Energy Textiles: A Multidisciplinary Approach to Wearable Energy Storage

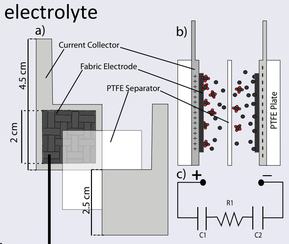
Kristy Jost, Carlos R. Perez, Advisor: Yury Gogotsi
Department of Materials Science and Engineering and A.J. Drexel Nanotechnology Institute, Drexel University, Philadelphia PA, USA

Energy for Smart Garments

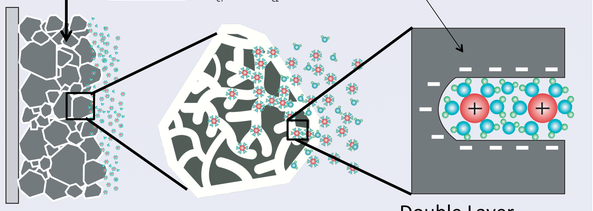
- The collaborative field of smart textiles operates between design and engineering, with applications in bio-medicine, the military, space suits and everyday garments
- **E-textiles (electronic textiles) need energy in order to operate**. This work describes the fabrication of a textile supercapacitor (electrochemical double layer capacitor) as a non-toxic, flexible, and integrated solution.

Electrochemical Double Layer Capacitors

- Electrical Energy Storage, safe, non-toxic, charges and discharges in seconds, 95% efficient, can be made flexible
- 4 main components: electrode, current collector, separator, electrolyte



Energy is stored by adsorbing/attracting counter ions to the charged surface of the electrode material creating a "double layer charge."



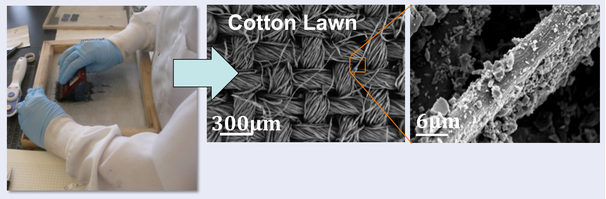
Carbon Particles that make up electrode

Diffusion of ions into porous carbon network

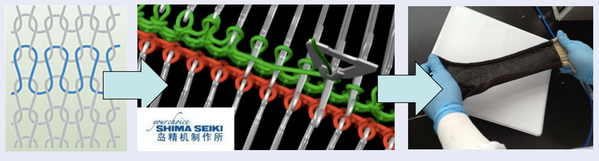
Double Layer formation between carbon material and solvated counter ions

Energy Textile "Fabrication"

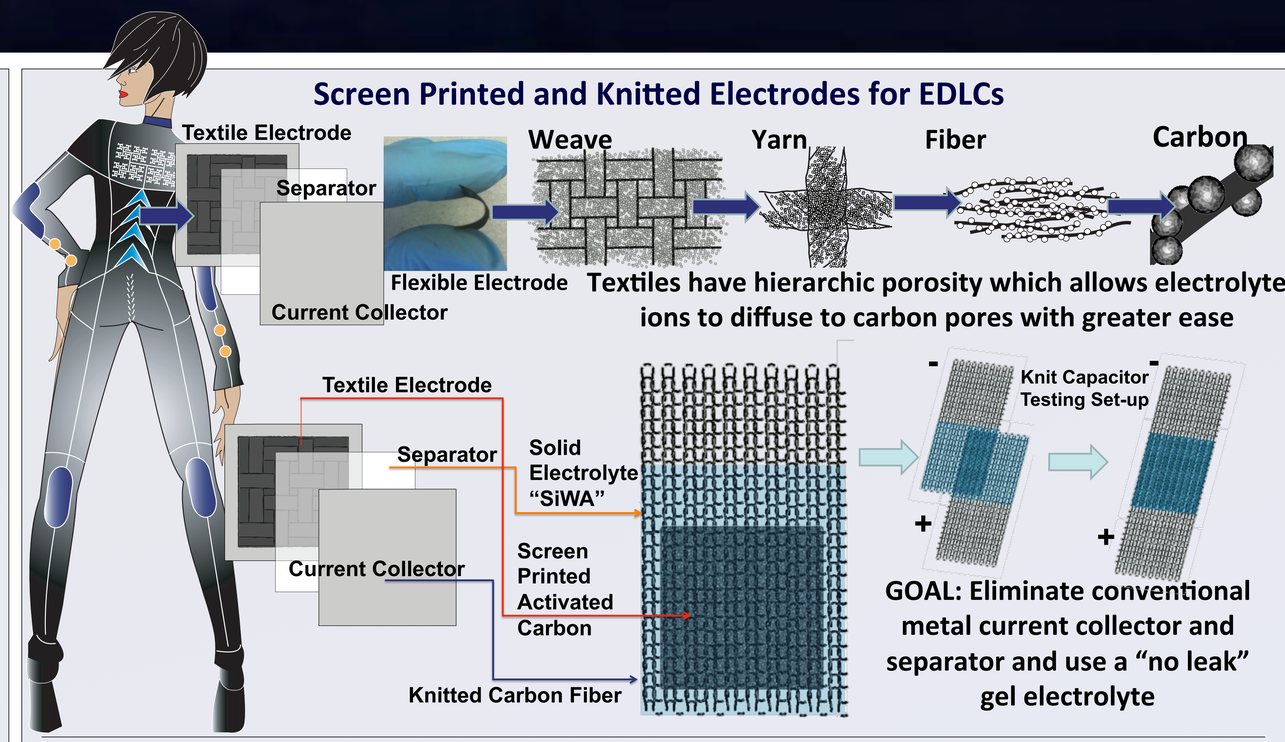
Screen printing is used to impregnate activated carbon to textile structures, including woven and knitted cotton, polyester and carbon fiber.

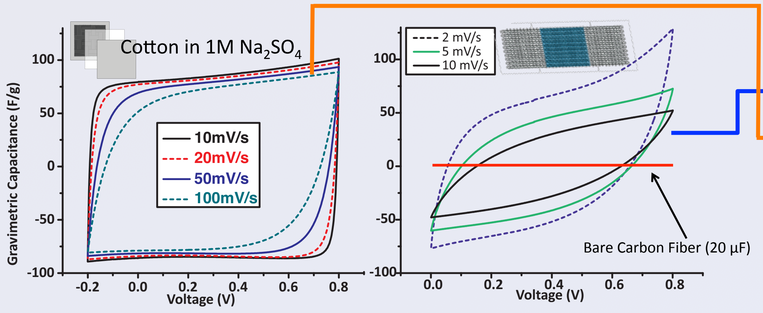


Knitting is a technique for intertwining different materials (yarns) together to create fabrics. In our case, we knit carbon fiber electrodes in a basic weft knit.



Screen Printed and Knitted Electrodes for EDLCs

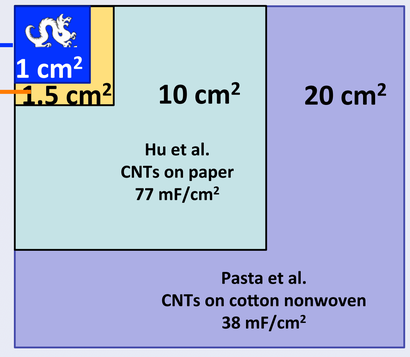




~ 5 mg/cm², 85 F/g¹, 0.43 F/cm²

~ 16 mg/cm², 41 F/g¹, 0.75 F/cm²

Each of these electrodes are 0.75F



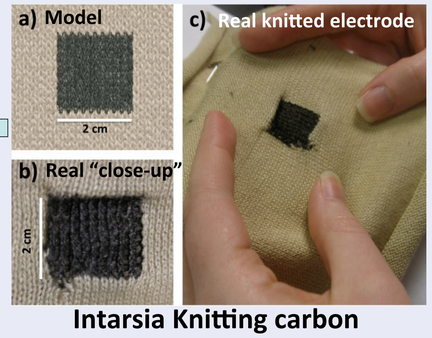
Compared to previous literature, our devices can store 0.75 F/cm² which is 10-20 times more energy than previously reported literature on textiles and paper

Fabricating all-in-one devices using a Shima Seiki Machine

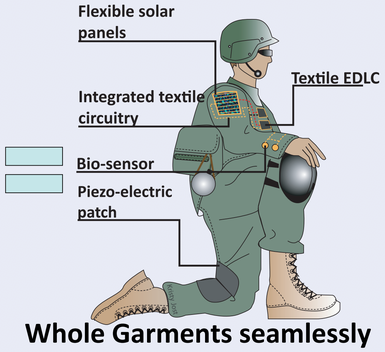
In the Haute Tech Lab

Design — 3D Animation — Real Garment

Whole garment knitting and design



Intarsia Knitting carbon electrodes

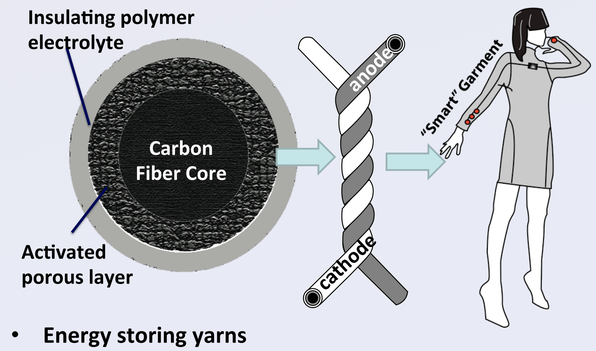


Whole Garments seamlessly embedded with energy storing materials

Conclusions

- We fabricated a **knitted carbon fiber current collector** on a Shima Seiki 3D knitting machine
- We **eliminated ALL HARD COMPONENTS** resulting in a fully integrated textile energy storage device
- We use 3D knitting as an **all-in-one approach** that will eventually lead to fully knitted garments with integrated energy storage.
- We also **increased the areal capacitance by 50%** by increasing the mass loading per cm² which is 10-20 times higher than previously reported literature

Future Work



- **Energy storing yarns**
- The figure above describes a concept for a carbon fiber coated in active and electrolyte materials, then paired with another yarn to act as the anode and cathode.
- Because it is a yarn, it can be **knitted, woven, or stitched** into any smart design.

Acknowledgements

Genevieve Dion, Shima Seiki Haute Tech Lab, for continued support and collaboration, and for custom knitted carbon fiber electrodes; **John K. McDonough** for research support; **Adam Fontecchio** and the NanoPhotonics group for continued support and collaboration; K. Jost would like to acknowledge support from the NSF-IGERT DGE-0654313; C.R. Perez acknowledges support from NSF-IGERT (DGE-0654313) and CHE-0924570

References

(1) K. Jost, C.R. Perez, J.K. McDonough, V. Presser, M. Heon, G. Dion, Y. Gogotsi, *Energy and Environmental Science*, **4**. 5060 – 5067 (2011)
(2) P. Simon, Y. Gogotsi, Materials for electrochemical capacitors, *Nature Materials*, 7 (2008) 845 – 854
(3) L.B. Hu et al., *Nano Letters*, **10** (2010) 708 – 714
(4) Pasta et al., *Nano Research*, 3 (2010) 452 – 458