Triple ion beam irradiation of a glass-ceramic for nuclear fusion technology

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Joining of SiC-based materials for nuclear applications is of interest in particular if the joining process can be done without using any pressure and possibly with localized heating. Moreover, it is crucial to use joining materials that satisfy several requirements, as a good wettability on SiC–based substrate, a thermal expansion coefficient close to that of SiC-based components, a shear strength matching the nuclear reactor design requirement and a radiation hardness comparable to that of SiC.

More particularly, a limited number of materials have been proposed for the joining of SiC/SiC components for nuclear fusion and fission reactors. Some glass-ceramics gave promising results as pressure-less joining materials suitable for a nuclear environment. [1]. In particular, a calcia-alumina (CA) glass- ceramic has been developed for slurry-based joining technology and showed potential as SiC-based indirect joining material for nuclear applications. [2]

The analysis of the radiation damage associated with energetic neutrons is a key factor for qualifying a joining material in nuclear fusion plants and very few studies are available on glass-ceramics tested in relevant conditions for nuclear plants. The present work investigates the effects of high flux and high energy neutron irradiations on this CA glass-ceramic material emulating the damage induced by neutrons via triple ion irradiation. The calcia-alumina samples were irradiated at temperatures ranging from 400◦ C to 710◦ C, with 8 MeV Si, 2 MeV He, and 0.333 MeV H ions, at fluences inducing the expected damage after a 0.75 year-long working period in the DEMO first wall location. This combination of ions and energies was chosen to reproduce as closely as possible the damage expected by 14 MeV neutrons in terms of displacement damage and transmutation products (He and H) as evaluated by Monte Carlo simulations. The irradiation experiments were carried out at JANNuS-Saclay (France) [3]. The TEM analysis, imaging accompanied by EDX and diffraction, highlighted that the irradiation temperature plays a prominent role in determining the induced damage in terms of amorphization, recrystallization, phase mixing and bubble formation. This study identified the type of defects to be expected in glass-ceramic materials at the working conditions for fusion technology. Each of these defects should be investigated in terms of their impact on mechanical properties of large samples of joined SiC pieces.

[1] Ferraris, M. Salvo, V. Casalegno et al. Joining of SiC-based materials for nuclear energy applications, Journal of Nuclear Materials 417 (1) (2011) 379–382

[2] Casalegno, S. Kondo, T. Hinoki et al, CaO-Al2O3 glass-ceramic as a joining material for SiC based components: A microstructural study of 510 the effect of Si-ion irradiation, Journal of Nuclear Materials 501 (2018) 172–180.

[3] A. Gentils, C. Cabet, Investigating radiation damage in nuclear energy materials using JANNuS multiple ion

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