SELF HEALING OF CREEP DAMAGE IN BORON AND COPPER CONTAINING IRON ALLOYS

Niels van Dijk [1], Shangming He [1], Mohan Paladugu [1], Henk Schut [2] and Sybrand van der Zwaag [3]

[1] Fundamental Aspects of Materials and Energy, Faculty of Applied Sciences,
Delft University of Technology, Mekelweg 15, 2629 JB Delft, The Netherlands.
Email: N.H.vanDijk@tudelft.nl

[2] Neutron and Positron Methods in Materials, Faculty of Applied Sciences,
Delft University of Technology, Mekelweg 15, 2629 JB Delft, The Netherlands.
Email: H.Schut@tudelft.nl

[3] Fundamental of Advanced Materials, Faculty of Aerospace Engineering,
Fundamentals of Advanced Materials, Kluyverweg 1, 2629 HS Delft, The Netherlands.
Email: S.vanderZwaag@tudelft.nl

Keywords: Self-healing, Creep damage, Steel, Neutron scattering, Positron annihilation.

ABSTRACT

Steels are among the most widely used construction materials as their mechanical properties can be tailored to obtain the required combination of strength and formability. However, in highly demanding applications the lifetime until failure is limited due to the accumulation of damage. Recently, it was demonstrated that a significant improvement in the creep life time can be obtained for austenitic stainless steels by additions of solute boron and copper [1]. It was proposed that the creep damage can be self healed by dynamic precipitation of Cu and/or BN.

In order to study the physical mechanism responsible for self healing in low-alloyed steels in detail we have designed high purity boron and copper containing model alloys. We studied the self healing of ultrafine cracks by dynamic precipitation at the crack surface in these model alloys by applying advanced in-situ positron and neutron techniques that characterize the defects and precipitates on a nanoscale within the bulk of the material. Creep experiments show an extended lifetime for underaged samples with mobile solutes with respect to fully precipitated samples.

With positron annihilation spectroscopy [2] we have probed the evolution of open volume defects during (repeated) deformation and subsequent healing. Positron annihilation spectroscopy characterises velocity spectrum of the electrons in the open volume defects and in the healing clusters that annihilate with the trapped positrons. A clear difference is observed between underaged and fully precipitated samples.

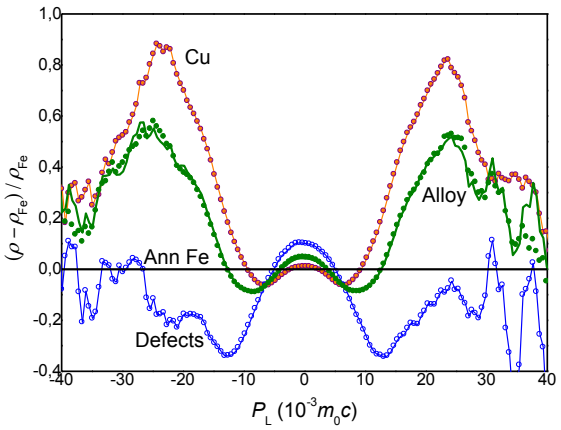


Figure 1: Positron annihilation spectrum as a function of the electron momentum pL. The deformed Fe-Cu alloy response is composed of the reference curves for pure Cu, Fe and defects in Fe.

With additional small-angle neutron scattering measurements [3] we have monitored the influence of plastic deformation and solute boron and nitrogen on the precipitation of copper during ageing. For comparison additional electron microscopy was applied. The potential for self healing of creep damage in steels will be discussed in relation to the recent results.

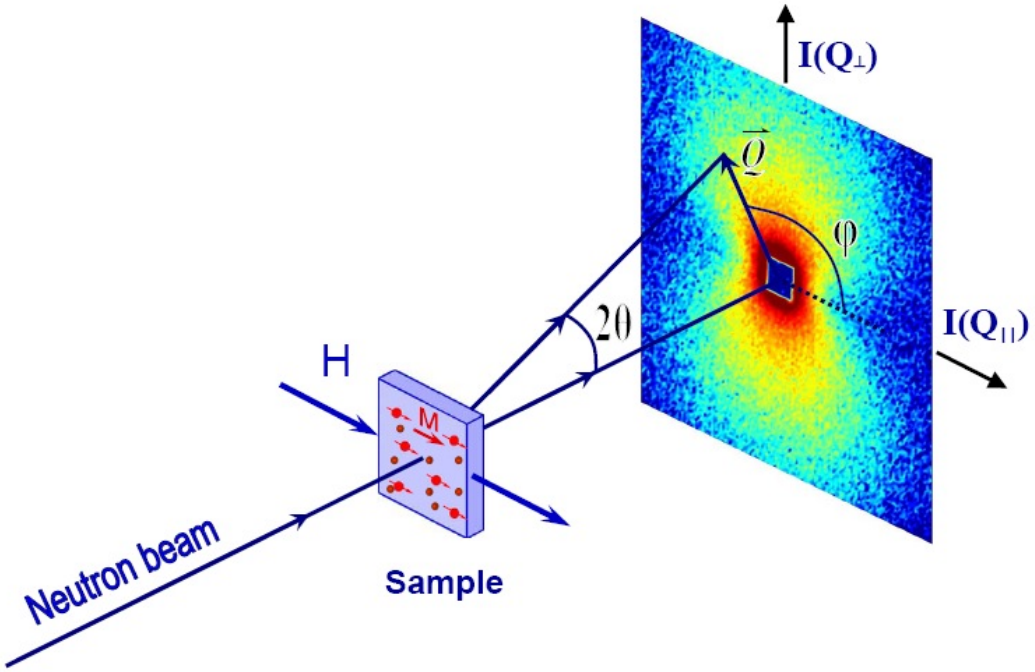


Figure 2: Small-angle neutron scattering characterising the nanoscale clusters in the Fe alloy. The anisotropic pattern arises from the spin dependent scattering of the magnetic contrast between the Cu cluster and the Fe alloy.

REFERENCES

[1] K. Laha, J. Kyono and N. Shinya, An advanced creep cavitation resistance Cu-containing 18Cr–12Ni–Nb austenitic stainless steel, *Scripta Materialia* **56**, 2007, pp. 915-918.

[2] S.M. He, N.H. van Dijk, H. Schut, E.R. Peekstok, and S. van der Zwaag, Thermally activated precipitation at deformation-induced defects in Fe-Cu and Fe-Cu-B-N alloys studied by positron annihilation spectroscopy, *Physical Review B*, **81**, 2010, 094103.

[3] S.M. He, N.H. van Dijk, M. Paladugu, H. Schut, J. Kohlbrecher, F.D. Tichelaar, S. van der Zwaag, In-situ determination of the aging precipitation in deformed Fe-Cu and Fe-Cu-B-N alloys by time resolved small-angle neutron scattering, *Physical Review B*, **82**, 2010, 174111.