Polymer Composite Images

Figure 2(a, b): SEM images of composites showing various types of damage at interphase regions.

Research question:
What are the mechanical properties of the through-thickness interphase of polymer matrix composites? What is the evolution of the adhesion and cohesion damage? What is the extent of adhesion and cohesion damage through the thickness of the interphase?

Why the Research is Important
Adhesion and cohesion damage through the thickness of the interphase region in composite systems is not readily available. Understanding the damage occurring at the interphase of composites needs to be researched as they drive the overall mechanical properties of the composite system. Various studies have shown considerable deviations in the results of mechanical properties using phase imaging tapping mode, nanoindentation, nano-scratch, and volume techniques [1-5]. This research utilizes Atomic Force Microscopy (AFM) with Peak Force Quantitative Nanomechanical Mapping (PF QNM) to determine the adhesion and cohesion damage of a polymer matrix composite (PMC). This research will “keep people and infrastructure secure” [6] by expanding the development and understanding of advanced materials, such as PMCs, utilized in critical structures, such as airplanes.

Steps of the Research
1. Manufacture multiple polymer matrix composites using carbon fiber and epoxy.
2. Cut samples at subsurface and depth, (see Fig. 1), from manufactured composite laminates.
3. Polish all samples to 1μm and clean to ensure a pristine surface to conduct AFM PF QNM testing on.
4. Calibrate AFM probes to be utilized using a substrate with known mechanical properties and conduct multiple tests using PF QNM technique on samples.
5. Conduct DMA and static mechanical studies for comparisons.
6. Analyze data collected from AFM PF QNM and DMA testing. Do calculations for mechanical properties from data.
7. Compare all collected data from preformed tests and draw conclusions and results.

Current Results
PF QNM technique was used to analyze topography, elastic modulus, and adhesion of the through-thickness interphase in polymer matrix composites. Results are shown in Table 1 and Figure 3 below:

Table 1: Microscale Properties at Depth and Subsurface of composite

<table>
<thead>
<tr>
<th>Sample Location</th>
<th>Interphase Thickness (μm)</th>
<th>Avg. E, f for interphase (GPa)</th>
<th>Range of E for interphase (GPa)</th>
<th>Aref percentage of delamination per fibers in 35μm – 75μm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>9.8 ± 4.3</td>
<td>22.3 ± 15.0</td>
<td>21.6 – 31.3</td>
<td>2.5 ± 0.3%</td>
</tr>
<tr>
<td>Subsurface</td>
<td>874 ± 4.2</td>
<td>21.2 ± 2.2</td>
<td>22.9 ± 20.8</td>
<td>2.6 ± 0.3%</td>
</tr>
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References