Early Stage Precipitate Formation in Cu-based Alloys for Nuclear Fusion Reactors

Abstract: This report details the progress of a research project into the ageing behaviour of CuCrZr alloys, carried out at IMR-Oarai and continued at the University of Manchester. In the initial stage of the ageing, the hardness and positron lifetime showed the similar ageing trends, suggesting that vacancy-type defects contribute to the hardening. The defects may be associated with Zr atoms.

Cu1.0Cr0.1Zr Alloys are the alloy of choice for use as a heat exchange component in the ITER fusion reactor thanks to their high conductivity combined with their superior mechanical strength induced through precipitation hardening [1]. The mechanisms taking place during the ageing process are not well understood, in particular the role that Zr plays in precipitate formation. To investigate this, PAS and microhardness testing was carried out on CuCrZr and CuCr samples, aged for a range of times up to 4 hours, and comparisons between the two were made.

The PAS results obtained during the time in Oarai showed that CuCrZr alloys had a similar vacancy no. density to CuCr but the vacancies were slightly larger in CuCrZr (V4 as opposed to V2), however no pattern emerged with regards to aging time. (Fig 1a & 1b) Microhardness testing results (Fig. 1a) indicate why this is the case, showing microhardness testing results on CuCrZr and CuCr alloy samples tested in Oarai, as well as new samples created after returning to Manchester.

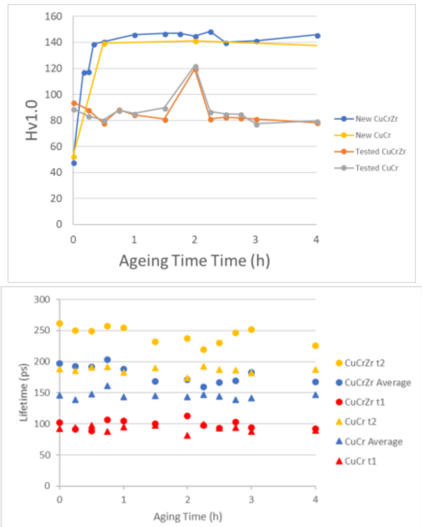

Fig 1: a.) Microhardness results for all samples

b.) Positron lifetime results for all samples

As one can see in Fig. 1, the PAS tested samples show little change across the first 4 hours of ageing, as indicated in the closely correlated positron lifetime and microhardness results. However, this was not expected, so new samples were created after returning to Manchester, indicating the tested samples had been oxidized during the heat treatment process.

In Fig. 1a, hardness results for the new samples revealed that ageing creates a rapid increase in hardness up to around 30 minutes before levelling off. Because of this, the new set of samples to be PAS tested will focus on the first 30 minutes of ageing.

PAS results do suggest a link between Zr and the defects in CuCrZr (Fig. 2).

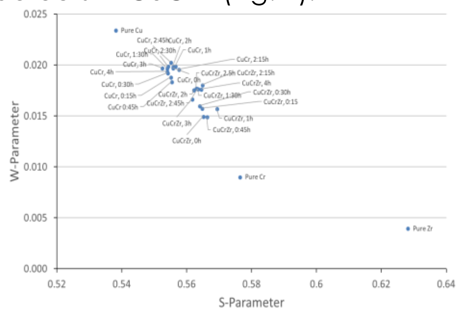

Fig 2: S vs. W parameter for tested samples

Plotting S vs. W parameter shows that the 0.1% Zr has the effect of increasing the proportion of low momentum annihilations (S-parameter), indicating that Zr plays a role in the formation of larger defects in CuCrZr as opposed to CuCr. In order to complete the experiment and characterize the association between Zr and the larger defects present in CuCrZr, PAS testing of a new set of CuCrZr and CuCr samples is still ongoing, with APT work to take place to support these results.

References

[1S.J.Zinkle, "Applicability of copper alloys for DEMO high heat flux components", Phys. Scr., vol. T167, no. T167, p.14004, 2016

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