

### Background

Current knowledge highlights the radiation induced segregation (RIS) [1] and the radiation hardening [2] as the two main effects on irradiation assisted stress corrosion cracking (IASCC). Stacking fault energy is considered as a key parameter of materials, which can influence IASCC of stainless steels in nuclear light water reactor (LWR), because it plays an important role in every process of plastic deformation, work hardening and creep behaviour [3]. The study of the impact of SFE variations on the plastic deformation and SCC behaviour of irradiated and unirradiated austenitic steels will contribute to the understanding of IASCC mechanism.

### Objectives

The objectives of this work, as a task within the FP6-European Project PERFECT, are to investigate the influence of the SFE on IASCC susceptibility of stainless steels, to correlation n-irradiation induced defect production, accumulation and mechanical deformation behaviour with SFE by using the state of the art experimental tools such as transmission electron microscope (TEM), positron annihilation spectroscopy (PAS), slow strain rate tests (SSRT) in simulated LWR conditions.

### Principal results

Detailed results are given in 3 SCK•CEN reports [4-6].

### Materials

3 model alloys named Ref SFE, LSFE and HSFE have been fabricated, cold rolled and then thermally annealed at high temperature in order to ensure full austenisation. Their compositions and experimental determined SFEs are listed in following table.

Alloy	C	N	Mn	Ni	Cr	Si	S	P	SFE ( mJ/m <sup>2</sup> )
Ref	0.04	0.015	1.56	8.5	18.4	0.33	0.02	0.033	31
LSFE	0.01	0.08	1.56	8.5	18.4	1.0	0.02	0.033	11
HSFE	0.07	0.319	1.59	16.23	18.63	0.1	0.043	0.035	46

The specimens were irradiated in the BR2 CALLISTO rig at the temperature about 300°C. The irradiation flux is  $7.51 \times 10^{13} (n/cm^2/s)$ , the fluence is  $5.27 \times 10^{20} (n/cm^2)$  and the dose is about 0.9 dpa. The TEM irradiation specimens were mechanical and electro-chemical polished in hot-cell.

### Microstructures of the 3 model alloys after irradiation

Fig. 1 shows that, for the LSFE alloy, the microstructure consists of black dots, high density stacking fault, edge-on microtwins, dislocation loops and stacking fault tetrahedra (SFT). Cell structure dislocations and dislocation pile ups are also shown near the grain boundary. To sum up, LSFE alloy has the more complicated microstructure. For the Ref SFE alloy, the microstructure is similar to the LSFE alloy's except the density of the stacking fault is lower. For HSFE alloy, there are no SFTs, stacking faults and microtwins but a higher density of black dot and lower content of defect loops are observed.

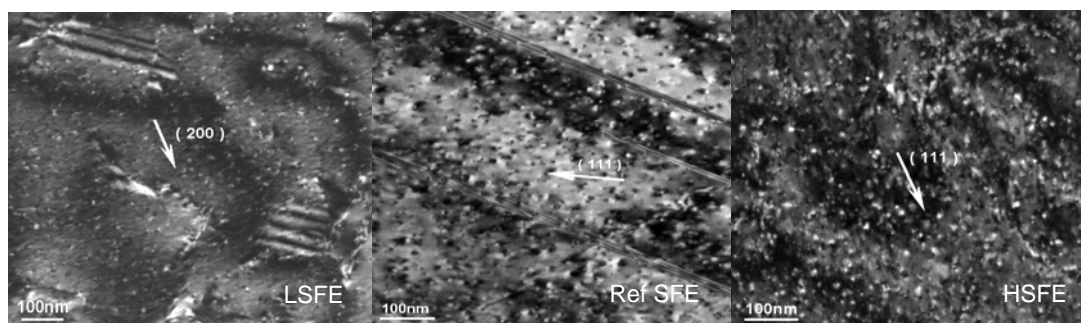


Fig. 1 Microstructures of 3 model alloys after irradiation observed by TEM

### SFTs and their nature determination

Using special TEM techniques [6], the morphology of the SFTs was determined following Kojima et al method [7], See Fig. 2. Their nature was found as vacancy type of defects.

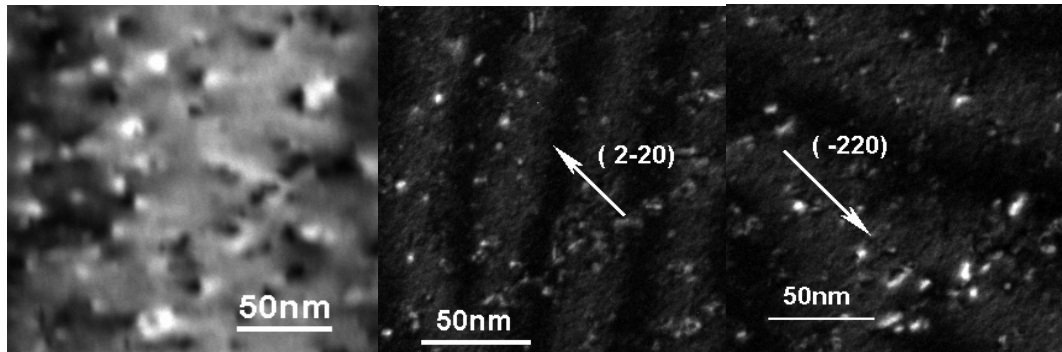


Fig. 2 SFTs and their nature determination

### The nature of the defect loops determination

Using different classical and special TEM techniques to determine the loops nature [6], both vacancy and interstitial loops are observed. See Fig 3.

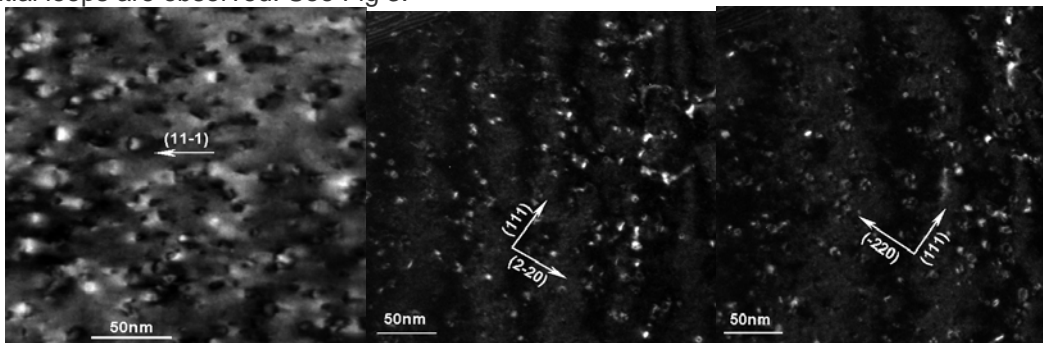


Fig. 3 Defect loops and their nature determination

### Densities and size distribution of dislocation loops in Ref SFE alloy

Using special TEM technique [6], the dislocation loops were identified as double arc Frank loops. Fig. 4 shows the dislocation loops, size distribution and density of Ref SFE alloy.

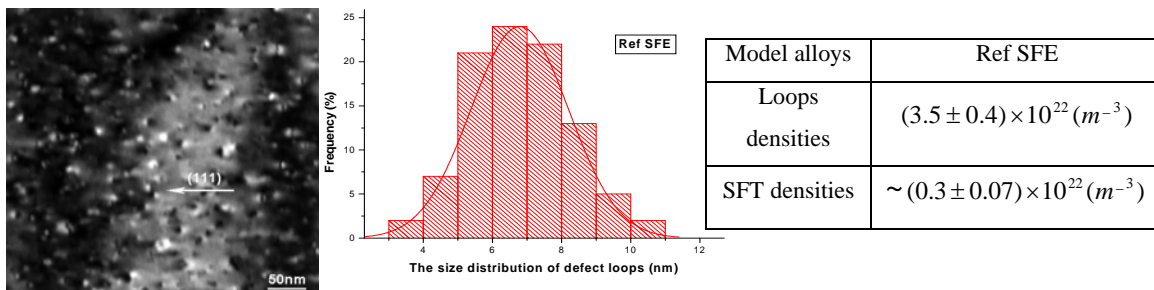


Fig. 4 Frank loops and their size distribution and density of Ref SFE alloy

### Future work

The mechanical properties of the 3 model alloys after irradiation will be tested at selected temperatures and strain rates in order to highlight the effect of SFE on the deformation mechanisms after irradiation and therefore to IASCC.

### Main contact person

Li Xiaoqiang, [xiaoqiang.li@sckcen.be](mailto:xiaoqiang.li@sckcen.be), Al Mazouzi Abderrahim, [abderrahim.al.mazouzi@sckcen.be](mailto:abderrahim.al.mazouzi@sckcen.be)

### Main reference

- [1] J. T. Busby, G. S. Was, E. A. Kenik, J. Nucl. Mater
- [2] S. M. Brummer, E. P. Simonen, P. M. Scott, P.L. Andresen, G. S. Was, J. L. Nelson, J. Nucl. Mater. 274, p299. (1999)
- [3] D. Hull and D.J. Bacon, *Introduction to Dislocations*, International Series on Materials Science and Technology, Vol. 37, Pergamon Press, 1984, p 98.
- [4] X. Li, A. Al Mazouzi et al. "Stack Fault Energy Determination-Theory and Procedure", SCK•CEN Report 4331, 2006
- [5] X. Li, A. Al Mazouzi et al. " Deformation mechanisms and deformation map building of stainless steels", SCK•CEN Report 4332, 2006
- [6] X. Li, A. Al Mazouzi et al. " Effect of SFE on Defect Accumulation in stainless steels", SCK•CEN Report 4546, 2007
- [7] S. Kojima, Y. Satoh, H. Taoka, I. Ispida, T. Yoshiie and M. Kiritani, Phil. Mag. A, 59, p.519, 1989.