

# Behavior of Tin under Low-Temperature Deuterium Plasma Irradiation

A. Manhard, T. Schwarz-Selinger, M. Balden, T. Dürbeck, R. Neu

*Max-Planck-Institut für Plasmaphysik, Boltzmannstr.2, 85748 Garching, Germany*

armin.manhard@ipp.mpg.de

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 ( $T_{\text{melt}} = 505 \text{ K}$ ) was identified [1], which promises low physical sputtering yields and a large operational temperature range because of its low vapor pressure. For this reason, the behavior 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  $\sim 10^{20} \text{ D m}^{-2}\text{s}^{-1}$  at a bias voltage of  $-25 \text{ V}$ . Since the sputter threshold of D on Sn is in the range of  $50 \text{ eV}$  according to SDTrimSP 6.0 calculations [2], the Sn erosion is expected to be negligible. However, as already indicated in the literature [3], Sn could form the metastable, volatile stannane ( $\text{SnD}_4$ ) when exposed to D plasma. Although no stannane molecules were found in the exhaust gas, a large mass loss was found after exposure at  $300 \text{ K}$ , which can only be explained by chemical erosion. At  $495 \text{ K}$  (i.e.,  $10 \text{ K}$  below the melting point), the mass loss was strongly reduced by a factor of ten (compared with the exposure at  $300 \text{ K}$ ). At the same time, the net re-deposition onto nearby witness samples was low. The picture changes at  $515 \text{ K}$ , when Sn is in the liquid phase. Here 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 retained D concentration close to the surface (measured by Nuclear Reaction Analysis) is very high ( $> 1 \text{ at.}\%$ ) in the case of  $300 \text{ K}$ , it is at or below the detection limit ( $5 \times 10^{-5} \text{ at.}\%$ ) in the case of liquid Sn ( $515 \text{ K}$ ). However in all cases, bulk retention in the form of D bubbles is observed. Specifically at  $495 \text{ K}$ , a sponge-like structure reaching deep into the bulk ( $100 \mu\text{m}$ ) is observed. At  $515 \text{ K}$ , a large  $\text{D}_2$  bubble was formed in the crucible underneath the liquid Sn. During Thermal Desorption Spectroscopy, most D is released in a sharp spike during the phase transition from solid to liquid if the exposure temperature was below the melting point. Only little D is released at lower temperature, and D release drops to background as soon as the complete sample is molten. In contrast to this, Sn exposed to plasma in the liquid phase exhibits practically no D release at temperatures below the melting point, but the release continues until long after the phase transition. The release occurs in the form of spikes superimposed on a continuous signal. Its magnitude strongly points towards bulk retention of D in Sn under these conditions. In all cases, it is likely that different kinds of gas bubbles are an important factor for the uptake and release of  $\text{D}_2$ . We propose that the formation of metastable stannane could play an important role in all the observations mentioned above. In order to clarify this, we compare Sn samples exposed to D and He plasmas under otherwise as similar as possible conditions. Finally, we highlight some possible consequences of the observed effects for the use of Sn as a liquid plasma-facing material.

[1] J.W. Coenen et al, Phys. Scr. T159 (2014) 014037

[2] A. Mutzke et al, (2019) SDTrimSP Version 6.00 (IPP 2019-2), Garching: Max-Planck-Institut für Plasmaphysik

[3] D.T. Elg et al, Plasma Chem. Plasma Process. 38 (2018) 223–245