DESCRIPTION OF THE RESEARCH PROJECT FOR THE 2019 SUMMER RET SITE

Project: Energy Storage Devices for Wearable Electronics

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Project Summary

What is the nature of the proposed RET project and the questions it answers.

The *big idea* for this project is to create wearable energy storage devices that can be incorporated into textile and clothing. This is part of the worldwide efforts to develop and fabricate "wearable electronics". The central *challenge* or objective of this RET project is to develop technology to produce a capacitor structure for energy storage that is incorporated into textile. We introduce here a novel way to incorporate Ionic Liquid (IL) electrolyte into any fabric material (from stretchable polyester sports-wear to sturdy military fabric) that utilizes only the essential amount of fabric material. For our tests we procured normal Bucky paper (BP) from General Nano, LLC which is a matrix of single walled carbon nanotubes under no alignment. Our procedure includes using the fabric as a separator to house the gel electrolyte and eventually be sandwiched between symmetrical BP electrodes.

The teachers will design, make and characterize fabric-integrated, ionic liquid-based supercapacitor as a tunable and flexible power source. Other energy storage devices such as batteries and supercapacitors for "wearable" electronics will be also fabricated. The basic materials for these devices will be carbon nanostructured materials including graphene and carbon nanotubes (CNTs). Our group has already published several papers in this field [1-5]. State-of-the-art facilities at the UC Nanoworld lab will be used for conducting the project.

What work needs to be conducted to achieve the objectives?

This research answers the <u>*guiding question*</u>*: How do we fabricate multiple supercapacitors and batteries with reproducible properties?* To answer this guiding question, following 6 tasks are proposed to be undertaken:

- Purchase of Bucky Paper
- Synthesis of 3D graphene.
- Manufacturing of the positive electrodes of the supercapacitors and batteries.
- Manufacturing of the negative electrodes of the supercapacitors and batteries.
- Assembling the supercapacitor and battery devices.
- Electrochemical testing the supercapacitor and battery devices.

What research facilities will be used to conduct the research?

The Nanoworld Laboratory at University of Cincinnati (http://www.min.uc.edu/nanoworldsmart) will be used for the RET research project. It is a college laboratory for material and device development, teaching, and demonstrations. Nanoworld is an internationally recognized laboratory for trailblazing and road mapping innovation, translating the discoveries to industry, and training a next generation workforce that will be in high-demand.

Four labs form the Nanoworld Labs at University of Cincinnati:

- NANOWORLD, Main Lab 414A, 414B & 413 Rhodes Hall, Ph. 513-556-4652
- Nanocomposite Materials and Characterization Lab, Rhodes 507
- Substrates and Nanomaterials Processing Laboratory, 581 Engineering Research Center (ERC)
- Pilot Microfactory for Nanomedicine Devices Lab, 587 ERC

Nanoworld may be the largest nanotube research laboratory in an academic setting with three commercial nanotube reactors to synthesize nanotube materials and transition the processes to industry. Nanotube reactors are in continuous operation along with post-processing and characterization equipment. Magnesium (**Mg**) single crystal manufacturing and coating systems are also used for developing biodegradable implants.

University of Cincinnati Nanoworld supports research for undergraduate and graduate students from across the university. Prof. Vesselin Shanov of the Department of Chemical and Environmental Engineering (**DCEE**) and Prof. Mark Schulz of the Department of Mechanical and Materials Engineering (**DMME**) direct the Nanoworld lab. Faculty members from across the University and from the University of Cincinnati College of Medicine collaborate with Nanoworld.

The main nanotechnology research in Nanoworld is in the field of synthesis, processing and characterization of carbon nanostructured materials, fibers, metal nanowires, nanocomposites, smart structures, electromagnetic devices, and sensors. Nanoworld is also developing innovations in medicine including Mg materials for biodegradable implants, microsensors and devices for interventional cardiology and cancer, and smart biodegradable implants.

Nanoworld is also comprehensively involved in education and is frequently used to host middle school and high school students along with their science teachers. Nanoworld leads teaching two undergraduate nanotechnology courses at University of Cincinnati and one graduate course. These courses use state-of-the-art instrumentation in Nanoworld to perform lab modules. Also, students from other courses tour Nanoworld and learn about nanotechnology, biodegradable metals, biosensors, biomedical devices, and other advanced topics. Undergraduate through Ph.D. students, post-doctoral fellows, faculty members, and industry collaborators all work together in Nanoworld. Hundreds of people visit Nanoworld each year. The faculty members affiliated with Nanoworld bring a great deal of expertise and time to mentoring the

students to assure the education and research experience is successful.
Illustration of the current results related to this research project.

Figure 1. displays achievements related to the proposed research, which also have been recently published [1].

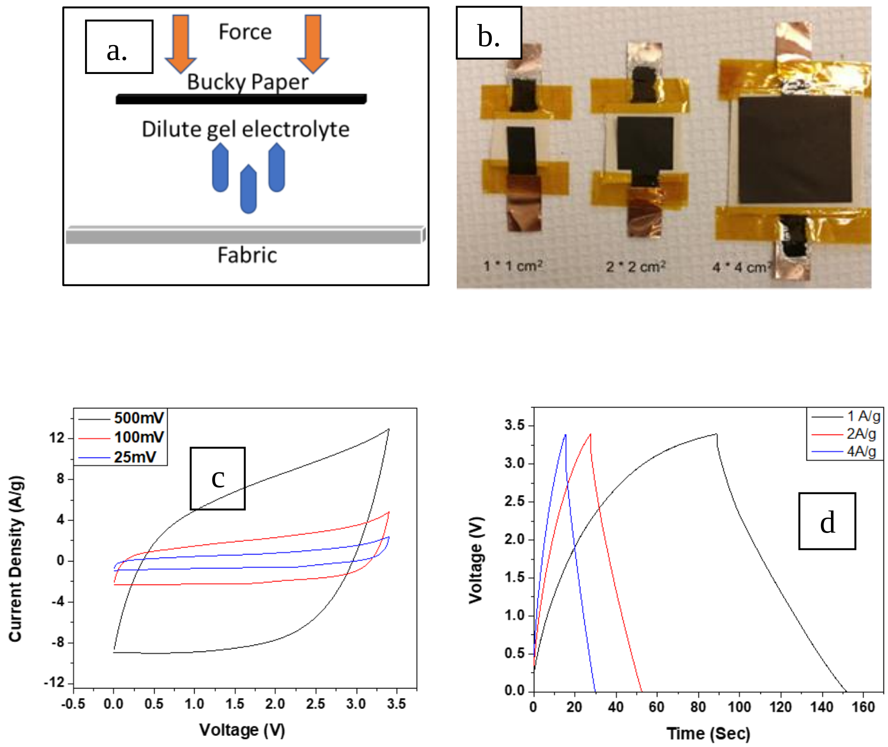

Figure 1: a) Schematic of creating gel fabric structure with Bucky paper electrode pressed on top; b) Pictures of different size Ionic Liquid (IL)-based fabric capacitors with increasing areas of electrode materials used for the fabric device c) Different scan rate cyclic voltammetry curves of IL-soaked device; d) charge and discharge curves of the fabricated device obtained at different current densities.

Who will be the Industrial Advisor for this project?

Mr. Larry Christy, Production Engineer, General Nano LLC, will join Prof. Vesselin Shanov, Prof. Noe Alvarez and the Graduate Research Assistant in increasing awareness of the real-world applications of the proposed research.

<u>Possible Ideas for Classroom Implementation</u>

Making small supercapacitors and batteries for energy storage is technically possible in a Classroom. The students can assemble flexible devices as shown in **Figure** and power a light emitting diode. University of Cincinnati can provide the needed electrode material and the housing for 5 energy storage devices annually. The *<u>big idea</u>* is to be able to integrate an energy storage devise into a wearable clothing. These flexible devices will help to power portable electronics, including lap tops, cell phones and tablets and recharge them for a short time. The end user of this technology is any person that is dealing with portable electronics, including cell phones, tablets and lap tops. In addition, military personal and first responders who are heavily equipped with electronic devices are expected to benefit from our light weight, wearable and fast recharging energy storage devise.

References

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