Novel Graphene Supercapacitor Structure Design for UAV Power Storage

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ABSTRACT

Supercapacitors are getting significant attention in recent years due to their quick charge/discharge capabilities, long cycle lives and are environmentally friendly. Supercapacitors can provide necessary power in short bursts. Aiming to reduce the weight and volume of traditional lithium-ion batteries, supercapacitors are already being used in hybrid vehicles, laptops, airplanes, electric trains, and anywhere a sudden burst of power is needed in a very short time [1-7]. These properties make supercapacitors well suited for electric powered UAVs with the advantage of reducing weight and volume of the device. Currently, supercapacitor manufacturing depends on the chosen graphene and the creation of the electrolyte, and has limitations in terms of efficiency, operational costs, and scalability. We are optimizing a novel approach for mass production supercapacitors, using graphene sheets and Polytetrafluoroethylene (teflon) which acts as both an electrical insulator and a good ionic conductor. The use of a liquid electrolyte limits the recharging speed and operating temperature but will introduce a higher specific capacitance when compared to a traditional capacitor. The current research focuses on the ease of production of supercapacitors through the development of a superior liquid electrolyte.

Keywords: graphene, supercapacitor, power storage

1 INTRODUCTION

Unmanned aerial vehicles, or UAVs, have become increasingly accessible in modern day society. Although UAVs have a variety of uses and are manufactured in different shapes, one aspect remains constant: every UAV must possess a viable, affordable, and efficient power management system that will allow the vehicle to maintain functionality [9].

We developed a version of Graphene Supercapacitors. The liquid electrolyte was fabricated using a PVA/H_3PO_4-H_2O system. The electrodes were made using graphene sheets. The insulator used was Teflon. The overall goal is to collect all the components for the supercapacitors and assemble them using robotic methods for mass production.

2 EXPERIMENTAL

A standard graphene supercapacitor includes two conductive plates with a liquid electrolyte (Gel Electrolyte) in between. The design materials include stainless steel shim coil substrates, graphene sheets as the activated carbon, an electrolyte gel including phosphoric acid, and Teflon as the insulator. Figure 1 shows the fabricated graphene supercapacitor.

Figure 1: Fully Fabricated Supercapacitor.

Fabrication of graphene electrodes

Cut a pair of equal sized stainless steel shim coils to desired sizes that include: 1” by 3”, 2” by 2”, and 3” by 3”. This pair must be as similar as possible to avoid fringe capacitance. This will serve as the conductive plate as well as sturdy backing for the fragile graphene sheets. The Graphene sheets are cut with a .25” reduction on all sides. Bonding the graphene sheets to the stainless steel shim coil is accomplished by using Polyurethane. Only a bit of Polyurethane is added since adding too much will also wet the graphene sheets and make them more susceptible to ripping which will make the supercapacitor unusable. Figure 2 shows the fabrication of Graphene Electrodes.

Figure 2: Fabrication of Graphene Electrodes.

Fabrication of gel electrolyte

The gel electrolyte was created by dissolving 1g of polyvinyl alcohol powder (PVA) in 10g of boiled distilled water. The mixture was stirred continuously while keeping the temperature around 85°C to 95°C. Once the mixture thickens and becomes white, it is cooled down to room temperature. Then 0.8 g of phosphoric acid was added to act as a proton donor until the acid is thoroughly mixed with the gel. Using a brush or a probe, spread the gel over the coated side of one of the electrodes (~100 uL/cm^2). The side with the graphene sheet will make contact with the gel electrolyte in the supercapacitor, which will allow for an easier transmission of ions. Figure 3 shows the fabricated electrolyte gel.

Figure 3: Electrolyte Gel.

Assembly of supercapacitor device

A robotic arm and control/vision system has been explored to assemble graphene supercapacitors. By utilizing a robotic arm and control/vision system, we could take advantage of the speed and precision and create a more efficient system for manufacturing supercapacitor components. This technology could replace the role of a human in performing the assembling task. It also avoids human contact, which is essential in avoiding introducing contaminants to the system and creating a safer work environment for those working with the components as hazardous material will be used in the process of making the supercapacitor. If the assembly line is designed and implemented well, robotic methods should improve the mass production that is cost-competitive to existing lithium-ion batteries. Figure 4 shows the automated assembly of supercapacitors.

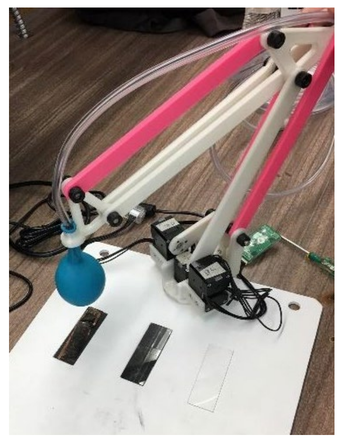

Figure 4: Robotic arm assembling supercapacitors.

3 RESULTS

Upon completion of numerous batches and tests, the team was able to develop a batch of supercapacitors that responded close to as desired. Prior to this, there were many variations per batch of supercapacitors. From the first batch of four 2” x 4” supercapacitors only one displayed a decent cyclic voltammogram (CV). Because of this, the current was far too low as it was in the units of nano-amperes. Improper sealing appeared to have a major influence on this result as the electrolyte gel had seeped out far too much.

The second batch included 2” x 2” supercapacitors as well as 3M tape sealing. The decrease in size was discovered to allot more current flow as there is less resistance. From the three different scan rates of 0.5, 1.0, and 2.0 V/s taken only supercapacitors #3 and #4 showed decent results as the range of current stretched from -.15 mA to -.1 mA as shown in figure 5 below:

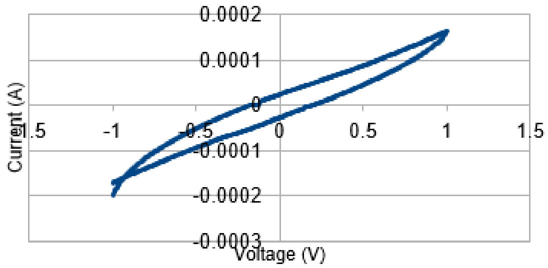

Figure 5: Supercapacitor: Stainless Steel with Phosphoric Acid, Sealed with 3M Tape.

The third batch incorporated plastic medical tape as an experimental parameter to see how sealing performed. Unfortunately, the responses were not very well. At a scan rate of 0.5 V/s only the fourth supercapacitor gave a reasonable response although the current ranged from -0.15 mA to 0.15 mA as show in figure 6.

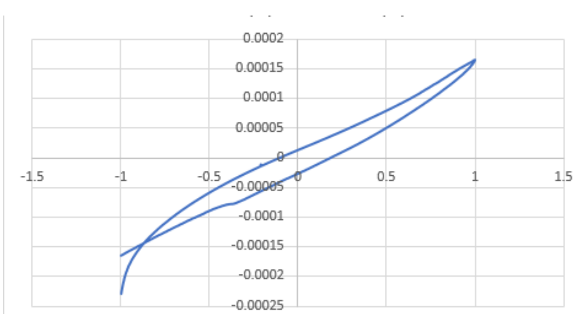

Figure 6: Supercapacitor: Stainless Steel with Phosphoric Acid, Sealed with Medical Tape.

This in turn provided the team evidence that medical tape was not a feasible sealing method so 3M tape is used for the remaining batches produced.

The fourth batch included eight super-capacitors and from the tests #1, #2, and #6 demonstrated exceptional results from each respective CV at a scan rate of 2 V/s. Respective voltage and current plots over time of these three maintained a relatively consistent response with one another as well. Still, a majority of the current range does not exceed -0.15 mA to 0.15 mA as shown in figure 7.

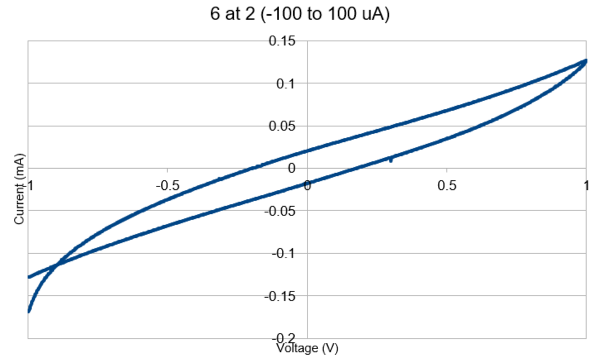

Figure 7: Supercapacitor: Stainless Steel with Phosphoric Acid, Sealed with 3M Tape.

The fifth batch of supercapacitors produced, resulted in successful current outputs. Figure 8 shows a current output from: -10 mA to 10 mA at a scan of 0.5 V/s. This specific test was conducted at 100 cycles. Figure 9 displays another supercapacitor from this batch tested at a scan of 1 V/s. This test resulted in a current output of: -10 mA to 8 mA. These current output results are a positive sign in the consistency of the development process.

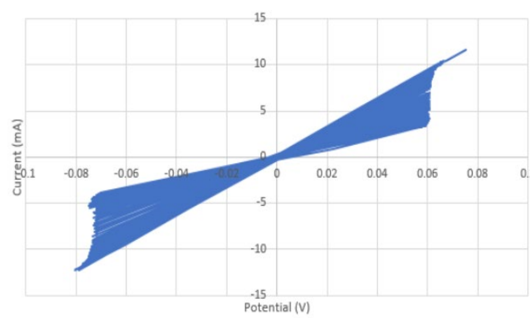

Figure 8: Supercapacitor: Stainless Steel with Phosphoric Acid, Sealed with Double Sided Tape.

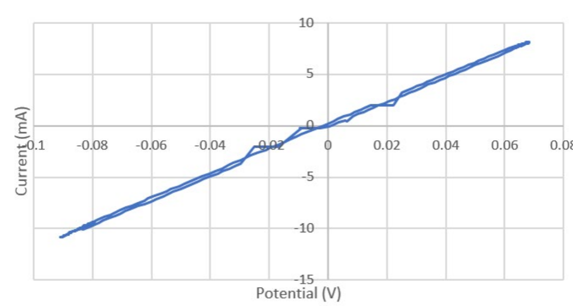

Figure 9: Supercapacitor: Stainless Steel with Phosphoric Acid, Sealed with Double Sided Tape.

4 DISCUSSION

Our approach makes it possible to compare supercapacitors of varying electrolytes as long as no other component is changed. This lets us develop a superior electrolyte gel which in turn will let us have high specific capacitance, high charge/discharge cycles, larger potential ranges and most of all be relatively inexpensive when compared to other supercapacitors.

5 CONCLUSION

We developed a supercapacitor fabrication method, in which the liquid electrolyte was fabricated using PVA/H_3PO_4-H_2O system. The electrodes were made using graphene sheets bonded to a stainless steel shim coil using polyurethane, with teflon as the separator. Larger sized designs will output more current but will trade off with an increased resistance. We hope that with supercapacitor technology developing, electric powered UAVs will be able to compete with internal combustion and jet engine-powered UAVs for long endurance fights.

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