Recognition of plasticity at the mesoscale using texture features from backscattered electron images

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The mechanism of plastic deformation in metals is an important topic in structural integrity. Numerous experimental approaches [1,3] have been investigated as means to characterise plasticity such as digital image correlation and thermal-elastic effect at the macroscale as well as X-ray diffraction at the microscale. Yang *et al* [1] reported that residual plasticity can be characterised by using the features of the Fourier transform of backscattered electron (BSE) images at the mesoscale.

Modern imaging techniques enable rich information be relatively easily captured at the microscale with useful information often embedded in redundant datasets (e.g. images, videos). Thus, effective and automatic data mining approaches, such as image processing and pattern recognition are desirable and offer great potential. For instance, Wang *et al* [2] employed image decomposition techniques to process strain and displacement fields at macro scale. The approach was demonstrated as effective and efficient in various applications such as computational model validation and vibration modal analysis [5].

In this study, a number of image analysis techniques have been evaluated for quantifying plastic deformation in metals based on BSE images. It is found that some texture features correlate well with the level of plastic strain. In particular, three types of feature extraction have been adopted: namely (1) statistical moments of the image histogram (e.g. standard deviation; skewness and kurtosis); (2) edge detection algorithms, such as Sobel and Canny techniques, which were effective in characterising intergranular boundaries; and (3) image entropy appears to provide a proper measure of pattern regularity that is relevant to the dislocation density.

Four samples of BSE images of a titanium specimen are shown in the first column in Fig 1. The images were captured from the same microstructure patch at increasing levels of plastic strain during an *in-situ* tensile test. Two types of texture descriptors, namely Image Entropy and Sobel Edge descriptors, were applied to recognise the extent of plasticity on the four sample BSE images. The maps of the descriptors are shown in the second and third columns of Fig 1, respectively. It may be observed that the density of the descriptors correlate quantitatively with the level of plastic strain.

Additional sets of BSE images from five different patches of the same specimen were captured at the same four strain levels. Similarly, Image Entropy and Sobel Edge were employed to extract the ‘plasticity’ features. The densities of both the Entropy and Edge maps were calculated for all images of the six patches at the four strain levels. Fig 2 shows the relations between the ‘plasticity’ features and the level of plastic strain. It may be observed that the graphs are linearly correlated. Hence, these relationships might be developed as an alternative gauge of the extent of plastic deformation. However, further investigations are need to establish the effect of grain size, grain topology and imaging qualities. In addition, separation of inter-granular boundary information from intra-granular texture features might better reveal the plasticity behaviour.

References

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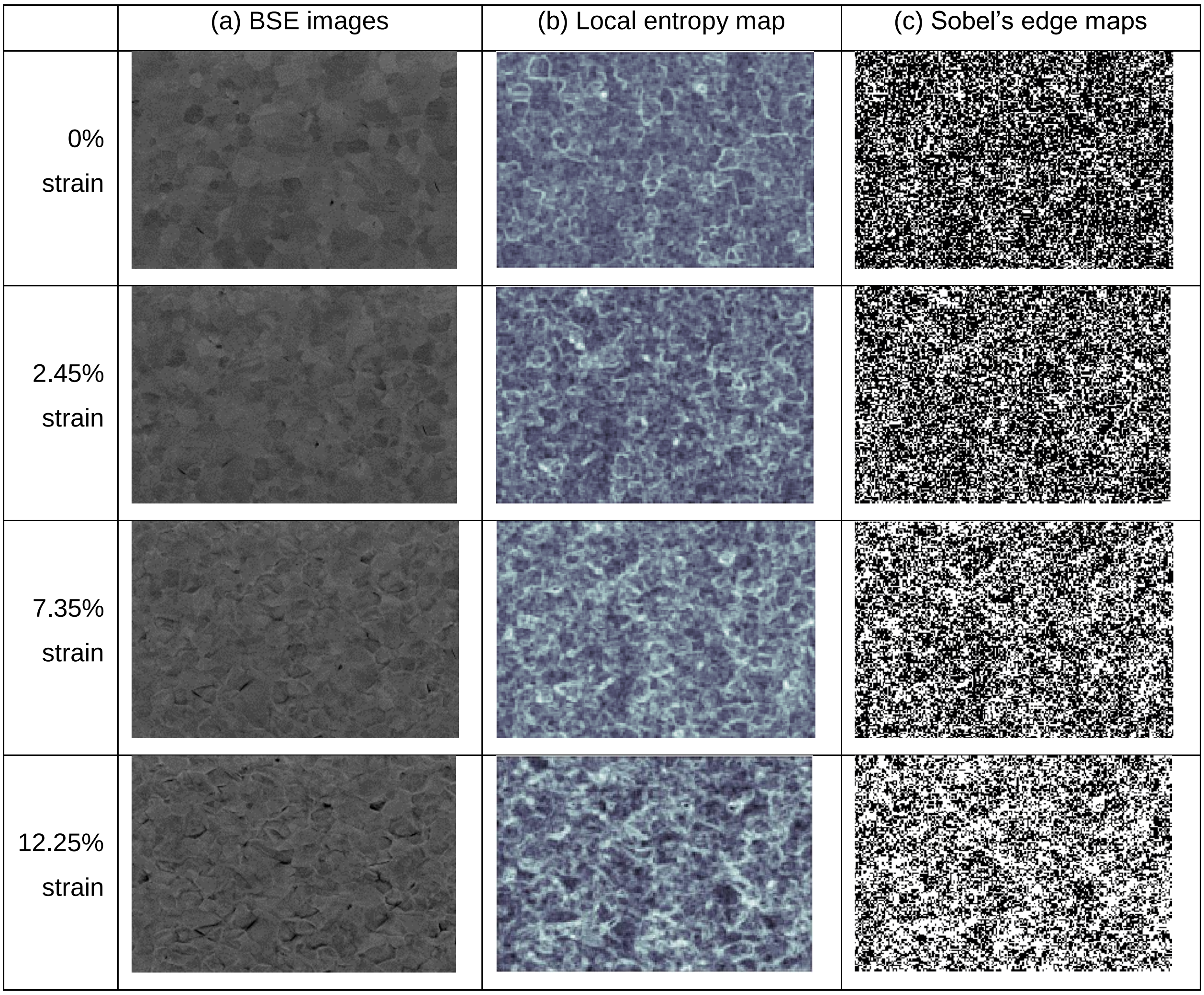

Fig. 1. Column (a): BSE images of same microstructure patch at different strains during in-situ tensile test, column (b): texture maps by Image Entropy of the corresponding BSE images, column (c): texture maps by Sobel's Edge detection method of the corresponding BSE images.

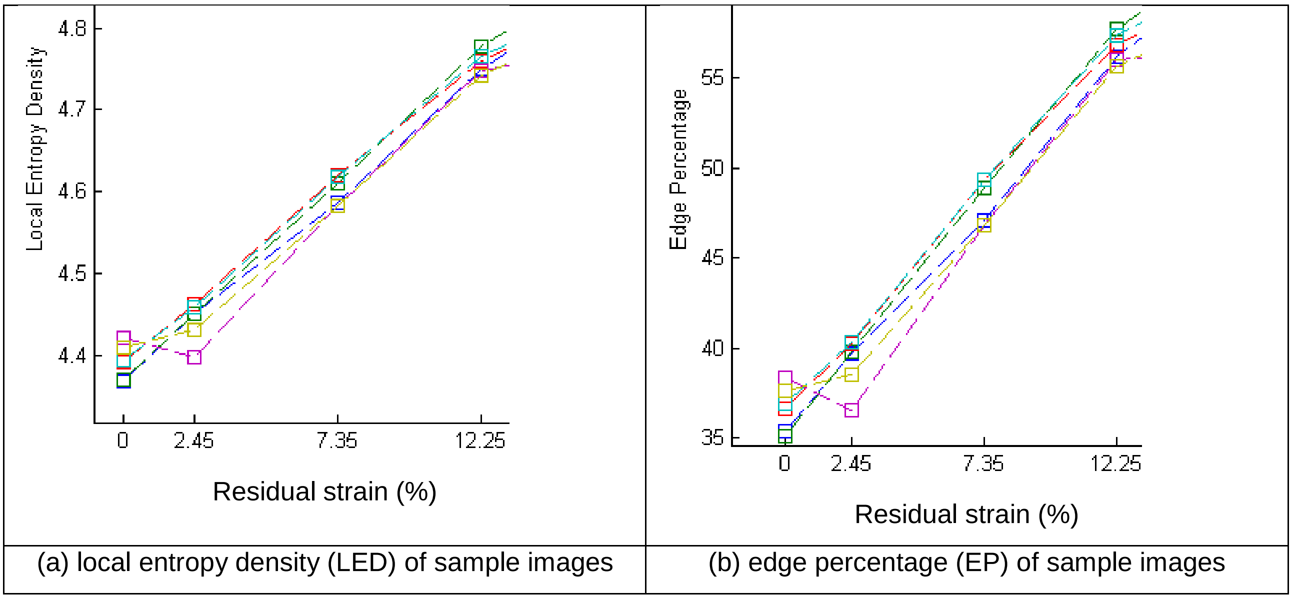

Fig. 2. Evolution of LED & EP with respect to residual plastic strain (Six sets of curves are shown in both the above graphs representing evolution of texture features of the six patches)