7P60 Characterization of micro-scale strength and deformation in ion-irradiated RAFM steel F82H using ultra-small testing technologies (USTTs)

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Fusion energy, as a clean and abundant energy, is a potential way for the current energy crisis. However, materials degradation in reactors has always been a challenging program due to the high-energy neutron up to 14 MeV. To avoid radioactivity and long period in neutron irradiation, irradiation with heavy-ions becomes an essential experimental to simulate the fusion neutron irradiation environment. Since the ion penetration depth is limited with several μm, researchers make use of ultra-small testing technologies (USTTs) to evaluate the irradiated materials. While nanoindentation hardness tests has been widely used to evaluate the irradiation hardening, it gives only the hardness value change which is not useful for structural designs. In contrast, micropillar compression tests provide a straightforward view on the value of yield stress and possibly other mechanical properties. Since the pillar height along the incident direction has to be less than 2 μm in the heavy-ion irradiations, the specimen size effect should be clarified among these tiny pillars. This study investigated the size effect in micropillar tests on ion-irradiated materials and compare them with a bulk value of irradiation hardening from nanoindentation hardness tests using a well-established correlation from nano to micro hardness.

The F82H-IEA steel was irradiated at TIARA by 10.5 MeV Fe^{3+} up to 20 dpa at 1 μm from incident surface. Micropillars were fabricated by Hitachi FB-2100 with an aspect ratio about 2, and were compressed using Nanoindenter G200. Continuous stiffness measurement method was used in nanoindentation hardness tests.

The size effect of micropillar tests was negligible in F82H-IEA steel. The irradiation hardening of yield stress obtained from micropillar tests was 140 MPa for the ion-irradiated F82H-IEA. Differently, irradiation hardening estimated from nanoindentation hardness was 241 MPa. The difference is considered to be due to distinct deformed zones in these two tests. The deformed zones in micropillar tests are limited within the shear bands, which are possibly concentrated in the irradiated materials through dislocation channeling, while those in nanoindentation hardness tests are complex under tri-axial stress condition. Therefore, it can be concluded that the nanoindentation hardness tests offer a better reliability to estimate irradiation hardening in ion-irradiated steels.