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Damage microstructure evolution of helium ion irradiated SiC under fusion relevant temperatures

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Abstract

In-situ transmission electron microscopy (TEM) with ion irradiation has been used to study the damage microstructure evolution of He ion irradiated 4-H SiC at nuclear fusion relevant temperatures. The SiC samples were irradiated with 20 keV He ions at 25, 400, 800 and 1200°C to a dose of 5.0 displacements per atom (DPA). At 25°C, the material fully amorphises at 1.5 DPA and no He bubble nucleation occurs up to the doses studied. At 400 and 800°C, He bubble nucleation occurs and the material remains crystalline. Bubble nucleation occurs at 2.0 DPA at 400°C but occurs at only 0.5 DPA at 1200°C. This is attributed the He atoms de-trapping from vacancies and migrating interstitially to larger He-vacancy clusters at higher temperatures, leading to faster nucleation of observable He bubbles. Helium platelets form at an irradiation temperature of 1200°C at 0.5 DPA showing a preference for nucleation between the {0001} basal planes.

Keywords: SiC, Irradiation, Fusion, Helium, In situ TEM

1 Introduction

Silicon carbide has received much attention in recent decades for potential applications in nuclear reactors due to its very high melting temperature (3000 K), good thermal and mechanical properties as well as its stability under irradiation [1], [2]. This makes it a very promising candidate for use in the extreme environments of a nuclear reactor core where the material will be exposed to extreme temperatures and radiation damage from neutron bombardment. After the Fukushima disaster, SiC-based cladding was proposed as an accident tolerant coating to replace the current zircaloy cladding [3] and is also the leading candidate for use as the protective structural layer of the TRistructural ISOtropic (TRISO) coated fuel particles for the Very High Temperature (VHTR) Generation IV