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Experiments and modeling of He transport and fate in irradiated Fe-base alloys for fusion

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The solubility of He in metals is extremely low and ultimately is the reason for its detrimental effects on mechanical properties. This low solubility results in a strong tendency for He to precipitate into clusters or bubbles. Accumulation of He at grain boundaries can lead to initiation of cracks and premature failure under stress. It is difficult to explore the effects of He under fusion relevant conditions due to lack of appropriate irradiation facilities. To design, develop and validate He resistant microstructures, novel experiments and modeling are needed to study the transport and fate of He in fusion relevant materials.

In this presentation we describe development and application of a multi-scale model of the transport and fate of He in irradiated Fe-base alloys for fusion. We employ molecular dynamics (MD) simulations to assess binding and migration energies of He and defects with each other and at various trapping sites such as coherent precipitate interfaces, dislocations and representative grain boundaries. Kinetic Lattice Monte Carlo (KLMC) simulations are used to determine migration mechanisms and diffusion coefficients. KLMC is also used to model He and vacancy clustering on precipitate interfaces, dislocation lines and in grain boundaries. The MD and KLMC simulations provide critical information for rate theory and cluster dynamics models that follow point defect and He transport and partitioning to, and recycling between, matrix cavities, precipitates, dislocations and grain boundaries.

We also highlight recent results from novel He-implanter experiments designed to introduce He into a variety of materials at fusion relevant He-to-dpa ratios. The He-implanter method avoids the limitations of other experimental techniques for introducing He, such as doping with B or Ni, by application of a surface layer that under neutron irradiation injects He into the adjacent material. We recently implemented this approach by depositing 1-4 µm thick NiAl coatings on TEM discs to produce a uniform He deposition zone of about 6 to 8 µm. In this presentation an overview of the experimental technique will be given along with initial microstructural characterization of He-injected materials irradiated at 300, 400 and 500°C to doses of either 3.9 or 9 dpa.

Lundi 26 mars 2007 à 10h30

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