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Rough-surface effect on sputtering of Cr bombarded by low-energy He plasma

F.-J. Chang[1], D. Nishijima[2], G. R. Tynan[1,2]
[1] Department of Mechanical and Aerospace Engineering, University of California San Diego
[2] Center for Energy Research, University of California San Diego
e-mail (speaker): fchang@eng.ucsd.edu

In fusion devices, the erosion of plasma-facing components (PFCs) limits the lifetime of PFCs and influences the migration of impurities inside the plasma and the vacuum vessel. Therefore, research of fundamental erosion mechanisms, such as physical sputtering, is critical for long-duration operations of fusion devices.

Recently, the effect of surface morphology on the sputtering of a material surface has attracted intense research interests. It was discovered that microscopic cones formed on a Cr surface during plasma exposure, if heavier impurities, such as Mo or Ta, were present on the surface [1]. ERO2.0 simulations showed that, due to the redeposition of eroded impurities onto nearby cones, rough surfaces reduced the sputtering yield and generated more backward-scattered, i.e. the opposite direction to the incident ions, angular distributions of sputtered particles [2].

In our previous work in the PISCES-A linear plasma device [3], hyperspectral imaging (HSI) observations showed that, when microscopic cones were growing on the surface of a Cr target exposed to a He plasma, the 2D profiles of the Cr I line emission intensity were elongated in the axial direction and the intensity dropped. While these results were qualitatively explained by the effect of rough surfaces, a quantitative study is necessary to understand the influence of the observed surface morphology on the sputtering behavior in more detail.

In the present work, the growth of microscopic cone-like structures on a Cr surface under He plasma exposure at a low incident ion energy of ~106 eV in PISCES-A is observed with scanning electron microscopy (SEM), while 2D emission profiles of the Cr I line intensity are measured with an HSI camera during the plasma exposure. The emission profiles at different incident ion fluences, ϕ_i, are compared with those simulated for the corresponding surface morphology using the GITR Monte Carlo impurity transport code coupled with the SDTrimSP binary collision code. With the growth of cones, the experimental 2D emission profile becomes axially elongated and the emission intensity significantly drops, both successfully reproduced in the simulations as well. The simulation reveals that the deposition of sputtered Cr atoms onto the neighboring cones results in the more backward-scattered angular distributions with a significant reduction of the sputtering yield. The consistency between the experimental and the simulation results, as shown in Figure 1 for the sputtering yield and in Figure 2 for the angular distributions, indicates that the formation of cones observed with SEM leads to the changes in the 2D emission profiles observed with HSI, and thus in the angular distributions of the sputtered particles.

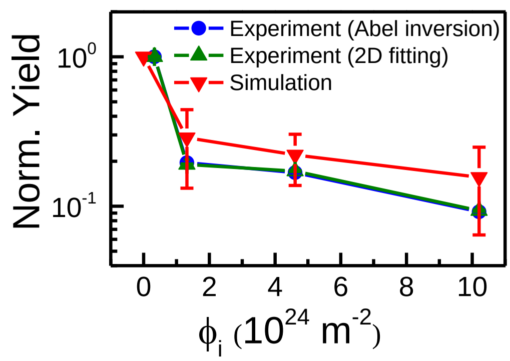

Figure 1. Sputtering yields at different ϕ_i, normalized by the maximum values, obtained from simulations and from experiments through two different methods.

References
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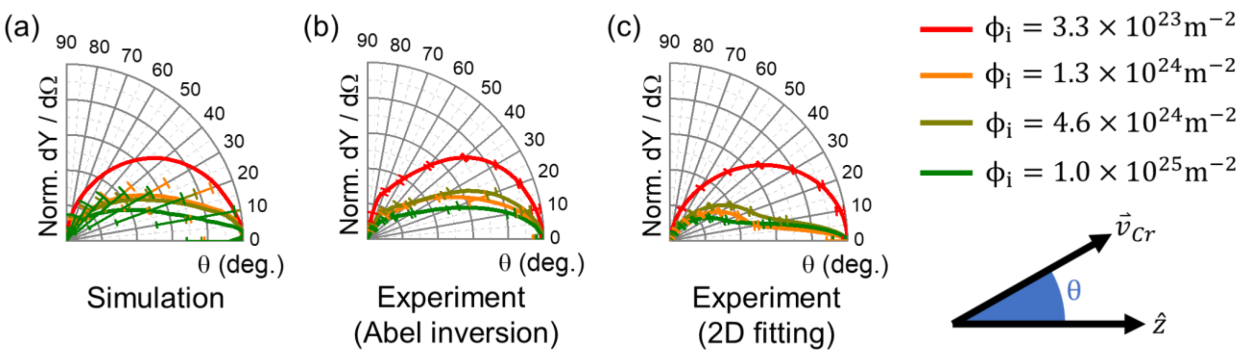

Figure 2. Normalized angular distributions of sputtered Cr particles at different ϕ_i, expressed by the differential sputtering yield per solid angle, $dY / d\Omega$, obtained (a) from simulations and (b)(c) from experiments through two different methods.