Inspection of High Magnification Fracture Surfaces using 3D from Stereo Images of Large Chamber SEM

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In this paper, we show 3D reconstructions of metal surface fractures obtained from affine stereo images. The images are captured with Large Chamber Scanning Electron Microscope (LC-SEM), matched with energy minimizing algorithm, and then reconstructed into 3D. A virtual 3D obtained from the stereo images shows the validity of our reconstruction. Furthermore, spectral information at two energy levels, one for AlK and the other for NbL, is extracted using Energy Dispersive Spectrometer (EDS) and overlaid on the 3D surface. Thus, in addition to performing various measurements on the 3D surface one is able to visually inspect the distributions of constituent materials and correlate them with the surface structure caused by fracture or other impacts.

The LC-SEM image capture is performed in a controlled fashion. The tilt angle between view points and the physical dimensions of the pixels of the images are known. The high magnification of the images allows the use of affine transformation. The principal points of both images are chosen to appear approximately at the centers of the images. Imaging in such a restricted and known set-up enables us to reconstruct the scene in the Euclidian space without calibration of the microscope (Fig. 1(a)) [1]. First, we rectify the images for matching. Since they are captured at high magnification (300X), the distortion effect on surface geometry due to the perspective projection is negligible. Therefore, we can assume that the image formation follows an affine process. Due to this assumption and the fact that the object is tilted around the X axis of the LC-SEM, the images become rectified only after a clockwise 90^o rotation (Fig. 1(b)). Matching on the rectified images is performed by applying an iterative energy minimizing algorithm. A grid is overlaid on the left image and matching is performed only at the grid points (Fig. 2(a)) [2, 3]. The energy equation performs a balance between the data likelihood and smoothness of the grid points. Stereo images captured with LC-SEM and SEM are generally noisy. Therefore, we choose a window based normalized cross-correlation to describe the data term. The smoothness term follows a Normal distribution. Gradient information is used to define the uniqueness score of a grid point. This score enforces matching in low-texture regions. Finally, we use the matched points to compute their 3D coordinates using the affine transform equation described in [1].

Figure 3 shows color coded 3D views of the fracture surface and EDS textures of surface constituents AlK and NbL overlaid on the 3D surface. These are renderings of VRML files written with the shape of the surface as triangular meshes and texture as color of corresponding vertices. Visually it is evident that the presence of the textures on the surface is complementary. NbL is dominant in valley regions and AlK is around the hill.

3D modeling and EDS texture overlay of a fracture surface are shown in this paper. Our future goals are to study the accuracy of the modeling as compared to ground truth models and also to find statistical correlations between depth and distribution of constituent materials on the surface.

References
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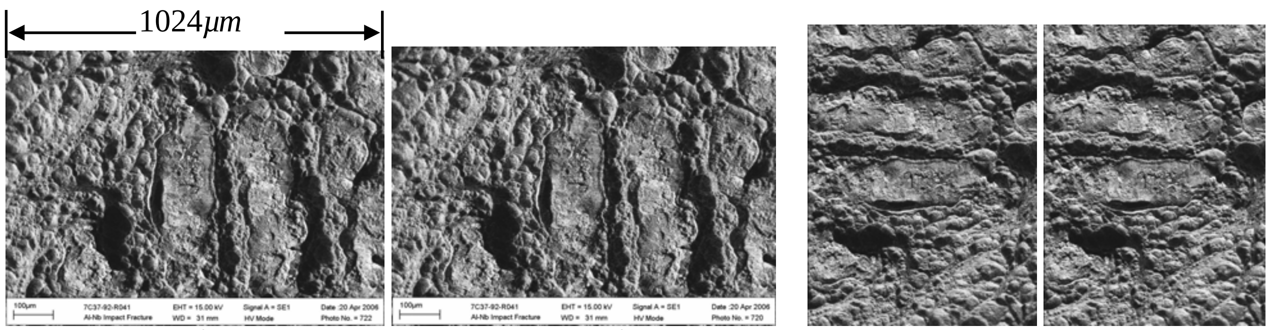

Fig. 1. (a) Stereo image pair captured at 300X magnification; image size 1024×690; (b) stereo image pair cut from images in (a) and rectified with a clockwise 90^o rotation.

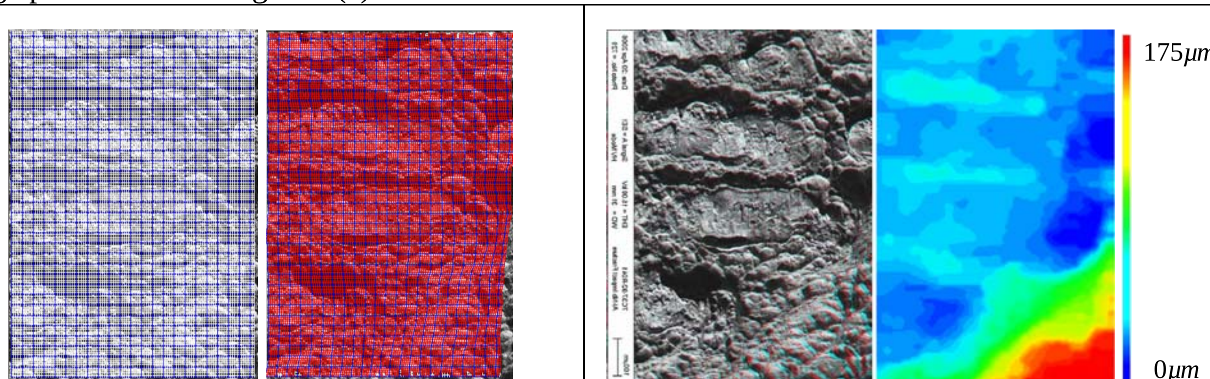

Fig. 2. (a) Stereo image pair matched at grid points; (b) virtual 3D combining red channel of the left image and green and blue channels of the right image; (c) color-coded 3D model.

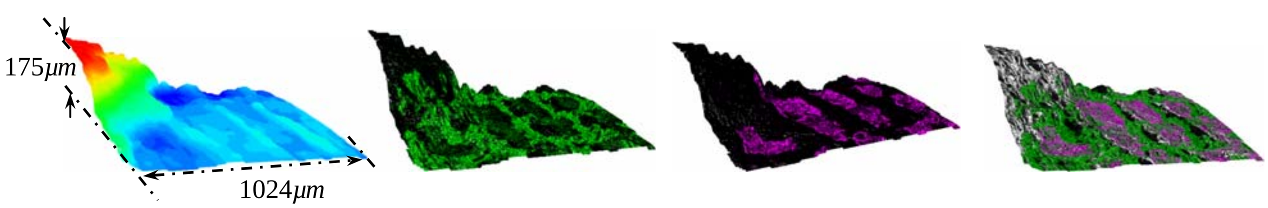

Fig. 3. (a) Color-coded 3D model; (b) AlK texture overlay on the surface; (c) NbL texture overlay; (d) LC-SEM complete textured model.