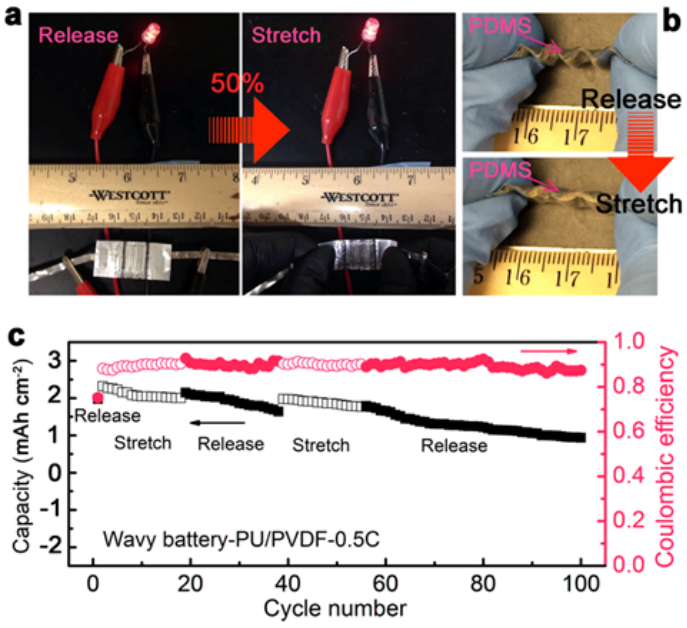
Docket #: S16-387

Stretchable Lithium-Ion Batteries Enabled by Device-Scaled Wavy Structure

Engineers in Prof. Yi Cui's laboratory have developed a high-performance, stretchable lithium-ion battery designed to provide long-term, stable power to wearable and flexible electronics. This technology employs a wavy structure with a novel, electrospun, sticky polymer separator between the electrodes to ensure good electrical contact at dynamic state. Therefore, the wavy battery retains full performance under high strain. All of the components, including the cathode, anode, current collectors and packaging are capable of being reversibly stretched without cracking. In addition, the electrodes and packaging can be fabricated with commercially available materials for low-cost, scalable manufacturing. This simple design concept for stretchable lithium-ion batteries could provide fully integrated stored power in flexible electronics with end-user applications such as smart clothing, robotic skin or surgical tools.



Performances of wavy battery. *(a) light-emitting diode powered by wavy battery at released and stretchable state at 50% strain. (b) view of PDMS separator stretched to accommodate deformation. (c) Cycling performance and Coulombic efficiency for the wavy battery under releasing and stretching states (50% strain).*

Stage of Research
The inventors have built a working prototype at device scale and demonstrated that all components of the battery, including the electrodes and packaging, were successfully stretchable. This prototype had long-term stability and high electrochemical performance (areal capacity of 3.6 mAh cm-2 and energy density up to 172 Wh L-1 could be achieved for the stretchable battery by packing double units in series).

Applications

- **Flexible and stretchable lithium-ion batteries** with end-user applications such as:
    - flexible and stretchable electronics
    - wearable electronic devices/smart clothing
    - flexible smart phones
    - sensitive robotic skin
    - soft surgical tools

Advantages

- **Fully stretchable and robust:**
    - all components, including the cathode, anode, current collectors and packaging are capable of being reversibly stretched by folding the battery into its wavy shape
    - long-term stability at repeatable release/stretch cycles
    - millimeter sized wavy structure avoids the aggregation and electrode detachment problems possible with micro-sized wavy structures that utilize gel electrolytes
- **High electrochemical performance:**
    - high areal capacity of 3.6 mAh cm-2 and a large energy density of 172 Wh L-1 could be achieved for the wavy battery by packing double units in

series
    - comparable performance in stretched and released states
    - novel stretchable, sticky and porous separator acts as glue between electrodes to ensure good electrical contact at dynamic state
- **Cost-effective, scalable manufacturing:**
    - compatible with commercially available cathode, anode and packaging materials
    - easily scaled up without complicated procedures at low cost and high efficiency

Publications

- Liu, W., Chen, J., Chen, Z., Liu, K., Zhou, G., Sun, Y., ... & Cui, Y. (2017). Stretchable Lithium-Ion Batteries Enabled by Device-Scaled Wavy Structure and Elastic-Sticky Separator. *Advanced Energy Materials*, 7(21).

Patents

- Published Application: 20180342756
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