High resolution surface field measurements by tracking gold nanodroplets

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Abstract

Remodeling of surface films is a well known method to create a pattern that can be used during in situ straining to measure surface displacements by digital image correlation (DIC). Originally done by a thermal treatment, it can now be done with the deposition of low fusion alloys that remodel at low temperature. The deposition conditions can be varied to provide a wide range of size for the surface features, down to a few nanometers (Hoef). It can therefore be used to perform high resolution DIC from images obtained on strained samples within an SEM.
In this work, an alternative is explored where gold nanodroplets are formed by laser dewetting. Each droplet is tracked individually. The displacements are measured at two scales : from the variation of the position of the droplet itself and, in case of localized deformation, from the deformation of the droplet when it is crossed by the slip discontinuity (either slip band or grain boundary), if the displacement is not too much oriented out of the surface.

Laser induced dewetting has the flexibility to create different density and sizes of droplets by playing on the initial film thickness. The fluence is kept low, just above the threshold to melt the film. Literature shows that the film solidifies again after a few 100 ns and therefore the heat cannot alter the microstructure. The droplets are very adherent and deform with the substrate. Another advantage is that in between the droplets, the substrate is apparent. Therefore, zooming out and using the BSE mode of the SEM, the contour of the grains is still distinguishable. This is useful when positioning slip bands with respect to grain boundaries during deformation when the grains experience deformation and rotation.

The capability of the method is demonstrated on Eurofer97, a ferritic steel obtained from an annealed martensite. A density of tracked droplets of 300 / μm2 with diameters ranging from 10 to 60 nm (peak at 35 nm) was obtained, allowing a spatial resolution of 70 nm. A tensile test was conducted up to 15% true strain. Slip bands were identified by calculating the Von Mises strain from the displacement field, over a field of view of 40 x 40 μm. The deformation within the bands were measured (when well oriented) from the deformation of the droplets intersected by the bands either thick (wider than the droplets) or thin (cutting the droplets). Blockage and transmission of bands and fracture of nanometer scale carbides when impacted by slip bands were observed.
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