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THE COLLAPSE OF HELIUM PLATELETS IN MOLYBDENUM

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Platelets of helium in molybdenum have been observed to collapse into several small helium bubbles rather than into a single bubble [10]. We show that the driving force for collapse into n bubbles increases as n decreases. However, kinetic factors associated with the nucleation of ledges on the flat faces of the platelets ensure that the frequency of nucleation of several small bubbles far exceeds that for a single bubble. The temperature at which this collapse is expected correlates well with the observed platelet behaviour.

1. Introduction

Helium emanating from the plasma, or generated by transmutation, will have an important influence on the long-term behaviour of metals and alloys in the first wall of a fusion reactor. The gas has a large negative heat of solution in metals [1] and it readily precipitates as small bubbles which not only degrade high-temperature mechanical properties [2], but also play an important role in the phenomenon of blistering [3]. In view of the technological significance of bubble effects it is important that we fully understand the fundamental aspects of their nucleation and growth. In recent years computer-based atomistic modelling and the well-established experimental technique of thermal helium-desorption spectrometry (THDS) [4.5] have provided a valuable insight into the helium-point defect interactions necessary for bubble nucleation. Similarly, extensive experimental investigations of bubble behaviour at high temperature ($> 0.4T_m$) using transmission electron microscopy (TEM) have revealed not only the mechanisms of bubble growth, but also the controlling kinetics and the values of the interfacial energy parameters which dictate the nature of the rate-controlling step [7–9].

Recent experiments using a combination of THDS and TEM to investigate helium clustering and bubble nucleation processes in molybdenum have yielded several interesting results [10–12]. Firstly, helium aggregates in the form of disc-shaped platelets approximately 1 nm thick were observed on {110} planes at room temperature. The platelet radii ranged between 1.7 and 7 nm, depending on the trap density and the gas filling level in the particular sample under investigation [12]. Secondly, it has been established that the number of helium atoms per vacancy in platelets is between 2 and 3 and hence the gas pressure within each platelet is enormous. It is therefore not surprising that platelets increase their thickness at room temperature by punching out interstitial dislocation loops in a manner analogous to the loop punching mechanism proposed Greenwood et al. [13] for the gas-driven growth of overpressurized spherical bubbles.

One of the most interesting aspects of the presence of helium platelets in molybdenum is their transformation during in situ TEM annealing into small spherical bubbles of diameter 3 to 5 nm. For example, platelets with radii of 4 and 5 nm containing 2900 and 7000 heliums per disc, respectively, are stable at room teperature but collapse to bubbles when annealed for a few minutes between 600 and 800°C [12]. Surprisingly, the transformation does not produce a single spherical bubble having minimum surface energy per unit volume, but a localized cluster of up to 7 bubbles [10,12]. It seems, therefore, that this process could lead to very high bubble densities and ultimately the bubble lattice observed in molybdenum as a consequence of implantation [14]. Caspers et al. [15,16] have shown that the platelet configuration is to be expected in a number of metals at high helium concentrations, although it is clearly only a metastable configuration. The reason why such a disc-shaped platelet should eventually transform

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