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Beyond the lab: Scalable production of electrochemically exfoliated graphene / transition metal oxide hybrids for wearable energy storage

Adrián Romaní Vázquez[1], Ali Shaygan Nia[1], Martin R. Lohe[2], Carsten Gröber[3], Andreas Röpert[3], Xinliang Feng[1]

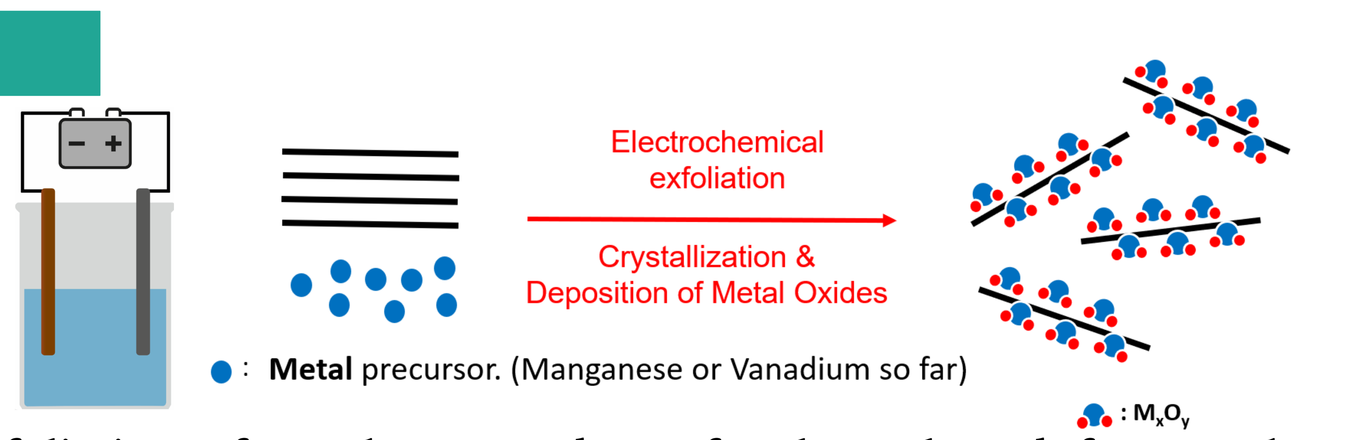
1: Chair for Molecular Functional Materials, TU Dresden, 2: Sixonia Tech GmbH, 3: InteractiveWear AG

Motivation

- Next generation energy storage calls for flexible, lightweight and sustainable devices. Supercapacitors are an attractive technology to this end.
- Graphene's electromechanical properties make it a prime candidate for supercapacitors that can be used in wearable electronics – but its charge storage is low by itself in practical applications.
- Transition metal oxides can solve this shortcoming while using graphene as a conductive, flexible backbone.
- Our work focuses on developing a scalable, inexpensive and green production method capable of breaking through to the consumer market.

Introduction

Figure 1: Production of metal-functionalized graphene sheets



Electrochemical exfoliation of graphene produces few-layer, low-defect graphene (EG) with large lateral sizes and high conductivity[1] . **This method allows one-step functionalization** with a variety of functional groups, while being **readily scalable with adequate optimization**[2].

Fabrication process

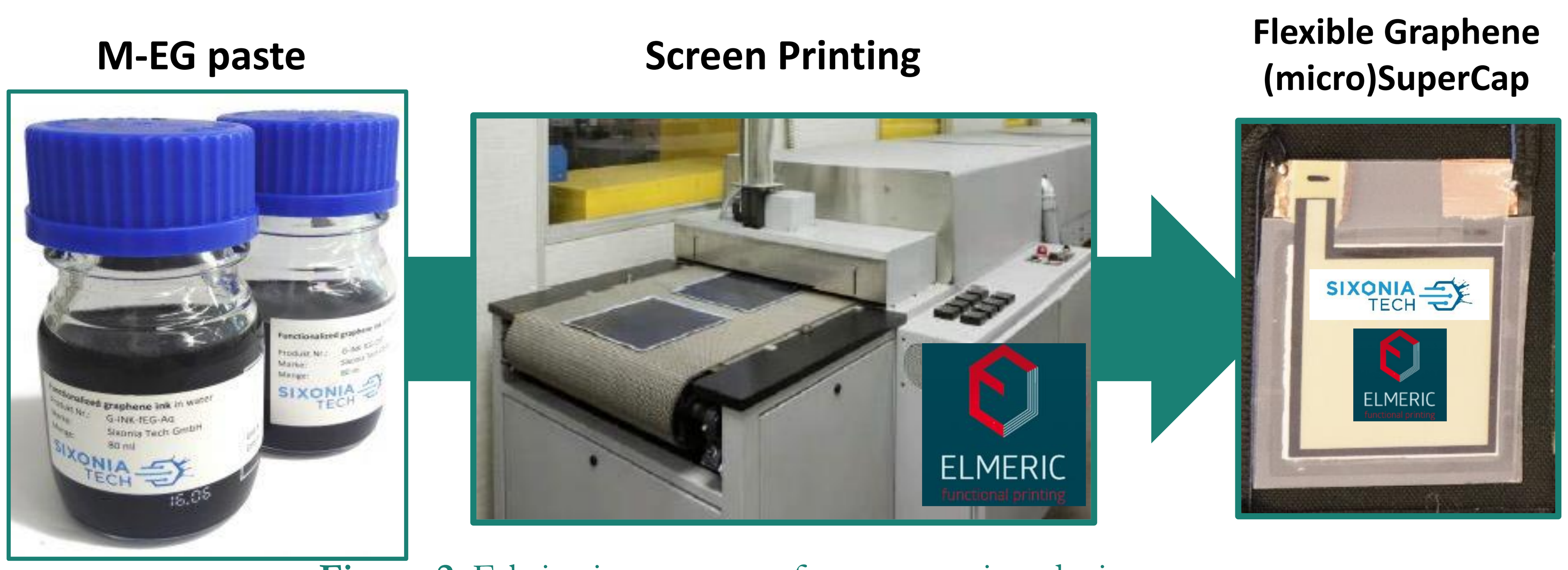


Figure 2: Fabrication process of supercapacitor devices

- Current production rate: ≈10000 cm2/day
- Simple, green and inexpensive process

Characterization

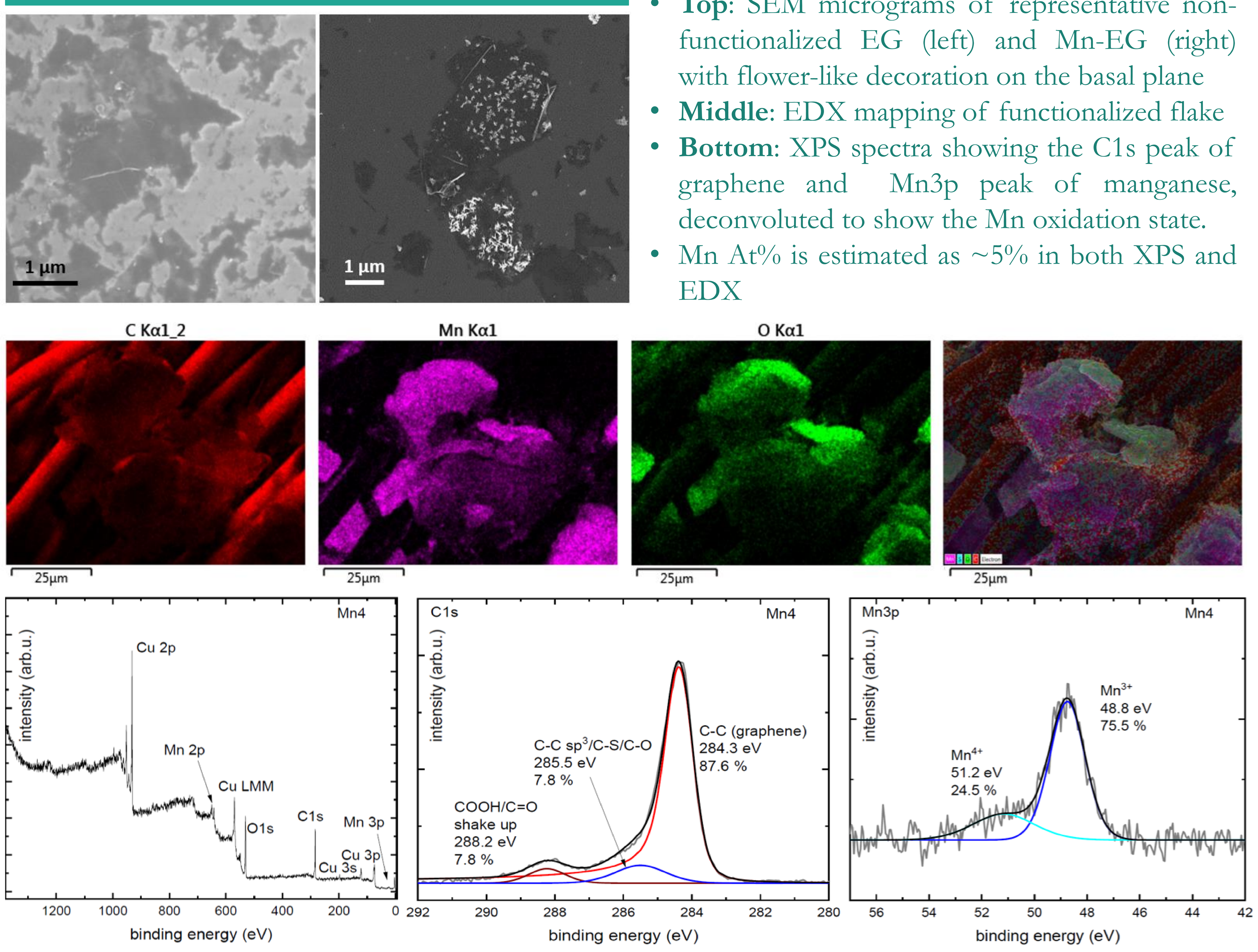


Figure 3:

- **Top**: SEM micrograms of representative non-functionalized EG (left) and Mn-EG (right) with flower-like decoration on the basal plane
- **Middle**: EDX mapping of functionalized flake
- **Bottom**: XPS spectra showing the C1s peak of graphene and Mn3p peak of manganese, deconvoluted to show the Mn oxidation state.
- Mn At% is estimated as ~5% in both XPS and EDX

Device performance: Manganese-EG supercapacitors

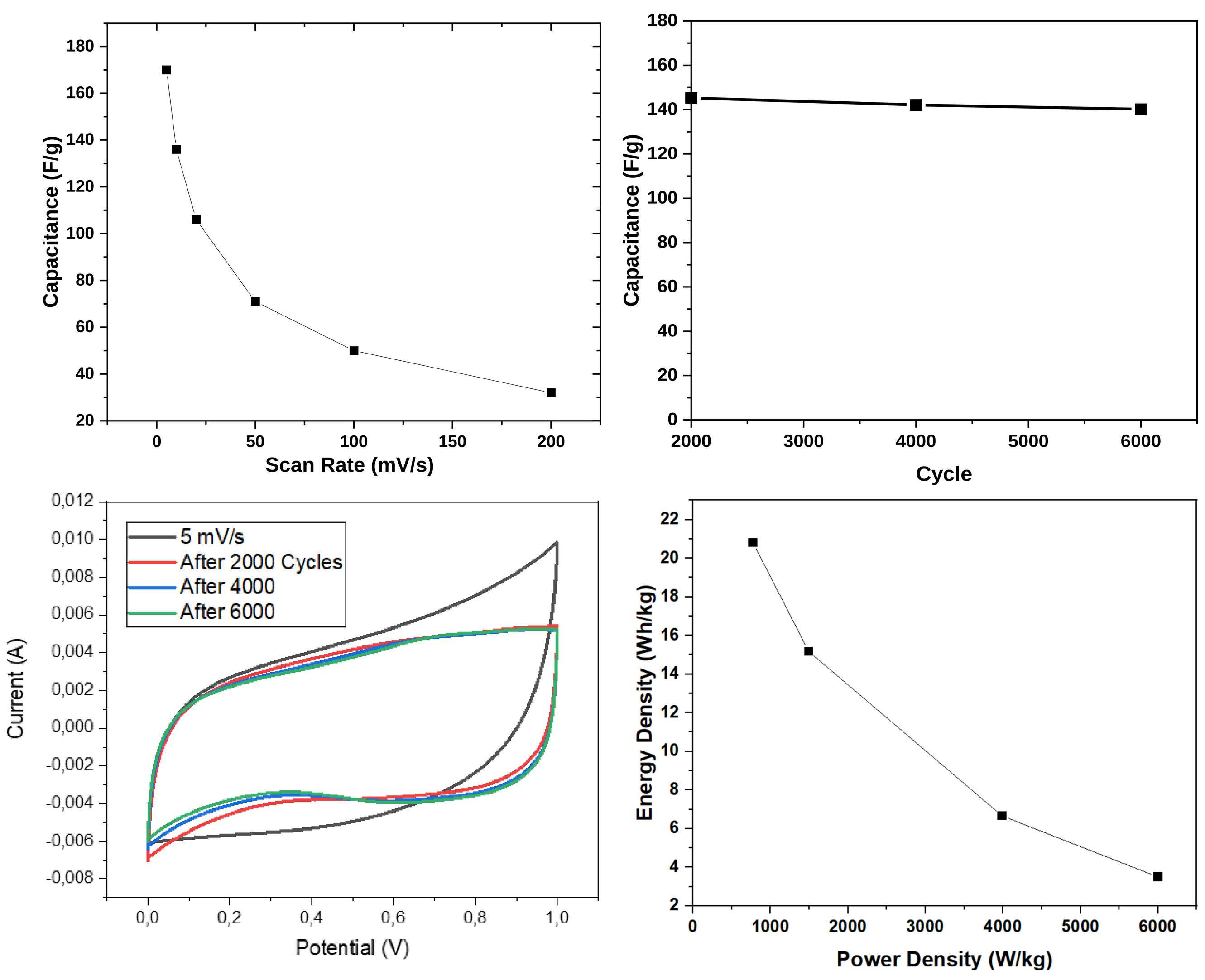
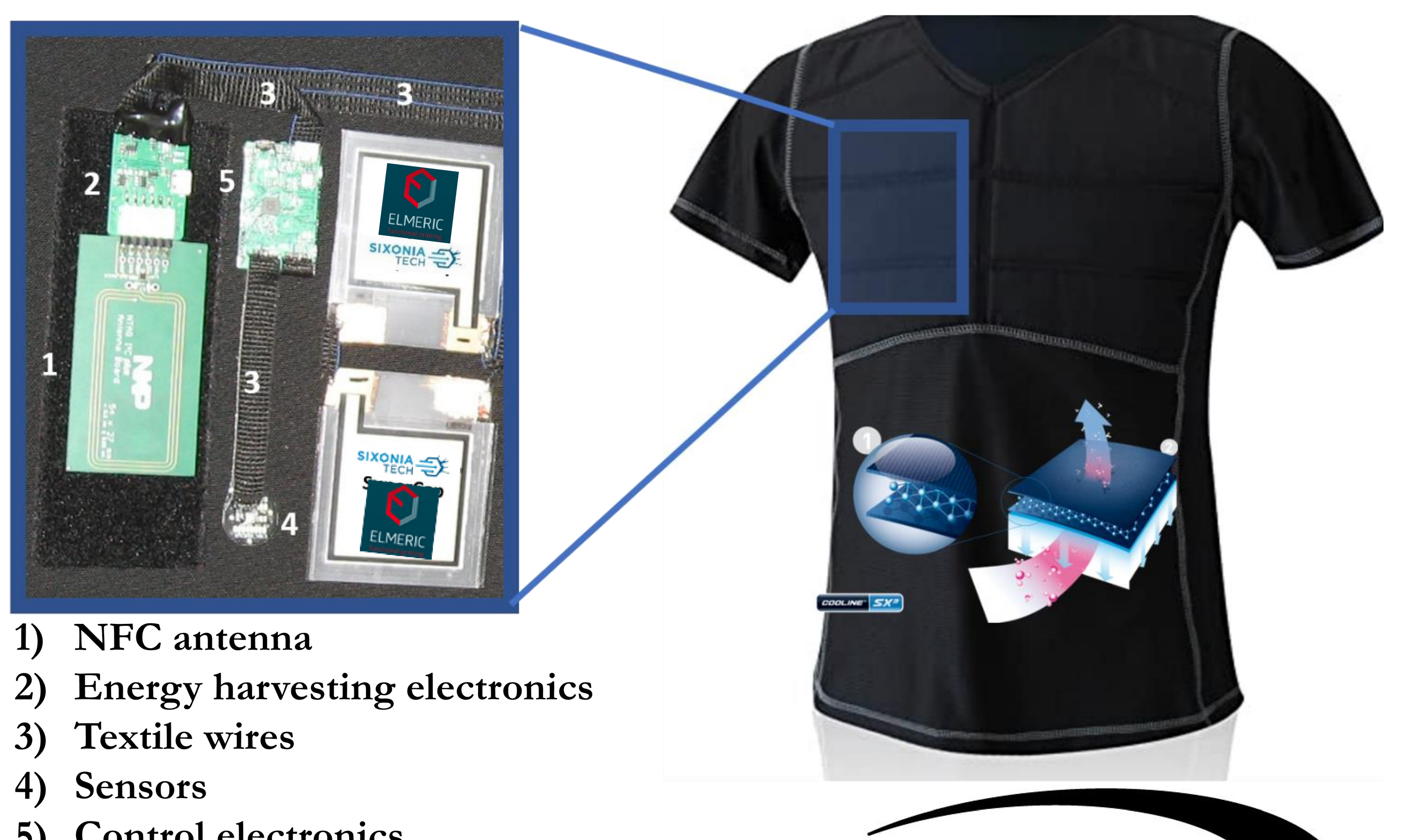


Figure 4: Characterization of devices. Capacitance, energy and power density calculated from mass of electrodes (active material + binder).

- Competitive performance
- High cycling stability
- Aqueous electrolyte ($NaSO_4$) as non-toxic alternative for wearable electronics

In conclusion, we have developed a facile, green method to inexpensively produce large quantities of supercapacitor devices for wearable electronics, which can help to push graphene outside research labs and into the hands of the general public.

Technology Demonstrator: Thermorregulator shirt



1) NFC antenna
2) Energy harvesting electronics
3) Textile wires
4) Sensors
5) Control electronics

INTERACTIVE WEAR · E·COOLINE cooling textiles

Figure 5: Integration of supercapacitors as energy storage for a thermorregulator shirt. The NFC antenna will draw energy from a smartphone, which will be stored in the supercapacitors. These will then charge the sensors spread throughout the fabric in seconds and their values will be transferred – via the NFC antenna – back to a mobile app.

CONTACT PERSON

Adrián Romaní Vázquez

Adrian.romani_vazquez@mailbox.tu-dresden.de

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