| ESRF | **Experiment title:** DEFORMATION MICROMECHANICS IN OPAQUE MODEL COMPOSITES | **Experiment number**: SC-1334 |
|---|---|---|
| **Beamline**: ID13 | **Date of experiment**: from: 24 July 2003 to: 28 July 2003 | **Date of report**: 27 JUNE 2004 |
| **Shifts:** 12 | **Local contact(s)**: Dr Richard DAVIES | *Received at ESRF:* |


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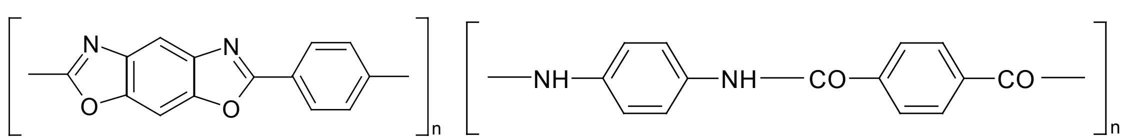
## Report:

Composites are being used increasingly in structural engineering applications but their performance is limited by the strength of the fibre-matrix interface. This project is 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 polymer 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 give strong and well-defined x-ray diffraction patterns.



*(a)* *(b)*

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

In this study [1,2], the deformation of different geometries of single-fibre model composites 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 interfacial shear stress values calculated.

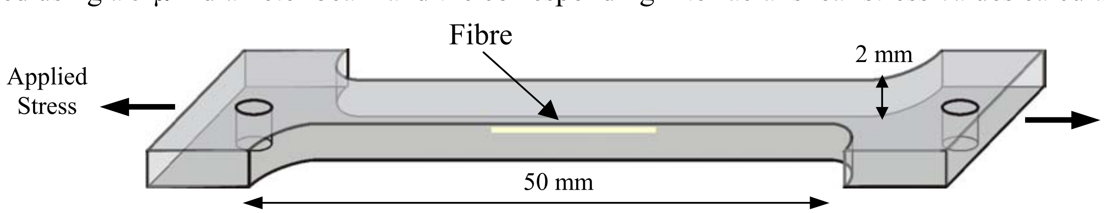



**Figure 2.** Illustration of single-fibre embedded sample

The matrix material chosen was a cold-curing two-part epoxy resin supplied by Ciba Geigy, UK. It consisted of 100 parts by weight of butane-1,4-diol diglycidyl ether resin (LY5052) and 38 parts by weight of isophorone diamine hardener (HY5052), cured at room temperature for seven days. Dumb-bell test specimens were prepared as shown in Fig. 2 and microdroplet specimens were also produced, as shown in Fig. 3.

**Figure 3.** Single fibre microdroplet composite sample showing a 250 μm droplet on a PPTA fibre

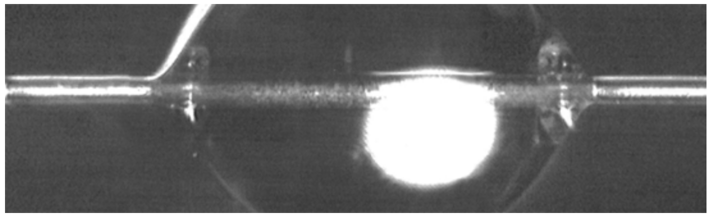


Fig. 4(a) shows the axial fibre crystal strain distribution in a PBO fibre model single-fibre embedded composite. The position values along the fibre refer to the distance in microns from the free fibre end. The diffraction data were generated at four different levels of loading. The initial stress of approximately 0.05 GPa in the unloaded specimen is possibly due to pre-stretching of the fibre during insertion. The fitted lines are for the data fitted to the Cox shear-lag model. The axial fibre stress distribution along a PPTA microdroplet composite is illustrated as Fig. 4(b). Seven load levels were applied in this experiment and the PPTA microdroplet composite results show a significant discontinuity in their curve profiles suggesting that extensive debonding occurred. The stress distribution has a symmetric shape for the first three deformation steps, which implies an intact interface that remained fully bonded. Two significant debonding regions on the right side of the spline fit result can be identified at higher loads. Furthermore, since the debonding regions do not remain symmetric, it suggests the propagation of interfacial failure with increasing stress.

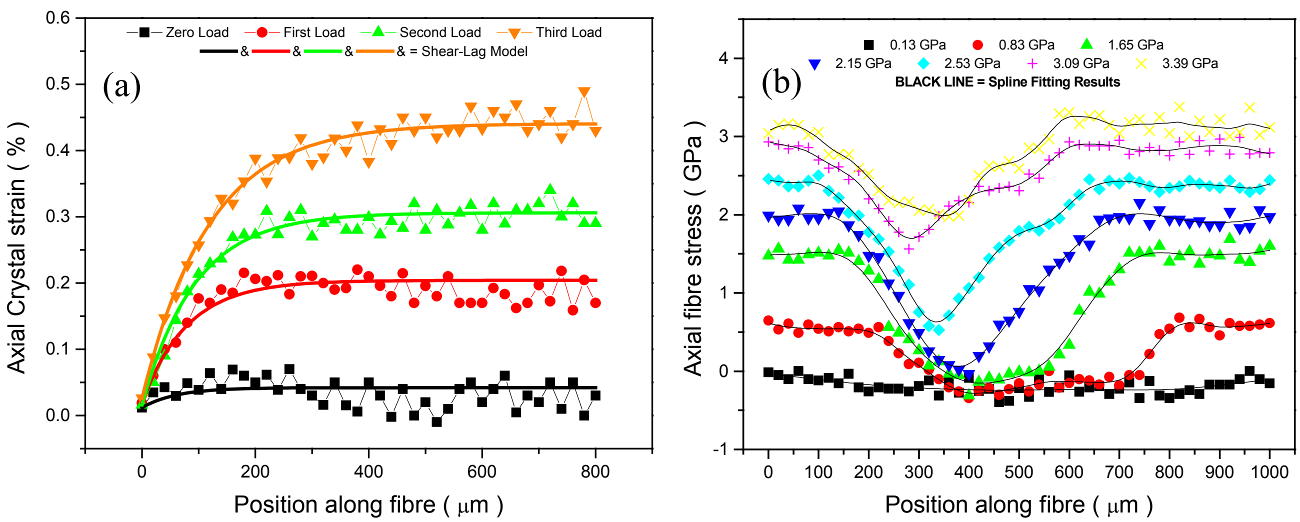



**Figure 4.** (a) Distribution of axial crystal strain along a PBO fibre in a single-fibre embedded composite. (b) Distribution of axial fibre stress along a PPTA fibre in an epoxy resin droplet.

It has been demonstrated that microfocus x-ray diffraction is a powerful technique for investigating the micromechanics of deformation in model composite geometries. The above examples are for a transparent epoxy resin; future studies will extend the technique to opaque matrices such as polypropylene and nylon 66.


1. Y.-T. Shyng, R.J. Young and R.J. Davies, *Analysis of Interfacial Micromechanics of Single-Fibre Model Composites using Synchrotron Microfocus X-Ray Diffraction*, ECCM11, Rhodes, Greece, 1-5 June, 2004 (Paper B124).
2. Y.-T. Shyng, S.J. Eichhorn, R.J. Young and R.J. Davies, *Investigation of The Interfacial Micromechanics of A Single Fibre Microdroplet Composite Using Synchrotron Radiation*, ECCM11, Rhodes, Greece, 1-5 June, 2004 (Paper B125).