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CAVITY GROWTH MECHANISM MAPS FOR REACTOR MATERIALS

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The growth and shrinkage of cavities place considerable constraints on the use of materials in reactors and other environments. Cavity growth mechanism maps are potentially useful because they enable the growth mechanism and rate to be predicted in regimes where experiments are difficult or impossible. Maps are presented which describe the cavity growth in several different physical environments including that found in uranium dioxide fuel pins and in future fusion reactor first walls.

1. Introduction

Mechanism maps are a useful means of representing a large amount of data in a way that is readily assimilated. This property makes them useful in numerous areas of science. Deformation mechanism maps were the first maps of this type to be constructed [1] but since then the mapping process has been used in many diverse areas.

A mechanism map is useful when there are several distinguishable and independent ways in which a particular process can occur. One example of this is bubble growth where the growth may occur by many different processes [2].

Mechanism maps have several useful applications. One is the design and interpretation of experiments. In the design of an experiment to study one particular mechanism, the appropriate map shows the conditions in which it is expected to dominate. The map also indicates how fast the process is expected to occur. Alternatively, given some information on the experimental conditions or the rate then the dominant mechanism can be predicted. Mechanism maps can also be used to make intelligent predictions from existing data into regions where experiments are difficult or impossible. This is probably the main use for bubble growth mechanism maps. It is difficult to simulate accurately the physical conditions of a reactor first wall but these maps enable us to predict the probable bubble growth mechanism and the growth rate. Knowing the growth mechanism, it may be possible to suggest ways of inhibiting growth. Maps may therefore play an important part in the choice of future reactor materials.

All maps must be based on our current understanding and modelling of the appropriate mechanisms and on the experimental data available. The more complete these are, the more accurate and trustworthy the maps will be. However, even inexact maps can give some useful general information and, by identifying the regions where data or theory are poor, they can be systematically improved.

2. Cavity growth mechanism maps

Mechanism maps were first used to describe particle mobility by Ashby [1] and cavity growth by Goodhew [3]. The general term term ‘cavity’ is used to include both bubbles and voids.

In order to construct a map, equations describing each mechanism are required. The extent of each field is then established by evaluating the equations and determining the region within which each mechanism dominates the growth process. The growth rates given by the equations must also be added in an appropriate way to give the total growth rate and thus to enable the plotting of contours of constant rate.

Many cavity growth mechanisms have been modelled in the past twenty years and the growth rate for each mechanism, acting alone, is quite well established (e.g. refs. [4,18]). The equations used to plot the maps presented in this paper are given in Appendix 2. We have omitted to consider the punching of dislocation loops or individual interstitials since these mechanisms are usually only applicable to very small cavities. An equation for loop punching is nevertheless included in