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As part of the research program on generation IV reactors, CEA is developing new grades of austenitic steels for the fuel cladding of Sodium Fast Reactors (SFR). Austenitic stainless steels show excellent properties in SFR's extreme operating conditions: corrosive environment, high operating temperature (400-700 ° C) and highly energetic neutron flux. However, the appearance of the swelling phenomenon under irradiation limits cladding lifespan. The most optimized French grade is AIM1, a 15Cr-15Ni austenitic stabilized steel, which sustain doses up to 100 displacements per atom (dpa).

The objective of this study is to evaluate the impact of metallurgical parameters and the role of chemical elements on the swelling under irradiation. The findings will contribute to develop AIM2, an optimized grade, successor of the AIM1, which should be usable up to 130dpa. Swelling is a threshold phenomenon that is a consequence of the formation and growth of cavities in the material. During the irradiation, collisions between highly energetic neutrons and cladding atoms induce an equal production of void and interstitial inside the matrix. Interstitials and voids can recombine mutually, be absorb by different sinks in the microstructure or agglomerate with defects of the same nature. In the case of swelling under irradiation, some biased sinks such as dislocation, causes to an overconcentration of vacancies. This overconcentration, in addition to helium produced by transmutation, leads to the formation of cavities inside the matrix.

The swelling heavily depends on the material's microstructure such as grain size, dislocation density, precipitation nature or chemical composition of the solid solution. Unravelling swelling mechanisms is a challenge in order to improve the AIM2 design and have a better understanding of the swelling phenomenon.

The cluster dynamics is a medium-field modeling that can describe the evolution of point defects and clusters. This approach allows to study the impact of different punctual defects and sinks populations on the swelling under irradiation. A sensitivity study of swelling with respect to nature and characteristics of nano-precipitates is conducted using CRESCENDO code [1]. The simulations are compared with the evolution of model microstructures irradiated with heavy ion (Fe3 + 2MeV) on the CEA Saclay JANNuS platform up to 120dpa.

[1] T. Jourdan, G. Bencteux et G. Adjanor, J. Nucl. Mater. 444 (2014) 298