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Sputtering of W-Pd Bimetallic System under Nitrogen Plasma Impact†

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It was suggested earlier [1] to use two-layer (bimetallic) diffusion systems, which comprise of rather thick palladium substrate and erosion resistant coating, e.g., tungsten on the plasma facing surface, for active control of hydrogen recycling process in thermonuclear fusion devices. In order to choose the optimal performances of tungsten-palladium bimetallic system, it is needed to carry out thorough investigations of its properties under plasma impact, in particular, its erosion behavior in hydrogen saturated or non-saturated states. Such researches could be useful not only for fusion problem, but for numerous plasma applications (hydrogen power engineering, plasma chemistry, biomedical applications, etc.), when above mentioned diffusion system could be used for hydrogen isotopes puffing through cathodes directly in reaction zone. Tungsten protective coatings on palladium substrate were produced by vacuum-arc method and by sputtering in magnetron-type discharge (so-called "rodtron" configuration) in argon atmosphere. So the different W-film structures and morphologies were realized. For a comparison also investigated were virgin samples made of pure Pd. The experimental setup for plasma impact studies was device with mirror Penning discharge, which was ignited at magnetic field 0.05T in nitrogen at pressure $2{\cdot}10^{-3}$ Torr. The ion energy values were 0.8 keV – 1.6 keV, irradiation doses were 10^{18}-10^{20} ions/cm^2. Erosion coefficient values were measured by weight loss method. Before sputtering experiments under nitrogen plasma impact, the current–voltage characteristics were measured with and without small hydrogen admixture. It was shown that there is no significant influence of hydrogen admixture in the working gas on plasma performances. Such behavior is explained by the fact that plasma column in mirror Penning discharge has no contact with the wall surface, so surface reactions, influencing recombination rate, do not play an essential role. It was shown that erosion coefficient weakly depends on ion energy for both Pd and W-Pd system and its value (1.3 at./ion for Pd and 0.2 at./ion for W) is in a good agreement with literature data on sputtering by monoenergetic N^+ ions. But practical independence of sputtering rate on hydrogen saturation of Pd up to concentration about H/Pd = 0.65 was unexpected result. The point is that in some recent works, e.g., [2] it was shown the possibility to decrease material erosion by hydrogen/deuterium saturation to high concentration. Possible mechanism is discussed to understand the reason of such differences in an erosion behavior. For hydrogen saturated W-Pd system the new kind of radiation damages were observed caused by not homogeneous adhesion of relatively thick ($\approx 10\mu$) W-films and the changes of sample form from flat to convex. The measured dose dependencies are different for coatings made by different methods. For W-films made by vacuum-arc sputtering, the erosion coefficient value is near to that for bulk tungsten, and it does not change to dose about $4{\cdot}10^{19}$ ion/cm^2. At the further dose increase, sputtering rate increases extremely up to typical values for bare palladium due to full film disruption. In the case of W-coatings made in magnetron-type discharge, erosion coefficient monotone increases on exposure time. Mechanisms are suggested and discussed to explain such erosion behavior.

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Diffusion of Cathodic Arc Plasma in a Magnetic Filter†

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A model based on Bohm diffusion is developed to investigate the optimal bias of a magnetic filter used in conjunction with a cathodic arc plasma source. Details regarding the derivation of the model as well as experimental results to corroborate the model are presented. According to the model, the optimal bias at which the magnetic duct produces the maximum plasma output is related to the ion speed, ion mass, ion charge state, and plasma density in the filter. Even though the magnetic field is taken into account, it is not a variable in the final equation. Our experimental results confirm that the magnetic field has almost no influence on the optimal bias when the magnetic field is above 400G. The presented work enhances our understanding on the mechanism of plasma transport through the magnetic duct.

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