27 SEPTEMBER – 1 OCTOBER 2010

PORTO, PORTUGAL

Simulations of Resistivity Recovery Curves of Electron-Irradiated Dilute FeCr Alloys using an Object Kinetic Monte Carlo Model

B. Gámez [1], L. Gámez[1], M.J. Caturla[2], D. Terentyev[3], L. Malerba[3] J.M. Perlado[1]

[1]Instituto de Fusion Nuclear, UPM, Madrid, Spain berta.gamez@upm.es

[2]Departmento de Física Aplicada, Universidad de Alicante, Alicante, Spain

[3]SCK·CEN, Mol, Belgium

An Object Kinetic Monte Carlo model is being developed for dilute (less than 1% Cr) FeCr alloys. The model includes the effects of Cr on the mobility of radiation effects, using information obtained either from density functional theory or molecular dynamics calculations. The results are compared to experimental measurements of electric resistivity for different Cr concentrations. We analyse the dependence of Cr on the first two observed peaks: ID2 and IE and the influence of parameters such as the interaction radius between Cr and an Fe self-interstitial.

Parameters for OKMC model

Migrating species:

I up to size 4, V up to size 4

ICr 0.23 eV

I_2Cr 0.30 eV

ICr_2, I_2Cr_2 do not migrate

Dissociation of clusters

$ICr \rightarrow I + Cr$ 0.08 + 0.34 = 0.42 eV

$ICr_2 \rightarrow ICr + Cr$ 0.08 + 0.23 = 0.31 eV

$I + Cr_2$ 0.394 + 0.34 = 0.73 eV

$I_2Cr \rightarrow ICr + I$ 0.65 + 0.23 = 0.88 eV

$I_2 + Cr$ 0.02 + 0.43 = 0.45 eV

$I_2Cr_2 \rightarrow I_2Cr + Cr$ 0.062 + 0.30 = 0.362 eV

And others of higher energies

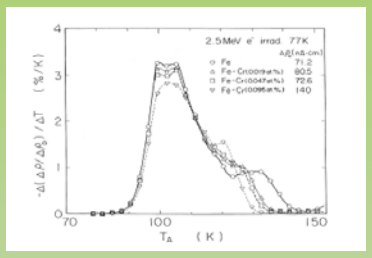
Simulation conditions

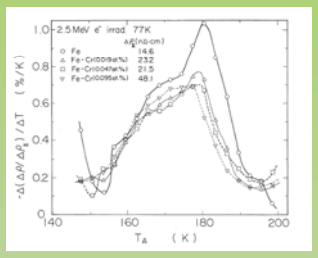
Electron irradiation at 77 K

Isochronal anneal from 77 to 200K, Heating rate 3K/3min

Pure Fe & FeCr at 0.019 at.%, 0.047 at.% & 0.095 at.%

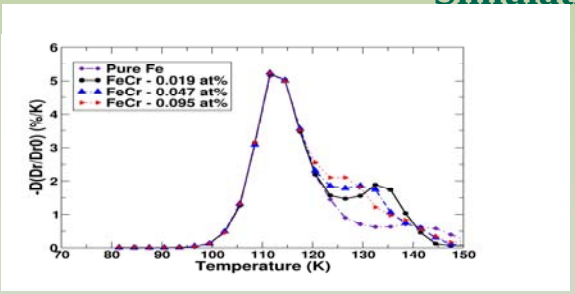
Experimental results from Abe & Kuramoto [1]

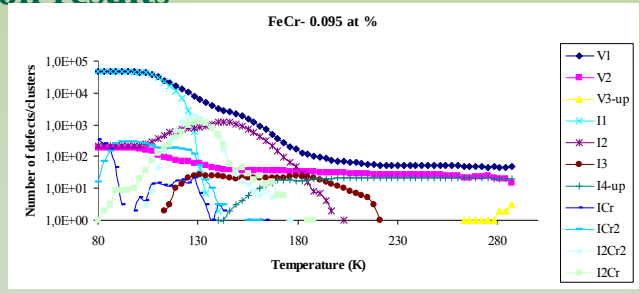




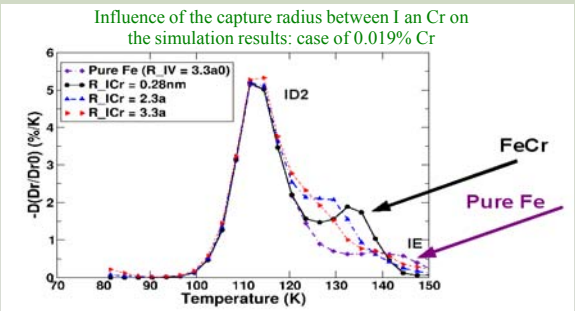
- Shift of stage IE to lower temperatures in FeCr
- Decreases in temperature and increases in amplitude with increasing Cr concentration
- Peak at 180K does not depend on solute concentration

Simulation results

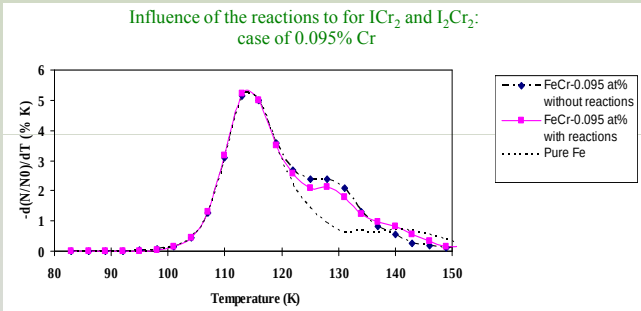




Influence of the capture radius between I an Cr on the simulation results: case of 0.019% Cr



Influence of the reactions to for ICr_2 and I_2Cr_2: case of 0.095% Cr



Conclusions: The model reproduces the shift of stage IE towards lower temperatures when Cr concentration increases. This peak is related to the formation of ICr and ICr_2 clusters. ICr migrates and recombines with V while ICr_2 dissociates into ICr and Cr. Since ICr migrates faster than an Fe interstitial the shift towards lower temperatures is reproduced. The position of the IE peak depends strongly on the ICr capture radius, with a capture radius of 0.28nm providing the best agreement with the experimental measurements. There is not a significative difference in the results when the I_2Cr and I_2Cr_2 reactions are not included. Further work is underway to study the behaviour at higher temperatures.

References.-

[1] H. Abe & E. Kuramoto, J. Nuclear Materials 271-272 (1999) 209-213

[2] F. Maury, P. Lucasson, A. Lucasson, F. Fudot, J. Bigot, J. Phys. F: Met. Phys. 17 (1987) 1143-1165

[3] C. C. Fu, J. Dalla Torre, F. Willaime, J.-L. Bouquet, A. Barbu, Nature Materials (2004)

[3] D. Terentyev et al., Comp. Mat. Sci. Doi:10.1016/ j.commatsci.2008.03.013

[4] P. Olsson, J. Nucl. Mater., accepted within ICFRM 2007.

[5] P. Olsson, C. Domain, J. Wallenius, Phys. Rev. B75 (2007) 014110

Acknowledgements.-

We thank P. Olsson for providing information about defect energies from DFT. This work has been funded by the FPVII projects FEMAS and GETMAT and by the MAT-REMEV task of EFDA.