Type of presentation: Poster

MS-11-P-1914 High-resolution radial distribution functions of several forms of pure amorphous silicon measured using tilted-illumination selected area electron diffraction

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Pure amorphous silicon (a-Si) is a model tetrahedral amorphous material that can be created by ion implantation and indentation [1]. These forms exist in small volumes, making measurements using transmission electron microscopy (TEM) an excellent option. We demonstrate high-resolution radial distribution measurements of implanted and indented a-Si measured using tilted-illumination selected area diffraction in the TEM.

At advanced x-ray and neutron facilities, large scattering angles can be achieved to yield high-resolution RDFs in bulk homogeneous specimens. Fixed apertures in the TEM and finite dynamic range of electron detectors can limit the accessible range of diffraction angles, and the resolution of the RDF. However, by sequentially tilting the incident TEM illumination and increasing corresponding acquisition times, large angles can be accessed, resulting in RDF resolutions comparable to those from neutron and x-ray measurements [2] yet from sub-micron areas.

Several forms of as-prepared and annealed a-Si were prepared as detailed previously [1]. Selected area diffraction patterns were obtained in a JEOL JEM 2100F operated at 200 kV. The dark-tilt was incrementally increased to access larger diffraction angles. By increasing the exposure time for higher angle diffraction patterns the Poisson noise contribution was kept below 15% across the whole range sampled ($2\sin(\theta)/\lambda$ = 3.3-3.7 Å^{-1}). The diffraction patterns were spliced together [2] (Fig. 1) and analysed using RDFTools, a free software package [3].

Fig. 2 shows the RDFs measured for the as-implanted a-Si and the relaxed implanted a-Si films [2]. Average coordination numbers for the as-implanted and relaxed specimens were measured to be 3.7±0.3 and 3.9±0.3, respectively. Bond angles of 109±0.5° and 110±0.6° were measured for the as-implanted and relaxed a-Si [2].

Tilted illumination selected area diffraction can produce high resolution RDFs of amorphous materials in small volumes to distinguish subtle pair correlation differences between specimens with different treatments. However, in striking contrast to other amorphous networks, the structural re-arrangements of ion-implanted a-Si due to a relaxation anneal are subtle.

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Acknowledgement: ACL gratefully acknowledges the support of the Science Faculty and the Monash Centre for Electron Microscopy (MCEM), Monash University. TP acknowledges support from the MCEM. The authors acknowledge use of facilities within the MCEM. JEB acknowledges an ARC QEII.

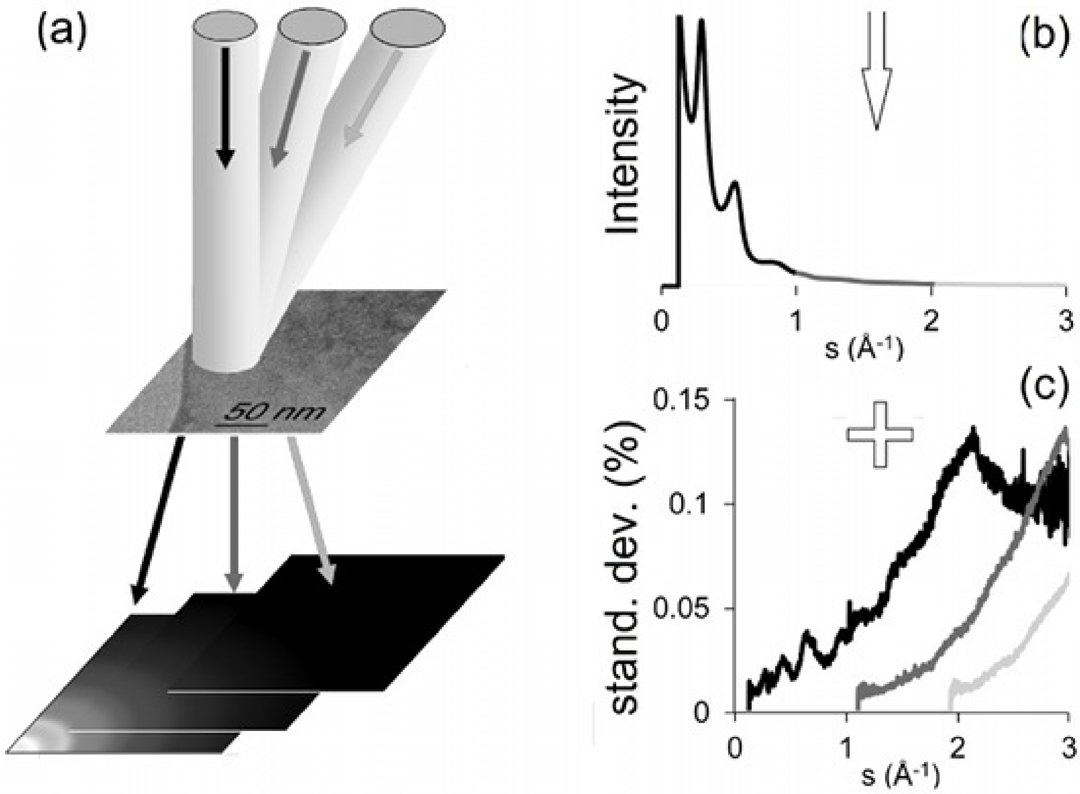

Fig. 1: a) Dark-field tilt is used to extend the angular range of a diffraction pattern. b) Diffracted intensities are spliced together, so that the noise level (c)) is below 15% of signal across the whole range.

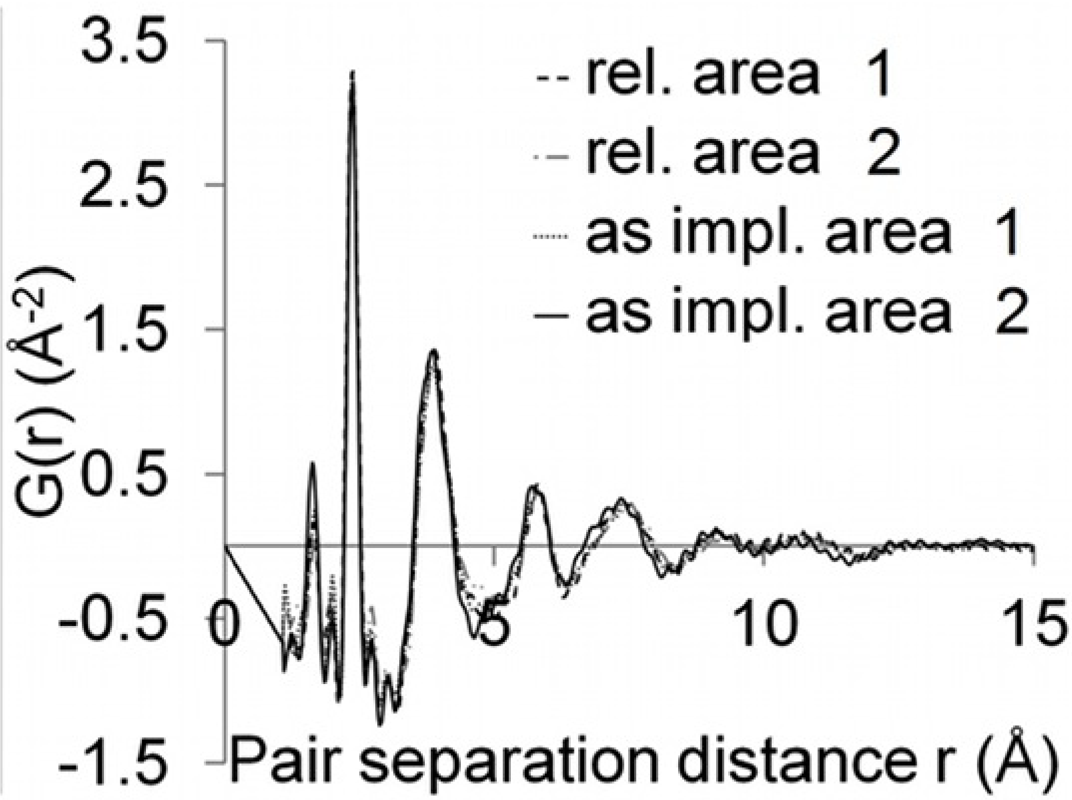

Fig. 2: Reduced radial distribution function of as-implanted and relaxed ion implanted a-Si.