Relationship between amorphous structure and radiation tolerance of silicon oxycarbide

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Silicon oxycarbide (SiOC) glasses are anticipated to be utilized as a component material for nuclear reactors, because of their high thermal stability, durability, and corrosion resistance. A recent research demonstrated that the formation of He bubbles in SiOC was highly suppressed after even 90 at% He implantation \([1]\). To clarify the origin of superior radiation tolerance of SiOC, knowledge of amorphous structures is required. In the present study, we prepared SiOC with different composition by sputtering and examined their structures as well as radiation tolerance using transmission electron microscopy (TEM). Figure 1 shows cross-sectional bright-field TEM images of 120 keV He ion irradiated SiOC: (a) SiC:SiO\(_2\) = 1:2, (b) 1:1, and (c) 2:1. Electron diffraction experiments revealed that amorphous structures were maintained after irradiation. No structural changes were detected in SiO\(_2\)-rich and equiatomic specimens (Figs. 1(a) and 1(b)), while remarkable He bubbles were formed in SiC-rich one (Fig. 1(c)). From a quantitative analysis of electron diffraction intensities, it was found that a first sharp diffraction peak (FSDP) appears at ~1.5 Å\(^{-1}\) in SiO\(_2\)-rich and equiatomic specimens (Figs. 1(a) and 1(b)), while remarkable He bubbles were formed in SiC-rich one (Fig. 1(c)). From a quantitative analysis of electron diffraction intensities, it was found that a first sharp diffraction peak (FSDP) appears at ~1.5 Å\(^{-1}\) in SiO\(_2\)-rich and equiatomic specimens. The FSDP revealed that the size of voids formed by connecting the SiO\(_x\)C\(_{4-x}\) tetrahedra in both the specimens is much larger than the diameter of He atom, suggesting that He atoms can easily migrate in the amorphous SiOC networks.


3D observation of degenerate pearlite structure by FIB-SEM

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Pearlite is a kind of steel materials consisted from ferrite and cementite. Although it is generally a layer structure, depending on the heat treatment condition, cementite becomes a dot pattern partially. This structure is called degenerate perlite and there are reports of observation by TEM and SEM \([1]\) \([2]\), but details of microstructure are not clarified. The purpose of our research is to capture the three-dimensional structure of degenerate pearlite by FIB-SEM (Focused-Ion Beam-Scanning Electron Microscope) serial sectioning method. As preprocessing, the sample was mechanically polished to expose the observation area, and two surfaces (FIB side and SEM side at the time of FIB-SEM observation) were smoothened using a single beam FIB (Hitachi: FB-2100). Serial sectioning was performed on 15 um cubic area by FIB-SEM (Hitachi: MI-4000 L). The following image processing was applied to the obtained 3D data. Contrast and size adjustment by Fiji (Free), noise removal and alignment by Avizo and Amira (Maxnet), and labelling by Trainable Weka Segmentation (plugin of Fiji). As a result, we succeeded in obtaining a 3D image of each cementite in the degenerate perlite structure (Fig. 1). It was revealed that the shape of each cementite is in the form of a bar or a split plate, and the cementite in the same block faces in the same direction.