MEASURING STRAIN DISTRIBUTIONS IN AMORPHOUS MATERIALS

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Diffraction methods have become standard in the characterisation of stress and strain fields in *crystalline* materials. To our knowledge, characterisation of strain in *amorphous* materials by diffraction methods has not been reported. This is remarkable, since their scope within materials science and engineering parallels that of crystalline materials. Most ubiquitously, polymer glasses are used in applications from medicine to transport to space flight. At present localised strain information is only available from surface probes such as optical or electron microscopy. This is unfortunate since surface and bulk characteristics in general differ. Hence, to a large extent, the assessment of strain distributions relies on untested models.

Here we present a universal diffraction method based on hard x-rays for characterising bulk stress and strain fields in *amorphous* materials. The transmission type set-up involves a focused monochromatic beam, an area detector and acquistion of images while rotating the sample around one axis. Using correlation functions, minute shifts in local maxima are determined in reciprocal space as well as direct space, that is in the S(Q) and g(r) profiles, respectively. The components of the strain tensor are determined with a resolution of 10^{-4}.

The method was verified by *in-situ* compression experiments on a bulk metallic glass (BMG) performed at ID15B at ESRF. Shown in **Figure 1a** are the resulting axial, transverse and shear strains during two consecutive loading cycles, as derived from the first maximum in S(Q). Probing the strain on a length-scale of ~10 Å in this way, the axial response for the homogenous specimen is found to be identical to the macroscopic strain evolution. By comparison, similar plots based on the shifts of the first three maxima in g(r) – **Figure 1b** - demonstrate that the atomic next-neighbor bonds are 2.7 times stiffer due to structural rearrangements at the 4-10 Å scale. Mapping strain fields is achieved by scanning the specimen, as illustrated in the example of **Figure 2**. Additional work on partially crystalline BMGs demonstrated that the method is applicable also to composites comprising an amorphous matrix and crystalline inclusions.

Reference:
H.F. Poulsen, J.A. Wert, J. Neuefeind, V. Honkimäki, M. Daymond. Nature Materials, in print.

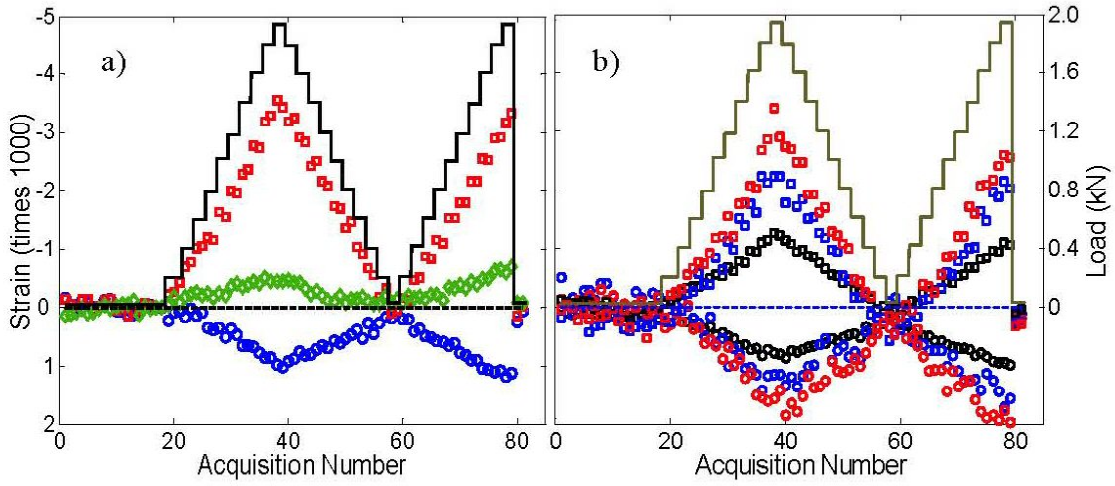

Figure 1
Evolution of strain components during uni-axial compression of a homogenous specimen, with the external load indicated by the line and refering to the scale at the right. (a) Axial (square), shear (diamond), and transverse (circle) strain components, resulting from an analysis based on the shift of the first peak in S(q). (b) Axial (square) and transverse (circle) components as derived from the shifts in the three first peaks in g(r). Symbols related to the first, second and third peak are coloured black, blue and red, respectively.

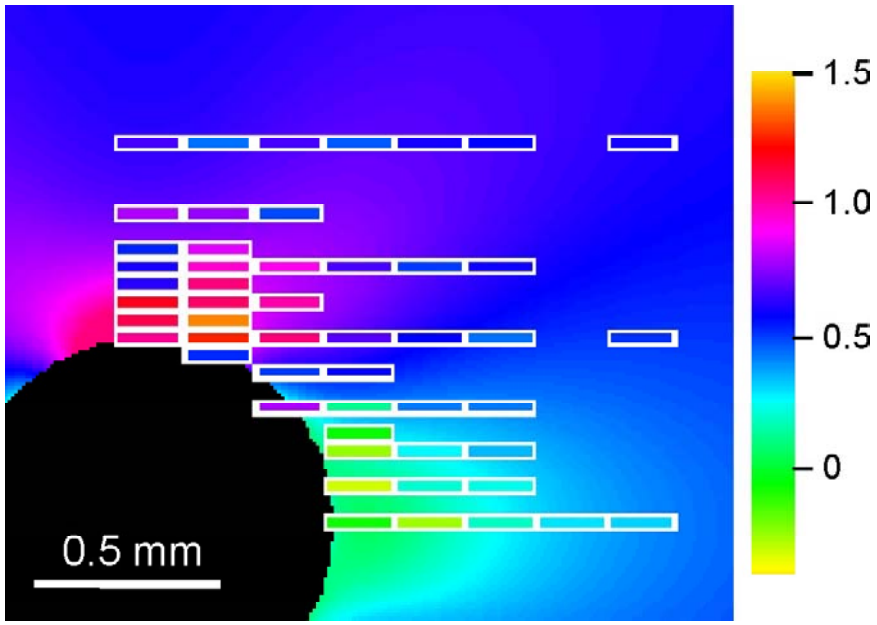

Figure 2.
The axial strain field around a circular hole in a 2 mm thick plate of a bulk metallic glass at a compressive stress of 390 MPa acting in the horizontal direction. Shown are the results from the x-ray diffraction experiment (boxes) as well as the result of an analytical model (background) – both with reference to the colour code to the right (lattice strain in %).