Although composites have a number of superior properties to most metals, their through-thickness properties and delamination resistance are poor. These limitations could be alleviated by the addition of nanoscale reinforcements such as surface treated carbon nanotubes and graphene nanoplatelets. This project looks at the manufacturing techniques of multiscale composites such as these for Mode I fracture toughness testing.

### Nanomaterials Used

Initial tapered double cantilever beam tests showed that untreated nanotubes do not disperse well (see figure 2) so were discarded for the DCB tests. Instead the following materials were used:

- $O_2$ treated GNPs
- $O_2$ treated Bayer tube CNTs
- $O_2$ treated Nanocyl CNTs
- Acid treated Bayer tube CNTs

### Double Cantilever Beams

#### Manufacture Process

The CNTs were dispersed in ethanol and pipetted at the top of a composite ply.

#### Testing

The DCB tests were carried out using the Mode I experimental set up as shown in figure 5.

#### Results

- As seen in figure 2 the dispersion quality varied between treatments: best being with $O_2$ treated CNTs and worst with untreated CNTs.
- Nanocyl CNTs were more viscous and required more ethanol for dispersion.
- The drawdown method resulted in some agglomeration and could often produce plies like that shown in figure 6.
- Some of the reinforced DCBs showed significant improvements when tested, particularly when using glass fibres as seen in figure 7.

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**Figure 1:** SEM photos L-R As received Bayer tubes, $O_2$ treated Bayer tubes

**Figure 2:** CNTs dispersed in ethanol L-R As received Bayer tubes, Acid treated Bayer tubes, $O_2$ treated Bayer tubes, $O_2$ treated Nanocyl

**Figure 3:** Drawdown coating procedure

**Figure 4:** Coated ply

**Figure 5:** Testing DCB

**Figure 6:** Inconsistent coated ply example

**Figure 7:** Glass Fibre DCB Results