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Irradiation damage in structural materials of fission and fusion reactors: effects of dose, dose rate, temperature, neutron versus ion beam irradiation, analysis techniques.

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Understanding and predicting the effects of irradiation on complex alloys such as structural "ferritic"steels used in fission and fusion reactors is a tremendous and complex challenge. Irradiations performed in experimental irradiation facilities always deviate to some extend from the irradiation conditions existing in nuclear reactors. For instance, the neutron spectrum can be different but even more importantly is the damage rate that is significantly higher in experimental neutron irradiation facilities. It is now well known that such effects affect the accumulation of defects in the microstructures, which in turn influences the evolution of the mechanical properties. Furthermore, the fission neutron irradiation facilities are quite limited, and no intense source of fusion neutrons of 14 MeV is available to produce by transmutation the expected helium and hydrogen contents in the first wall and blanket of the future thermonuclear reactors. Therefore, the nuclear material community has often to rely on alternative irradiations to neutron irradiations, such as ion beam implantations or neutron spallation irradiations. In this presentation, we will make first a short overview the irradiation effects on materials and discuss the advantages and limitations of the various techniques used as surrogate to neutron irradiations. We will outline the fact that extracting information on mechanical properties from irradiated specimens requires the use of small specimens test techniques. This is especially true for ion beam irradiations that, for the usual ion energies, result in a thin irradiated surface layer of several microns, with an associated strong gradients of dose The need to use small specimens has also fostered a science-based approach to their development, which pertains to ad-hoc modeling activities. An overview of the work already done in the context of small specimens test techniques will be presented as well as the challenges and future opportunities to build methods to obtain reliable information from non-conventional tests. The emphasis will be put on the plastic flow and fracture properties.

Primary author: Dr SPÄTIG, Philippe (PSI-EPFL)

Presenter: Dr SPÄTIG, Philippe (PSI-EPFL)

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