Graphene Nanoplatelet Thin Films as an Electrostatic Actuator

Zeyang Yu, Lawrence Drzal
Department of Chemical Engineering & Materials Science, Composite Materials & Structure Center
Michigan State University

**Introductions & Objectives**

In an electroscope, when conductive parallel thin films are charged to the same potential, they repel each other and separate. When the potential is removed, the two thin films return to their original positions. This project seeks to investigate if this principle can be utilized to produce an actuator that could serve as a motor to propel a submerged body in water. A goal is to produce motion through separation of conductive films to be the movable components. One is fixed in space and the other is allowed to move through a hinge mechanism. The composite films return to their original positions.

**Assembling of Experiment**

Two thin composite papers have been selected as candidates for the thin films to be the movable components. One is fixed in space and the other is allowed to move through a hinge mechanism. The composite papers are the anode and the cathode is connected to ground. Application of voltage causes motion.

**Electrode Materials: Graphene Paper**

The graphene nanoplatelet thin film is prepared by vacuum filtration of a graphene nanoplatelet water suspension using PEI as the dispersing agent. This is followed by drying at room temperature overnight and then drying in a vacuum oven for 24h.

**Epoxy and Graphene Composite Paper**

The composite is prepared using a doctor blade to coat a mixture of epoxy and curing agent on both sides of the graphene nanoplatelet paper with a controlled thickness. The composite paper is cured in an oven. The epoxy layer encapsulates and isolates the graphene paper electrically and increases its mechanical properties.

**Modifications to Composite Thin Film**

Various compositions of thin films were made with graphene M15 and graphene C750 via a layer by layer approach creating a sandwich structure. The graphene nanoplatelet paper is prepared by vacuum filtration of a graphene nanoplatelet water suspension using PEI as the dispersing agent. This is followed by drying at room temperature overnight and then drying in a vacuum oven for 24h.

**Actuating Performance**

The actuating performance was measured at various voltages ranging up to 12.5kV. The separation generated under each voltage was recorded to evaluate the various compositions. The dimensions and weight of each thin film were also recorded.

**Results**

<table>
<thead>
<tr>
<th>Sample</th>
<th>0kV</th>
<th>6.5kV</th>
<th>7.5kV</th>
<th>10kV</th>
<th>12.5kV</th>
<th>AVE mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.0</td>
<td>5.5</td>
<td>7.0</td>
<td>12.0</td>
<td>16.0</td>
<td>2.4472</td>
</tr>
<tr>
<td>2</td>
<td>2.0</td>
<td>5.0</td>
<td>7.0</td>
<td>10.5</td>
<td>15.0</td>
<td>2.0294</td>
</tr>
<tr>
<td>3</td>
<td>1.0</td>
<td>5.0</td>
<td>6.0</td>
<td>9.5</td>
<td>14.0</td>
<td>2.2536</td>
</tr>
<tr>
<td>4</td>
<td>1.5</td>
<td>2.5</td>
<td>3.5</td>
<td>6.0</td>
<td>8.5</td>
<td>3.5653</td>
</tr>
<tr>
<td>5</td>
<td>2.0</td>
<td>3.5</td>
<td>4.5</td>
<td>7.0</td>
<td>10.5</td>
<td>2.2542</td>
</tr>
<tr>
<td>6</td>
<td>1.0</td>
<td>2.5</td>
<td>4.5</td>
<td>8.0</td>
<td>12.5</td>
<td>1.5961</td>
</tr>
<tr>
<td>7</td>
<td>1.0</td>
<td>2.5</td>
<td>3.5</td>
<td>6.5</td>
<td>10.0</td>
<td>2.2684</td>
</tr>
</tbody>
</table>

* Sample 1: pure GNP R10 paper (437g suspension)  
* Sample 2: pure GNP M15 paper (437g suspension)  
* Sample 3: GNP M15 (218.5g suspension) +C750 (437g)+M15 (218.5g)  
* Sample 4: GNP M15 (218.5g suspension) +C750 (437g)+M15 (218.5g)  
* Sample 5: GNP M15 (120.2g suspension) +C750 (240.4g)+M15(120.2g)  
* Sample 6: pure GNP R10 paper (218.5g suspension)  
* Sample 7: GNP R10 paper +CNC (10wt% 43.8g)

Graphene R10 paper gives the best results, with the largest separation distance achieved even though this was the heaviest sample. Compared to pure graphene M15 paper, adding some graphene C750 (smaller diameter of graphene nanoplatelets) shows some improvement. However, increasing the ratio of C750 to M15 gives the negative results attributed to the microstructure of C750. The graphene nanoplatelets are aggregated in C750 and require an extensive sonication to separate the individual nanoplatelets. The graphene paper with cellulose micro fibrils did not show a significant improvement.

**Future Work**

Additional capacitance increase are required to further improve the performance of these composite electrodes. Refinement of the C750, the use of metal particles, and adding a conductive polymer, polyaniline as an additive to make composite paper with graphene will be investigated.

**References**
