§59. Microstructural Development in Model Ferritic Alloys Irradiated in FFTF/MOTA Over 100 dpa

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Ferritic stainless steels are attractive materials for applications to fusion reactor first wall / blanket structures. This is in part due to superior irradiation performance, namely excellent swelling resistance and acceptable irradiation embrittlement for selected compositions, as well as maturity of ferritic alloys as practical engineering materials. The objectives of this work are (1) to characterize swelling behavior and microstructural evolution in simple Fe-Cr ferritic alloys under fast neutron irradiation over 100 dpa, (2) to clarify the influence of chromium content on radiation-induced microstructural changes in Fe-Cr binaries, and (3) to aid understanding of inherent swelling resistance of ferritic alloys.

A series of Fe-Cr binary alloys with chromium concentrations varying from 3 to 18 percent in 3 percent increments was irradiated in FFTF/MOTA. The cumulative fluence was 3.33×10^{27} n/m^2. The dose achieved varies from 137.7 to 140.1 displacement per atom (dpa), depending on alloy composition.

Microstructural examination revealed that cavities, network dislocations, dislocation loops and precipitates had developed in all the alloys. Spatial distribution of cavities were quite uniform within the matrix, although grain boundaries and the adjacent regions were free of cavity formation. Cavity microstructure is most advanced in Fe-6Cr and Fe-9Cr alloys (Figure 1). Swelling was less than 3 percent at the dose of about 140 dpa in all the specimens examined. This result ensures superior swelling resistance of this class of alloys. Swelling peak appeared at an intermediate chromium concentration, i.e., 9 percent chromium.

Dislocation networks were observed in all the specimens, but the degree of development varied depending on alloy composition. The network dislocation density was generally low. Dislocation loops were also found in all the specimens. Variations of the loop configuration were more prominent than of the network dislocation. The dislocation loops are predominantly of a<100> type. Loop concentration comes to the minimum at 6 percent chromium, at which the dislocation evolution was most advanced. Larger loop size correlates with the lower loop number density, as generally observed in irradiated materials. The dislocation loop microstructure was insensitive to the chromium content in 12 ~ 18 percent chromium range. Figure 2 provides the chromium concentration dependence of total dislocation density, network density and its breakdown to each component.

After detailed analysis on correlation among development of various microstructural features, the variation of swelling depending on chromium concentration was attributed to the difference in sink strength of microstructural features, e.g., the increased dislocation density with the increasing chromium content, due to probably both solid solution effect and precipitation effect, should have reduced swelling in a high chromium concentration range, and the precipitation caused by the impurities should have suppressed swelling in the Fe-3Cr alloy.

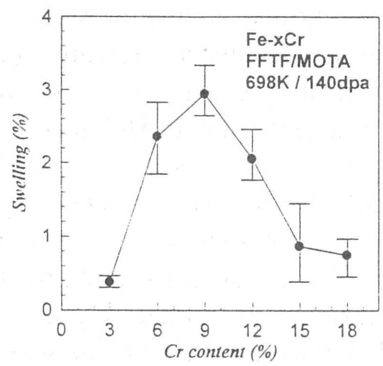

Figure 1 Swelling in the Fe-Cr binary alloys as a function of chromium concentration

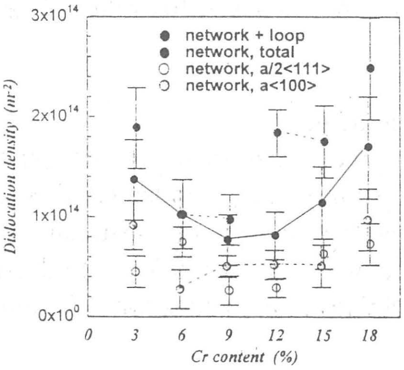

Figure 2 Chromium concentration dependence of network and total dislocation densities.