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Laser-Scribed Graphene Micro-Supercapacitors

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Introduction

Supercapacitors are capacitors that have high energy and power density, comparable to lithium-ion batteries. Currently, they are large and bulky, and this makes it hard to be implemented into smaller electronic devices or on-chip.

This research is based on El-Kady and Kaner’s Scalable Fabrication of High-power Graphene Micro-supercapacitors for Flexible and On-chip Energy Storage. El-Kady and Kaner developed an inexpensive and reliable method for making micro-supercapacitors (MSC) that have a surface area of 40.28 mm⁴ and a thickness of 7.6 μm.

Fabrication Process

1. Deposit 15mL of an aqueous solution of graphite oxide (GO) onto a polyethylene terephthalate (PET) film that is adhered to a LightScribe disc. Allow to dry.

2. The disc is then inserted into a LightScribe DVD drive and run at the highest contrast setting. It etches the GO into Laser-scribed graphene (LSG) in an interdigitated pattern.

3. A hydrogel-polymer electrolyte is drop casted on the pattern creating a planar MSC. Allow to dry. The GO and electrolyte form a catalyst that promotes the movement of ions between the electrodes.

4. Copper tape is attached to each electrode and the MSC is sealed around the edges with Kapton tape.

What is Graphene?

Graphene is a thin layer form of carbon that is reduced from GO. This reduction happens from the intense laser light that boils off the oxygen as CO₂. Graphene has high electrical conductivity (i.e. low resistance), and its 3D structure increases its accessibility to ions in the electrolyte.

The above images show the difference between the GO and the LSG. In the right image, the reduction and expansion of the GO is visible.

Interdigitated Pattern

A smaller surface area is desirable for higher capacitance, and faster charge and discharge rates.

The interdigitated patterns were created in Adobe Illustrator with specs that follow the table below.

<table>
<thead>
<tr>
<th>Version</th>
<th>Surface Area (mm²)</th>
<th>Inter-space, i (mm)</th>
<th>Edge, e (mm)</th>
<th>Length, l (mm)</th>
<th>Width, w (mm)</th>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4 wires</td>
</tr>
<tr>
<td>V1</td>
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<td>0.15</td>
<td>0.2</td>
<td>4.8</td>
<td>1.77</td>
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<td>V2</td>
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<td>0.1</td>
<td>0.2</td>
<td>4.85</td>
<td>1.81</td>
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<td>0.1</td>
<td>1.0</td>
<td>4.85</td>
<td>1.81</td>
</tr>
</tbody>
</table>

Characterization

Methods of characterization include field emission scanning electron microscopy and optical microscopy to view the molecular surface structure of the MSC and its electronic properties. I-V curves were measured using a two-electrode setup. This provides a way to calculate the conductivity and thickness of the film.

Other properties of interest are the LSG-MSC’s energy and power density, its capacitance at various frequencies, and various current densities. These were attained using galvanostatic curves and using the following equations:

\[ P = \frac{\Delta E}{4 \pi \varepsilon_0 V} (W/cm^2) \]

\[ E = C \times \Delta E / (2 \times 3600) (Wh/cm^2) \]

\[ C_{enr} = l / (dV/dt) (F) \]

Conclusion

The power performance of these LSG-MSC’s have been comparable to lithium-ion batteries, which is what is in most phones today. However, these have the advantage of being tiny, flexible, and faster charge and discharge rates, giving it a wider range of applications, such as wearable devices (smart watches).

Future work for this research project include fabricating and characterizing the laser-scribed graphene micro-supercapacitor, and finding the most efficient ratio between the length, edge, and interspace that will provide the most capacitance.

References
