Energy Storage Textile

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[1]Backstories

April 28, 2020

This is the backstory of: *From industrially weavable and knittable highly conductive yarns to large wearable energy storage textiles (Huang et al., 2015a).*

We have launched our research on wearable energy storage textiles since 2013, which are a next frontier in personalized electronics (Huang et al., 2017b; Zhu et al., 2017; Huang et al., 2016, 2015b; Zhu et al., 2016). However, the lack of industrially weavable and knittable conductive yarns in conjunction with high capacitance, is a long lasting problem in this area. We tried many times to weave and knit carbon-coated cotton yarns. However, they couldn't be weaved or knitted by industrial machines due to their high surface roughness.

We considered this long lasting problem thoroughly. On one hand, in practical weaving and/or knitting, high tensile stresses (magnitude of MPa) are imposed on yarns by weaving/knitting machines. This requires mechanically tough materials. On the other hand, to obtain high capacitance especially in the wire or yarn format, the electric conductivity of yarns must be high for effective long-distance electron transport. Therefore, we believed these two requirements could only be met by using metallic materials.

Then how to solve the intrinsic problem of weavability, knittability, and wearability challenges of conventional metallic wires? It is known that when the size of diameter scales down to microns, these challenges in bulk materials would disappear. So the solution is to fabricate micron-size metallic yarns ((Huang et al., 2017a, 2015b, 2017c, 2015c). Fortunately the textile industry has been highly developed. Tiny metallic filaments can be spun at high temperature and then twist-bundle-drawn to be soft yarns, which are both highly conductive and mechanically tough.

As the key problem of metallic yarns have been solved, the subsequent steps are much easier. With wettability treatment first, multiple electrocapacitive materials including reduced-graphene-oxide (rGO), MnO2 nanosheets and a polypyrrole thin film are subsequently grown on the metallic yarns (Huang et al., 2015c,a). Then they are assembled to be a symmetric solid-state supercapacitor yarn with the use of polyvinyl alcohol (PVA)/H3PO4 gel electrolyte. The supercapacitor yarn has high energy densities of 0.0092 mWh cm-2 and 1.1 mWh cm-3 (both normalized to the whole device) with a long cycle life, which are the highest or at least close to the highest values reported so far. Large energy storage textiles are further fabricated by weaving these supercapacitor yarns on a toy loom and knitting in a woollen wrist band by hand, enabling dual functionalities of energy storage capability and wearability.

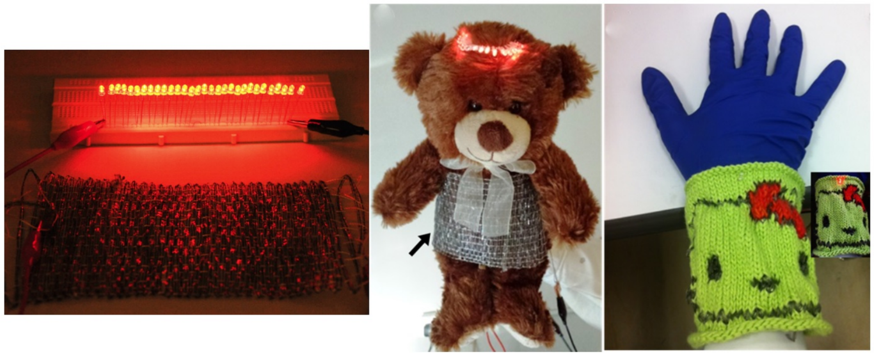

Figure 1: Energy textile powering LEDs

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