NUCLEATION OF VOIDS

Progress Report

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Abstract

Investigations were made to determine the effect of the previous history of an embryonic void on its nucleation rate. It was found that the effect was small. Therefore, nucleation theory, as previously developed by the author, is valid. Investigations are also being made into the effect of stress on interstitial loop nucleation.

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By the start of the present contract period, we (Dr. Hartmut Wiedersich, Materials Science Division, Argonne National Laboratory and myself) had been able to: 1) show how to generalize nucleation theory to correctly account for the anti-nucleating effect of interstitial atoms on void nucleation and make sample calculations using properties typical of those of nickel¹ 2) show how to account for the nucleating effect of insoluble gas when the rate of arrival of vacancies and interstitials at a gas vacancy cluster is much larger than the rate of arrival (and of loss) of gas molecules² and make sample calculations using the properties of nickel³ 3) show how to account for the nucleating effect of supersaturated gas when the gas can enter and leave the vacancy cluster so readily that it is in equilibrium with the gas interstitially in the lattice⁴ (this last study also involved Dr. J.J. Burton, now at Exxon Corporate Research Laboratories). All of these studies were cases where the standard ideas of nucleation theory could not be used directly because of the existence of the anti-matter to the nucleating species, i.e. the interstitial atoms.

Dr. Wiedersich and I therefore decided to carefully examine the fundamental steps in nucleation theory and make certain that all the assumptions made were still valid when applied to void and interstitial loop nucleation. In particular we were especially worried about the fact that nucleation theory neglects the difference between those clusters of a given size that are formed by the decay of the next larger sized cluster and the ones formed by the growth of the next smaller sized cluster. In the former case the concentration of the monomer units would be slightly increased while in the latter it would be decreased. This difference can be neglected in ordering nucleation theory because the concentration of clusters has such a strong minimum at the

critical size. But when the vacancy to interstitial arrival rate ratio gets close to unity this minimum becomes very broad (see Fig. 1 in reference 1). Many elemental steps are involved and it appeared possible that a large effect could therefore accumulate in exactly the same way that the competitive anti-nucleating effect of the interstitials builds up. However, such is not the case.

We also examined in detail the differences between void nucleation and interstitial loop nucleation, such as the necessity to use both a line (or edge) tension and a surface tension, and the question of the effect of stress. At the moment, it appears that no unusual difficulties arise. Stress can be included as a non-isotropic free energy. We found that the observed⁵ difference in nucleation rates obtained for interstitial loops oriented in different directions relative to the direction of the tensile stress axis can be accounted for by proper application of nucleation theory. However, in contrast to void nucleation, where the exact value of the motion energy of the interstitial is of little significance to the calculated void nucleation rate, interstitial loop nucleation is very sensitive to its value. The values suggested in the literature for the motion energy span a range large enough to change the character of the calculated nucleation behavior from a barrier controlled nucleation mechanism to a growth controlled nucleation mechanism. Detailed calculations on this are now being made at Argonne by Drs. H. Wiedersich and S.P. Choi.

References

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