Multiscale Investigation of the Creep Damage Mechanisms in CuCrZr alloy using High Resolution and Optical Digital Image Correlation in Conjunction

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Abstract. Copper Chromium Zirconium alloys (CuCrZr) is the candidate heat sink material for heat sink application in fusion devices. The material exhibits excellent heat transfer capabilities due to 99% copper in the matrix but also shows profound mechanical strength compared to pure copper due to the micro and nanoscale chromium and zirconium precipitates. The alloy is still at low technology readiness level to be used in fusion relevant regimes, especially the high heat flux, hoop stresses, thermal mismatch stresses and neutron irradiation. A detailed investigation of the materials response under elevated temperature and stress regimes is of vital importance before generating the standards of manufacturing. The research conducted attempts to create an understanding about the creep response of this copper alloy. An understanding about the material's creep response under fusion relevant conditions at macro and micro-structural length scales has been presented by the employment of multi-scale characterisation techniques. The study also attempts to shed a light on the ways of reducing the number of testing specimens, hence saving the material as well as the time of testing. An insight on the dominant creep mechanisms at macro and micro mechanistic length scales along with grain scale understanding is obtained by incorporating macro and high resolution DIC test to map multiple strain response states at the bulk and grain scales. EBSD measurements before and after the test enable the examination of the inter and intragranular creep response of the material on the same sample. The results pave the way to investigate different creep damage mechanisms, ranging from dislocation-based creep to discontinuous dynamic recrystallisation. The hardness profile of the specimens has also been mapped before and after the creep tests to confirm the results from the grain scale textural analysis and strain maps. They also highlight the role of dislocation pileups, high strain accumulation and their association with material failure. The research enables the development of an understanding of the material's behaviour by correlating the data on surface deformation, grain boundaries, orientation distribution and dislocations. The image for the one of the analysed regions of interest is shown in Figure 1.

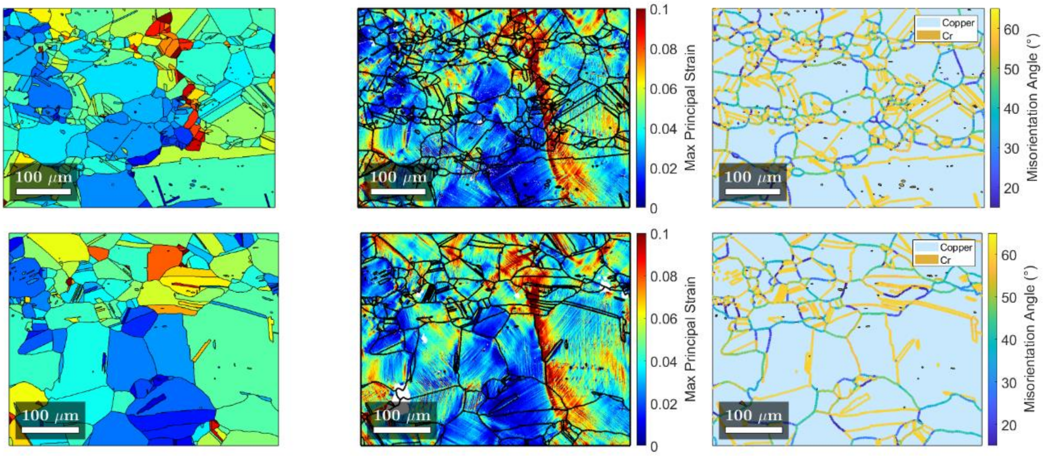

Figure 1 – The Top row consists of high-resolution strain maps overlayed with pre-test grain boundary maps obtained from EBSD measurements followed by post-test EBSD maps plotted on the high-resolution strain maps in the second row.