# Synergistic Influence of Displacement Damage and Helium/dpa on Microstructural Evolution and Radiation-Induced Hardening of Reduced Activation Ferritic/Martensitic Steel

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Reduced activation ferritic/martensitic steels, RAFs, are leading candidates for blanket and first wall of fusion reactors where effects of displacement damage and helium production are important subjects to be investigated. To obtain systematic and accurate information of microstructural response under fusion environment, dual-ion irradiation method was applied. In order to estimate the microstructural response under fusion neutron irradiation environment, ion-beam irradiation was carried out with helium and metallic self ions. The objective of this work is to clarify correlation between irradiation hardening and microstructural evolutions in RAFs under ion irradiation to high fluence.

JLF-1 (9Cr-2W-V, Ta) steel was irradiated up to 60 dpa at 693, 743 K. Single ion irradiation was performed with 6.4 MeV $Fe^{+3}$. Energy degraded 1.0 MeV $He^{+}$ was simultaneously irradiated for dual ion irradiation. The damage rate and helium injection rate were $1.0\mathrm{x}10^{-3}$ dpa/s and 15 $\mathrm{x}10^{-3}$ appmHe/s. As the post-irradiation examination, transmission electron microscopy (TEM) and nano-indentation were carried out.

Microstructural evolution was characterized for irradiation conditions where significant changes in micro-hardness in RAFs were found. At 693 K, irradiation hardening was not decreased under single-ion irradiation. Under dual-ion irradiation, the dislocation structure consisted of loops and network was detected. Here, an important role of dislocation evolution in irradiation hardening is confirmed. Irradiation hardening in dual-ion irradiation at 693 K was larger compared to that of single-ion irradiation. At 743 K, void cavity structure was observed under dual-ion irradiation where the contribution of void structure on hardening was not so significant.

JLF-1 under single-ion irradiation exhibited excellent irradiation resistance, although irradiation hardening and swelling were depended for the case of dual-ion irradiation. However microstructural evolutions could be detected mostly on lath structure. Contribution of dislocation structures, distributions of precipitate and others on swelling and hardening will be presented in detail.