a temperature of 2-3 K, and the thickness ranged from a fraction of a monolayer up to several thousands monolayers. For ultrathin films the interaction between the underlying metallic substrate and the ion is important, but it is not clear how this process works.
The sputtering yield of the film depends strongly on the thickness. The sputtering yield decreases with two orders of magnitude from a maximum of about one monolayer (~ 10^{15} H_2/cm^2) with increasing film thickness *d*. Even for very thick films - 10 times thicker than the ion range - the yield continues to decrease as $d^{-3/2}$ for films preparedint thermodynamic equilibrium. This surprising dependence on average thickness even for films much thicker than the ion range can only be explained by a thickness dependent surface morphology, e.g. the film molecules aggregate as clusters on top of a uniform film of a few monolayers. Under these circumstances some ions can still reach the substrate even for an average film thickness larger than the range and influence the sputtering yield. Only isotopic combinations of the hydrogens exhibit such a behavior with a large surface mobility required to form clusters at these low temperatures. The dependence of the sputtering yield will be discussed in terms of the surface morphology.

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