Understanding the structure of disordered materials remains a challenge. In the aberration-corrected scanning transmission electron microscope (STEM) intense, coherent, quasi-parallel and nanometre-sized beams may be achieved allowing diffracted information to be obtained from small volumes. Electron nano-diffraction (END) patterns from thin metallic glass specimens contain angular correlations related to symmetries in nearest-neighbour polyhedral clusters [1]. Examining the persistence of these angular correlations in a scanned array of END patterns allows a measure of the medium-range order in the material [1]. We apply this novel technique to understanding the excellent glass formability of Zr_{36}Cu_{64} glasses [1].

Scanned arrays of END patterns from a melt-spun Zr_{36}Cu_{64} glass were obtained in a Titan 80-300 FEGTEM (Fig. 1 a) and b)). Subtle angular symmetries in the END patterns were detected by calculating the angular autocorrelation function (Fig. 1 c) and d)). The autocorrelation function was decomposed into a Fourier Cosine series at each scattering vector magnitude and the symmetry intensities in each pattern were measured (Fig. 1 e)) and mapped as a function of scanned distances to examine the extent of any order (Fig. 2).

We statistically analysed the incidence of two-, six- and ten-fold symmetries in the SEND patterns and found that these compare favourably to those expected for a random ensemble of icosahedra, consistent with many modeling studies.

Fig 2. shows the 2-, 6- and 10-fold symmetry maps for both the experimental glass and a model glass structure. The only correlation length that extends beyond the probe diameter is the experimental two-fold map, demonstrating that the glass has extended order. The MRO consistent with this trend is face-sharing or interpenetrating icosahedral clusters in which the 2-fold symmetry axes align, but the 5- and 6-fold do not. The correlation length in the 2-fold map corresponds to four face-sharing or seven interpenetrating icosahedra.

Using scanning END and a novel analysis of the angular correlations in END patterns we determine that the S-MRO in Zr_{36}Cu_{64} is consistent with efficiently packed icosahedral clusters [1], suggesting a structural basis for glass formability.


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Fig. 1: a) HAADF reference image of glass with scanned area b) END pattern c) angular cross-correlation function and d) profile at 4 nm\(^{-1}\) e) magnitude of 0-12-fold symmetry intensities.

Fig. 2: Maps of symmetry intensity from array of END patterns for model glass (a), (c), (e)) and experimental glass (b), (d), (f)) and corresponding radially averaged, two-dimensional autocorrelation functions.