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Behaviour of Tin under Low-Temperature Deuterium Plasma Irradiation

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Liquid metals have the potential to mitigate several issues inherent to solid divertor targets, e.g., problems arising from erosion, embrittlement due to neutron irradiation and crack formation under fast transient loads. As possible choice for such a liquid metal tin ($T_{melt} = 505$ K) was identified, which promises low physical sputtering yields and a large operational temperature range because of its low vapour pressure. For this reason, the behaviour of tin under deuterium plasma irradiation was systematically investigated at different target temperatures by exposing it to a well-characterized D plasma with an ion flux of $\approx 10^{20}$ Dm^{-2}s^{-1} at a bias voltage of -25 V. Since the sputter threshold of D on Sn is in the range of 70 eV the Sn erosion is expected to be negligible. However, as already indicated in the literature, Sn could form the metastable, volatile stannane (SnD_4) when exposed to D plasma. Although no stannane molecules where found in the exhaust gas, a large mass loss was found after exposure at 300 K which can only be explained by chemical erosion. At 495 K (i.e. 10 K below the melting point) the mass loss was strongly reduced by a factor of ten (compared with the exposure at 300 K). However at 515 K, in the liquid phase, the mass loss was dramatically increased. The latter increase is most probably due to the ejection of Sn micro-droplets, which were found on surrounding witness samples. These might be caused by bursting gas bubbles (see below). Depending on temperature and aggregation state (solid/liquid) large differences in the deuterium retention were found. Whereas the retention close to the surface (measured by Nuclear Reaction Analysis) is very high (> at. 1%) in the case of 300 K, it is at or below the detection limit (5x10^{-5} at. %) in the case of liquid Sn (515 K). However in all cases, bulk retention in the form of H bubbles is observed. Specifically at 495 K, a large sponge like structure reaching deep into the bulk (˜100 µm) is observed. At 515 K, a large D2 bubble was formed in the crucible underneath the liquid Sn. It seems that the formation of metastable stannane could play an important role in all the above mentioned observations, but the detailed explanation and the consequences for the uses of Sn as a liquid plasma-facing material are not yet clear.

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