GRAPHENE POWER PACK

A SENIOR HONORS PROJECT BY

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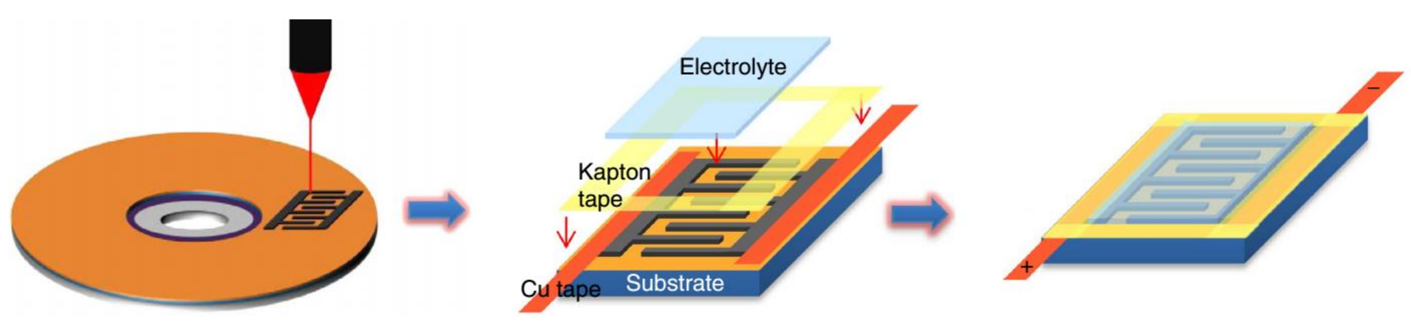
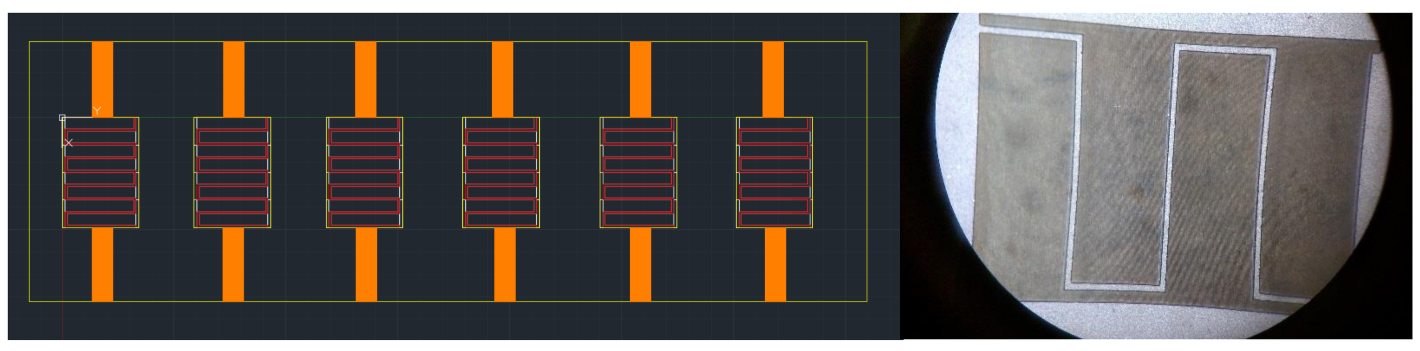
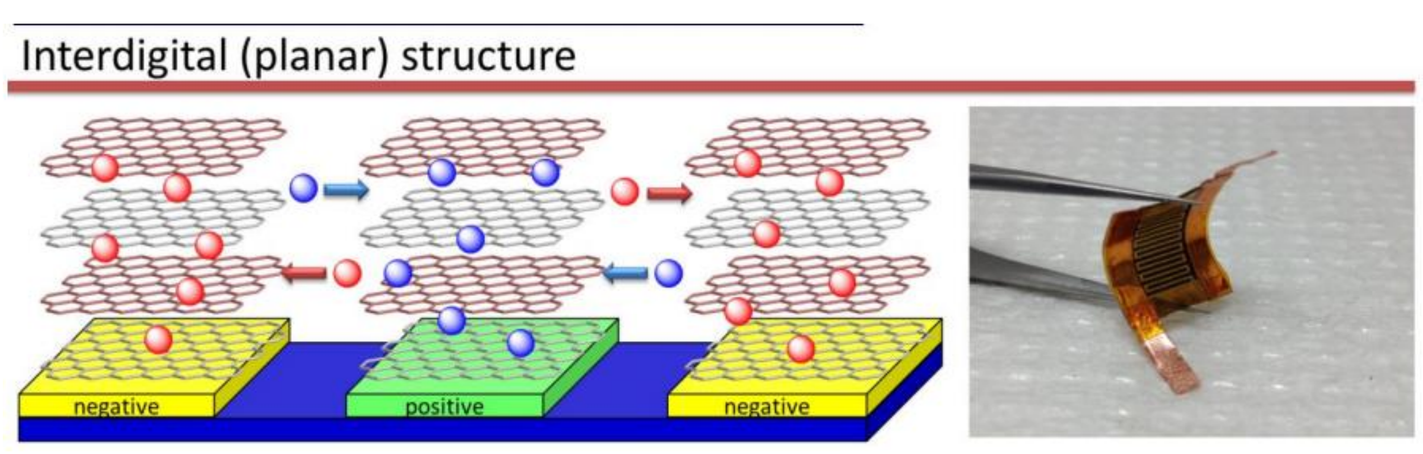
FABRICATION AND ASSEMBLY





UCLA developed a method of processing graphene capacitors in a scalable and inexpensive manner. By adapting their method to the tools provided at UMass, I was able to fabricate and assemble capacitors. Beginning with graphene oxide (GO) deposited on a substrate, such as glass, one can laser irradiate a programmed pattern into the GO so as to render the illuminated areas into graphene. This method is called Laser Reduction, and the planar interdigitated pattern depicted above yields a large surface area for increased capacitance and a short mean ionic path for faster (dis)charging. Copper tape is then adhered to the two terminals as electrodes. An electrolyte paste was used to greatly increase the capacitance and therefore energy storage capability.



ELECTROLYTE

The UCLA group and others use electrolyte gels in the capacitors as an essential component for high energy and power density. The electrolyte serves as a medium for ions to diffuse from one capacitor electrode to the other, allowing for a short mean ionic path that gives rise to a high power density. The electrolyte also has intrinsic salt ions, which intensify the electric field and increases the energy density. Given the fact that the gels developed by the other groups are chemically demanding to manufacture as well as caustic, the electrolyte for this project is a simple paste that can be made at home. The solid structure of the paste is a wet-ground mica. Mica is a silicate sheet composed of variations of combinations of potassium, sodium, calcium, aluminum, magnesium, iron, silicon and aluminum, which has a tendency towards stacked psuedohexagonal crystals that are maintained when wet-ground. Salt from the Dead Sea was then added to the paste to increase the amount of ions present for charging the capacitor. Additionally, the literature suggests that Graphene Oxide (GO) is a good ionic conductor, and therefore GO was also tested as an electrolyte.

DISCUSSION

The fabrication of these capacitors was successful. The capacitance tends to be in the low tens of pF, which greatly increases with electrolytes. Adding mica raised the capacitance by around 1000, GO by 1000, and salt by an additional 200-700 times the original value. Even with these results, the energy density is 4 orders of magnitude less than UCLA's capacitors and the original benchmark goal of 3.75 mWh to drive the LED.

FUTURE WORK

Further measurements for the capacitance will be taken using known resistances for discharge curves, as well as measuring ESR that the power densities of these devices may be calculated. Following this, multiple capacitors for optimal voltage and current outputs will be configured to power an LED.

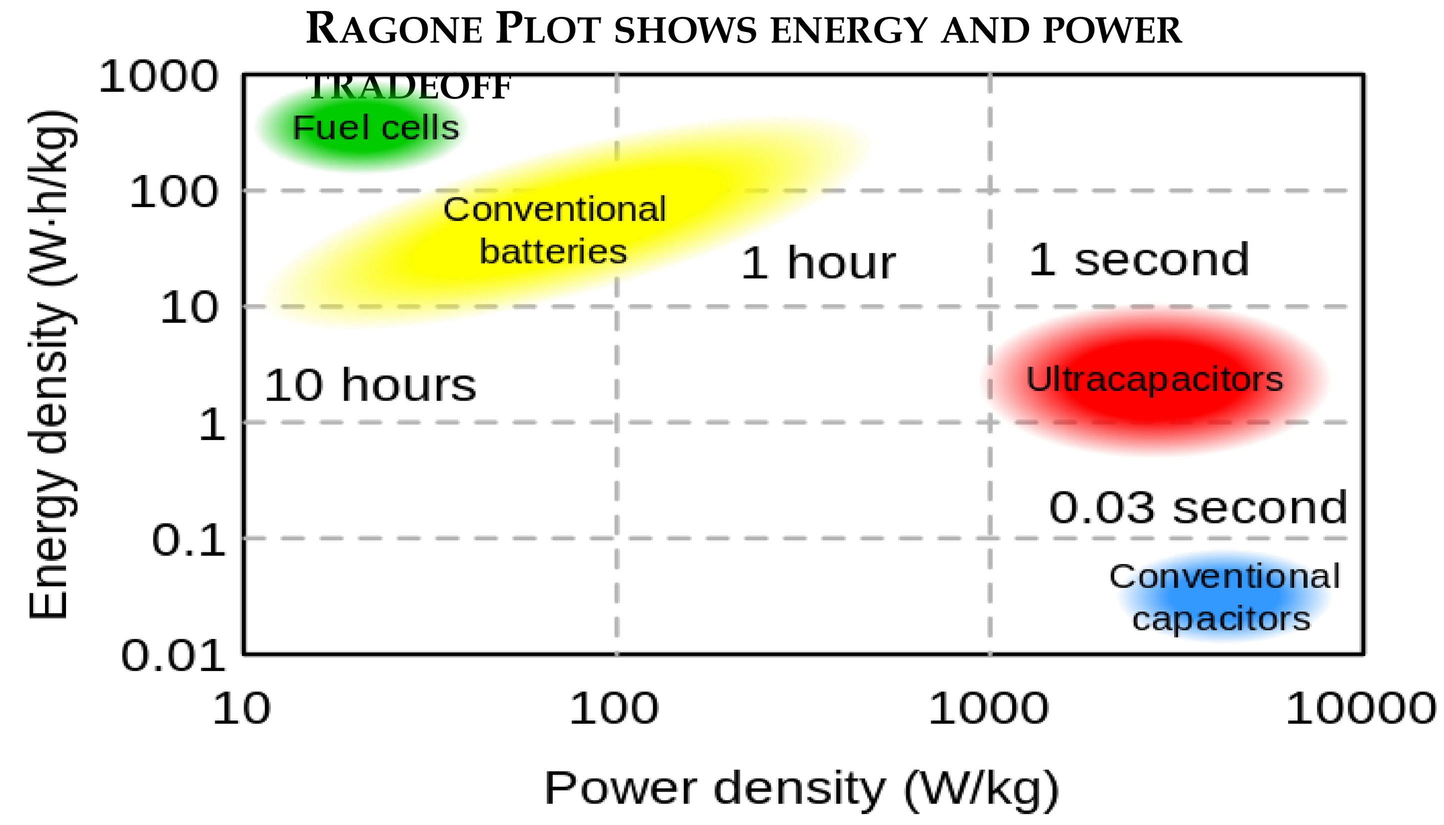
ABSTRACT

This project is an exploration of energy storage capabilities and power delivery of capacitors made from a material called graphene. The product resulting from this independent work will be an array of graphene capacitors arranged in series and parallel for optimally sustained voltage and current output. The benchmark is a source capable of producing 3V and 15mA to drive an LED for a 5 minutes (3.75 mWh) off of a flash charge. The activation specifications for LEDs vary. Typically, an LED will activate with a 2V supply, and a common current draw is around 15mA.

BACKGROUND

The evolution of technology in mankind's recent history has been rapid and expansive. New disciplines emerge in this flourishing field of engineering, and at the core of every new venture or innovation is energy. One of the bottlenecks for discrete miniature and portable devices is on-chip energy storage, which requires a micro-scale battery or capacitor. On the opposite side of the energy spectrum, a lack of inexpensive and large-scale energy storage has limited the renewable energy industry, as many electricity-generating systems are tied to a grid that inefficiently handles the excess power and loses it in heat dissipation. An alternative to a mass overhaul of the power grid is a distributed network of high energy and high power storage banks. Another application is in electric vehicles, where the battery is currently the main limiting factor in practical functionality.

RAGONE PLOT SHOWS ENERGY AND POWER TRADEOFF



PROGRESS AND RESULTS

The values of interest for this experiment include: capacitance, energy density, equivalent series resistance (ESR), power density, and voltage and current maximum ratings. So far capacitance and energy density have been measured. The capacitance was measured using the a capacitance meter, and specific capacitances were subsequently calculated by dividing by the area and volume, which are 0.4028 cm² and 3.06e-4 cm³ respectively. These values allow the energy to be determined using

$$E = Cv * (\Delta V)^2/(2*3600)$$

Where Cv is the volumetric capacitance. Below is a table of the capacitances and energy densities of the graphene capacitors with various electrolytes dispersed on top. S#.# denotes the sample, DSS denotes dead sea salt, and GO denotes graphene oxide.

Sample	ΔV (V)	C (nF)	CA (nF/cm2)	CV (nF/cm3)	Energy (nWh/cm3)
S6.3	0.82	0.015	0.0372393	48.9991115	0.004575973
S6.3-Mica	0.82	10	24.826216	32666.0743	3.050648385
S6.3-Mica-DSS	0.82	700	1737.8352	2286625.2	213.545387
S6.1	0.82	0.03	0.0744786	97.998223	0.009151945
S6.1-GO	0.82	10	24.826216	32666.0743	3.050648385
S6.1-GO-DSS	0.82	200	496.52433	653321.486	61.01296771
Mica	0.82	12.5	31.032771	40832.5929	3.813310482
Mica-DSS	0.82	200	496.52433	653321.486	61.01296771
UCLA	2.5	5E+09	1.191E+10	1566720000	1360000

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