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Novel materials and fabrication techniques for wearable energy generation and storage devices - from piezoelectric fibers to li-ion threads

Maksim Skorobogatiy
Polytechnic School of Montreal, Canada

In the past decade, the R&D of novel materials and fabrication techniques for wearable energy generation and storage devices has received considerable attention due to the fast-growing market of wearable personal electronics. In this presentation, we will talk about these materials and fabrication techniques. In particular, we will divide the talk into three sections focusing on energy-generation piezoelectric fibers, Li-ion battery threads (stripes), and capacitor fibers for energy storage and tactile sensors, respectively.

Piezoelectric fibers: We will review the commonly-used piezoelectric materials and several typical techniques for fabrication of piezoelectric fibers. These techniques include: 1) direct deposition of ceramic piezoelectric materials on metallic wires or microfibers; 2) melt- or wet- extrusion of piezoelectric polymer fibers; 3) fabrication of microstructured piezoelectric fibers via preform heating and drawing (also called the fiber drawing technique). Particularly, we would like to elaborate the fiber drawing technique in detail (from preform fabrication to fiber drawing process), as this technique offers many advantages such as complicated microstructures of the fiber with improved piezoelectric functionalities, increased active-area for piezoelectric generation, integrated on-fiber electrodes for easy connectorization, and capability of mass production. Based on the fiber drawing technique, we report the fabrication and characterization of the piezoelectric PVDF-BTO fibers, PVDF-CNT fibers as well as PVDF-PZT fibers. We also demonstrate several applications of these fibers and the multifunctional textiles based on these fibers. These applications include sensing of human-body movements, detection of acoustic waves, detection of airplane model vibration, and power generation for in-car applications.

Li-ion battery threads (stripes): Several techniques for fabrication of Li-ion battery threads (stripes) will be reviewed, and materials used as electrodes and electrolyte will be summarized. As typical examples of Li-ion battery threads (stripes), we will talk about an all-solid stripe-shaped LFP-LTO battery and a thread-shaped LFP-Al (or LPF-Sn) battery which are proposed by our group. The LFP-LTO stripe-shaped battery is fabricated by sequential layer-by-layer deposition (e.g., in a cathode-separator-anode sequence) of battery active materials with solution casting method. The LFP-Al (or LPF-Sn) thread-shaped battery is fabricated by interwinding together the cathode and anode threads, and each electrode thread is produced by depositing battery active materials on a conductive thread substrate using the dip-and-dry method. Both of the batteries show great flexibility, and the electrochemical properties of the batteries are well studied. The examples of applications of these batteries will be also demonstrated.

Capacitor fibers: In this section, we will talk about our pioneer work on the fabrication of capacitor fibers via preform heating and drawing. The capacitor fiber features one or two metal-wire cores (as inner electrodes) surrounded by a multilayer structure consisting of alternating conductive/isolating polymer layers. The fabrication technique and electric characterization of the capacitor fibers will be presented. Finally, we also demonstrate a 2D tactile sensor textile made from the capacitor fibers. In summary, we will give a talk on wearable energy generation and storage devices. A great number of demonstrators based on our piezoelectric fibers, battery threads, and capacitor fibers will be presented for tactile sensing, compliant energy storage, avionics, etc. We believe that the techniques presented in this talk would draw extensive interest in the academic community.

maksim.skorobogatiy@polymtl.ca