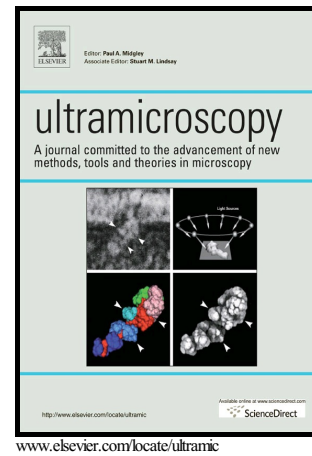


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Photogrammetry of the three-dimensional shape and texture of a nanoscale particle using scanning electron microscopy and freeware software

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Abstract

We apply photogrammetry in a scanning electron microscope (SEM) to study the three-dimensional shape and surface texture of a nanoscale $\text{LiTi}_2(\text{PO}_4)_3$ particle. We highlight the fact that the technique can be applied non-invasively in any SEM using free software (freeware) and does not require special sample preparation. Three-dimensional information is obtained in the form of a surface mesh, with the texture of the sample stored as a separate two-dimensional image (referred to as a UV Map). The mesh can be used to measure parameters such as surface area, volume, moment of inertia and center of mass, while the UV map can be used to study the surface texture using conventional image processing techniques. We also illustrate the use of 3D printing to visualize the reconstructed model.

Keywords: Three-dimensional scanning electron microscopy, photogrammetry, surface texture, image processing, freeware, nanoscale particle morphology, $\text{LiTi}_2(\text{PO}_4)_3$.

Several different techniques are available for the three-dimensional (3D) characterization of micro- and nano- scale structures using electrons. In the transmission electron microscope (TEM), electron tomography [Crowther et al., 1970; Koster et al., 2000; Weyland, 2001; Gontard et al., 2012; Midgley & Dunin-Borkowski 2013] and single particle reconstruction [Penczek et al., 1992] can be applied to studies of thin samples. In the scanning electron microscope (SEM), scanning TEM (STEM) tomography can be used to study very thin samples [Sailer et al., 2010; Guise et al., 2011; Jornsano et al., 2011; García-Negrete et al., 2015], while for sample dimensions of between μm and mm an ensemble of techniques based on the destructive *slice and view* approach has been developed [Bang & Bang, 1957; Soto et al., 1994;

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