<table>
<tr><td>ESRF</td><td>Experiment title:
DEFORMATION MICROMECHANICS IN OPAQUE MODEL COMPOSITES</td><td>Experiment number:
SC-1451</td></tr>
<tr><td>Beamline:</td><td>Date of experiment:
from: 23rd June 2004 to: 27th June 2004</td><td rowspan="2">Date of report:
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<tr><td>Shifts:
12</td><td>Local contact(s):
Dr Richard DAVIES</td></tr>
<tr><td colspan="3">Names and affiliations of applicants (* indicates experimentalists):
Professor Robert J. Young
Dr Stephen J. Eichhorn
Mr. Y.-T. Shyng</td></tr>
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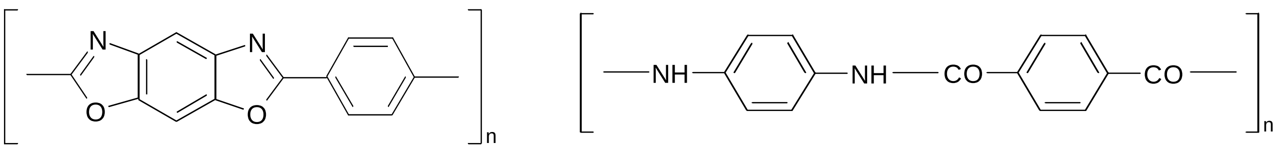
Report:

Composites are being used increasingly in structural engineering applications but their performance is limited by the strength of the fibre-matrix interface. This project has been concerned with the use of microfocus x-ray diffraction to measure stress in individual fibres in both optically transparent and opaque matrices. Synchrotron radiation has been proven as a powerful tool for studying the structure and deformation of high performance fibres such as PBO and PPTA (Fig. 1). It is well-known that their so-called "rigid-rod" structures are able to sustain a high tensile load for a relatively low elongation. Furthermore, the well-packed and highly crystalline structures of these fibres gives strong and well-defined x-ray diffraction patterns using short exposure times (5 seconds).



(a) (b)

Figure 1. Molecular structures of (a) PBO and (b) PPTA aramid fibres

In this study [1,2] the deformation of a particular geometry, namely a droplet-fibre model composite (see Fig. 2), was examined on the microfocus beamline ID13 of the ESRF. The stress distributions along the 12 μm diameter fibres were mapped using a 5 μm diameter beam and the corresponding stress profiles were determined. We have previously reported the use of a transparent matrix (two-part cold curing) epoxy resin

for the microdroplets, but this time we were successful in obtaining clear fibre diffraction patterns through polypropylene resins.

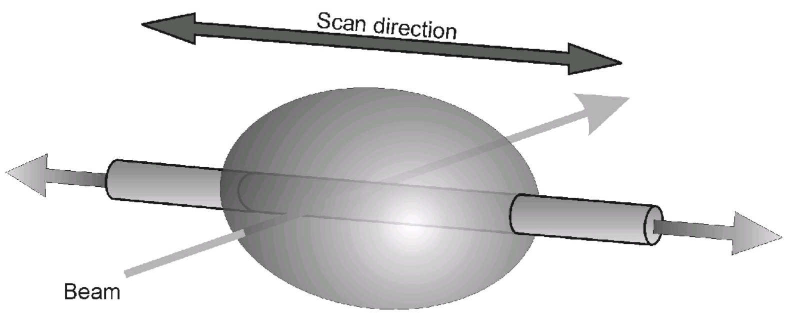


Figure 2. Schematic diagram of the experimental set-up for the microdroplet specimen.

Figure 3(a) shows the axial fibre crystal strain as a function of the position of the beam along the fibre. Using the intensity of the diffuse scattering from the resin (epoxy) we were also able to calculate the geometry of the droplet. Figure 3(a) therefore shows a debonded fibre within the droplet, and demonstrates that a full picture of the mechanics of the model composite can be

(a) (b)

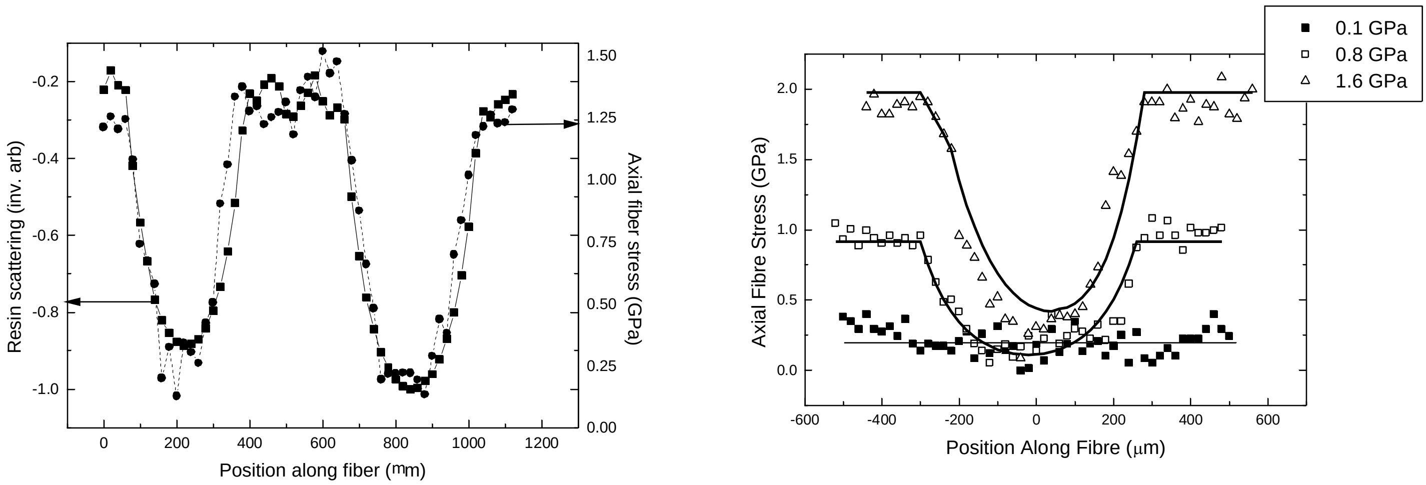


Figure 3. The (a) resin scattering and axial fibre stress as a function of the position along the fibre and the (b) axial fibre stress as a function of position along the fibre for three loading levels (fitted lines are for a new micromechanical model [2]). Model composite is a PPTA-epoxy droplet system.

obtained. We have been able to obtain similar profiles from fibres with opaque resins such as polypropylene. This has significantly extended our abilities to understand composite systems which hitherto have not been possible using our conventional methods of mapping stresses using Raman spectroscopy (due to the non-transparency of matrices such as polypropylene). We have also worked extensively on data-processing techniques, in conjuntion with the beamline scientist (Dr Davies), such that we are now able to extract resin diffraction data from fibre/resin data in a way that does not compromise the intensity of the fibre meridional layer lines. We have also now developed models, based on a double-pull out geometry with a non-zero fibre stress at the centre of the droplet to enable us to better understand the stress-transfer in this novel composite system [2]. The model fits the elastic stress-transfer regions well (see Figure 3(b)), and with additional debonding criteria, we have been able to calculate the interfacial shear stress at all load levels.

1. Young, R.J., Eichhorn, S.J., Shyng, Y.-T, Riekel, C., Davies, R.J. 2004. Analysis of Stress Transfer in Two-Phase Polymer Systems Using Synchrotron Microfocus X-ray Diffraction. *Macromolecules*, **37**, 9503-9509.
2. Eichhorn, S.J., Shyng, Y. T., Young, R. J., Davies, R. J. 2005. Analysis of interfacial micromechanics in model composites using synchrotron microfocus x-ray diffraction. *Composites Science and Technology* - in preparation.