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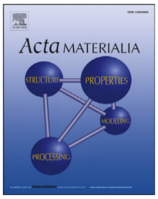

Full length article

Defect-interface interactions in irradiated Cu/Ag nanocomposites

Min Wang [a], Irene J. Beyerlein [b], Jian Zhang [c], Wei-Zhong Han [a], *

[a] *Center for Advancing Materials Performance from the Nanoscale (CAMP-Nano), State Key Laboratory for Mechanical Behavior of Materials, Xi'an Jiaotong University, Xi'an, 710049, China*
[b] *Mechanical Engineering Department, Materials Department, University of California, Santa Barbara, CA, 93106-5070, USA*
[c] *College of Energy, Xiamen University, Xiamen, 361005, China*

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ABSTRACT

In this work, we employ transmission electron microscopy and helium ion irradiation to study the response of biphase interfaces to radiation induced point defect fluxes from the two adjoining phases. Analysis of interface-affected defect accumulation was carried out over a wide range of radiation damage levels from near zero displacement per atom (dpa) to 16 dpa and helium concentrations of 0 at.% to 8 at.%. Results show a strong interface density dependence in which Cu/Ag interfaces in the nanolayered regions spaced <500 nm were remarkably microstructural stable over the entire range without accumulating micro-scale defects, while those spaced >1 μm apart were destroyed. We report the concomitant development of a bubble-free zone in Cu that was independent of defect levels and interface-contacting bubbles zone in Ag. This finding is explained by bias segregation to the interface of interstitials from Ag and vacancies to misfit dislocation nodes in the interface from Cu. The point defect transfer across the interface can be explained by the spatial variation in interface pressure within the interface and gradient in pressure across the interface, both originating from the lattice mismatch and surface energy difference between the two crystals.

1. Introduction

Structural materials used in nuclear reactors are subjected to a high level of irradiation, an extreme environment that over time causes defects to form and accumulate inside the material and eventually lead to internal damage [1–4]. Radiation-induced defects are first produced in the form of atomic scale point defects, vacancies and interstitials, which evolve into larger point defect clusters, such as dislocation loops, voids, and bubbles [1–4]. Accumulation of these radiation defects degrades mechanical performance typically in the form of significant increases in hardening and embrittlement [5–10]. In order to reduce radiation damage, the key is to enhance the recombination/annihilation rate of radiation defects as soon as they are produced [10–18]. It is well known that the recombination processes of radiation defects are influenced by a number of factors, such as, radiation dose, the nature of energized particles, radiation flux, radiation temperature, the diffusion and migration behavior of defects, the intrinsic properties and microstructures of materials, etc [1–4].

Interface engineering is becoming a recognized and widely adopted method for designing radiation tolerant materials [14–22]. Under the same service conditions, material radiation tolerance can be dramatically enhanced by introducing a large number of interfaces, either homophase or biphase, into its microstructure. The basic strategy exploits the idea that interfaces are efficient defect "sinks"; that is, they are preferable regions within the material, where the interstitial and vacancy combination rates can be significantly enhanced relative to the adjoining bulk crystals [14–22]. The sink properties of free surfaces [23–26], grain boundaries [27–34] and interfaces [16,35–37] have been studied extensively. By microscopic quantification of the width of defect-free-zone formed along these interfaces, the sink efficiency of different interfaces or grain boundaries can be measured, and therefore, they can be ranked [16,33]. It becomes clear from such analyses that not all these interfaces exhibit similar sink efficiencies, and that the differences can be rationalized based on differences in their atomic structures and interaction energies with point defects. In addition to selecting or engineering the optimal interface structure, in order to achieve high radiation tolerance, it is also of high importance to increase the volume fraction of interfaces. Several methods have been used to fabricate interface-

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* Corresponding author.
E-mail address: wzhanxjtu@mail.xjtu.edu.cn (W.-Z. Han).

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