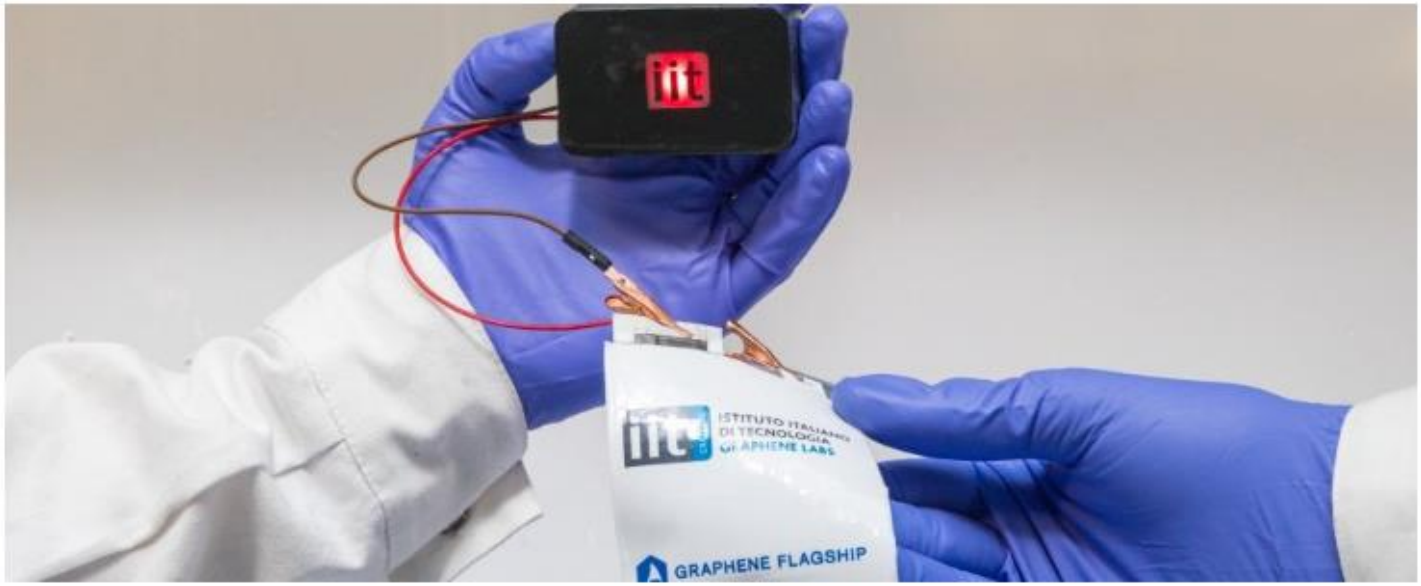
Università degli Studi di Messina

ISTITUTO ITALIANO DI TECNOLOGIA
GRAPHENE LABS

Graphene/Carbon nanotubes for advanced flexible supercapacitor



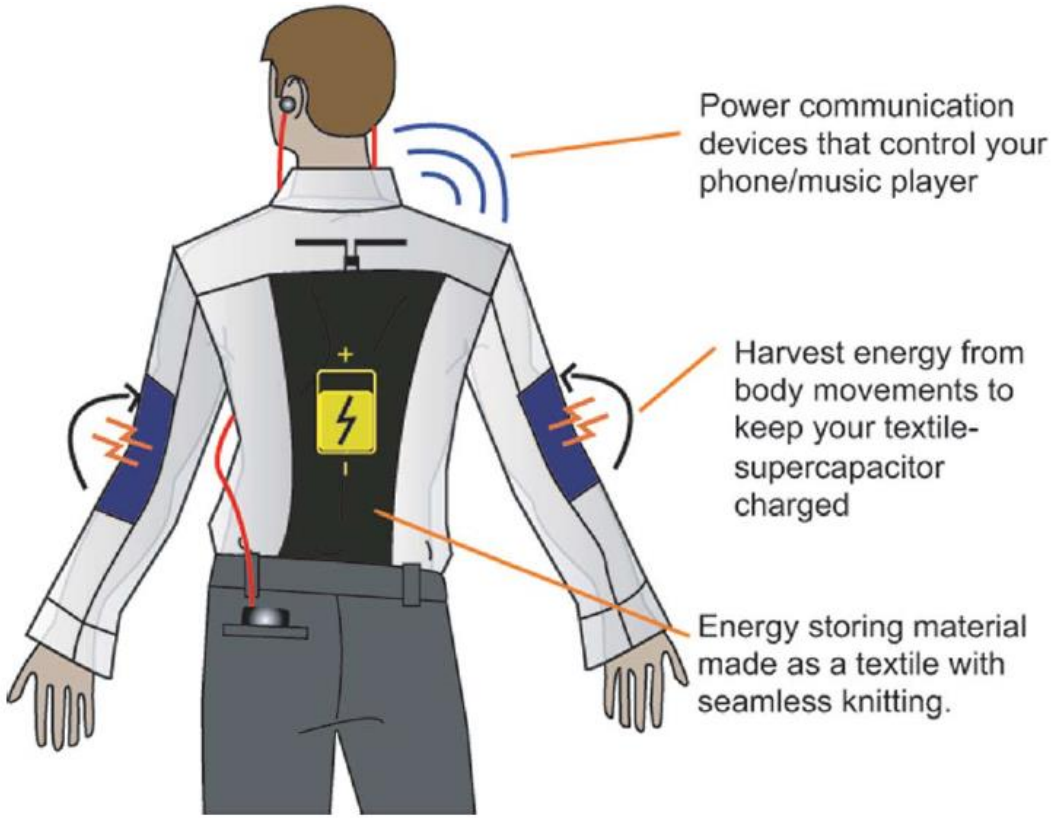
V. Romano, S. Bellani, B. Martin-Garcia, L. Najafi, A. E. Del Rio Castillo, M. Prato, G. D'Angelo and F. Bonaccorso

Graphene 2018 - Dresden, 27th June 2018

Possible applications

Wearable electronic applications

Average human body surface $\approx 1.5\ m^2$
High C_{areal} (F/cm^2) is needed



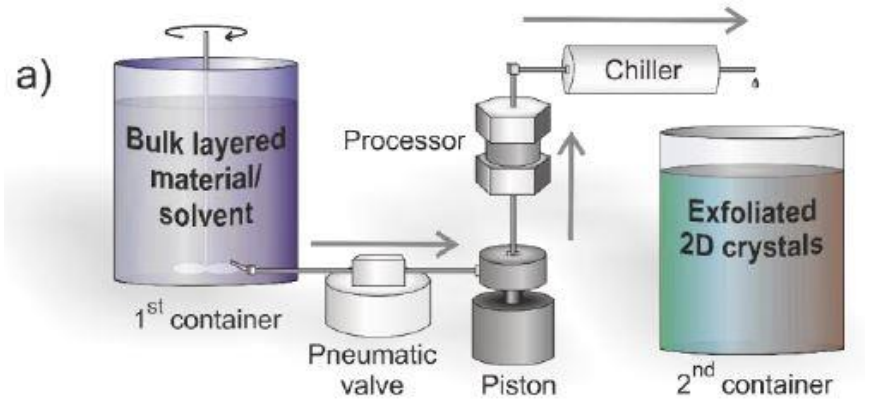
Jost, K., et al (2013), En. & Environm. Sc., 6(9), 2698-2705.

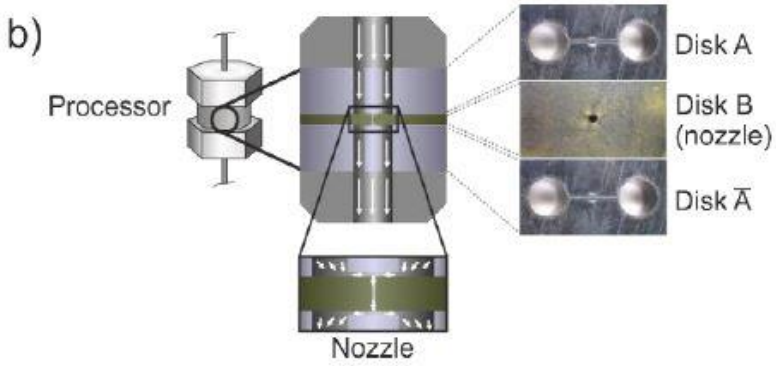
Selection of materials

- Flexible and stretchable devices
- Scalable production of materials
- Scalable fabrication of devices

Graphene – Single Wall/Double Wall Carbon Nanotubes (CNT)

Graphene production





Production

$2\ \mathrm{L/h}$

$c = 10\ \mathrm{g/L}$

Wet Jet Milling

200 g – graphite flakes

20 L - NMP

$c_i = 10\ \mathrm{g/L}$

Pressures up to 250 MPa

Nozzle diameters

0.3 mm

0.15 mm

0.1 mm

Patent number: UB2015A005920

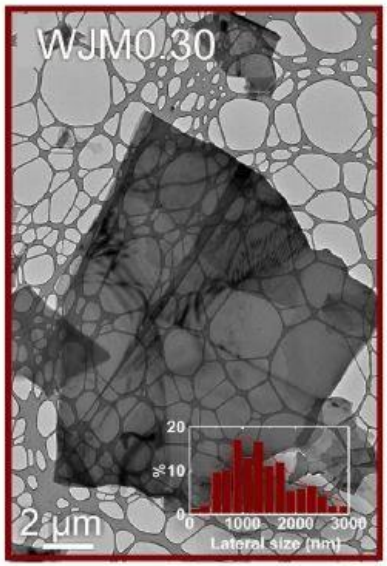
Castillo A. E. D. R., et al (2018), arXiv preprint arXiv:1804.10688.

Ink characterization

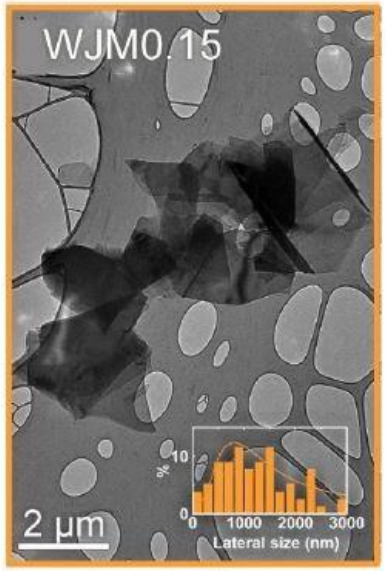
Lateral size (TEM)

reduction by successive nozzle diameter reduction

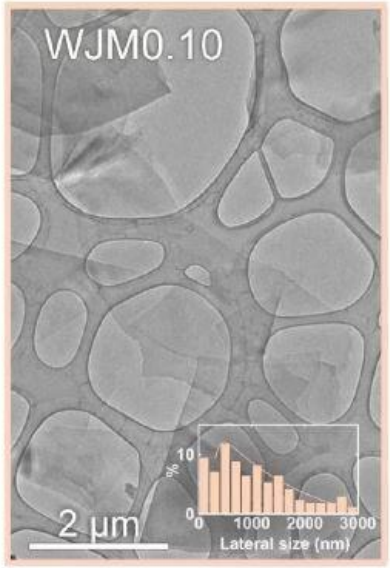
1000 nm



850 nm



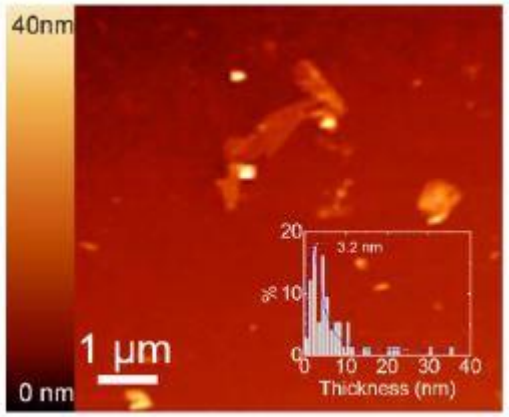
460 nm



Thickness (AFM)

WJM 0.10
Few layers graphene

3.2 nm

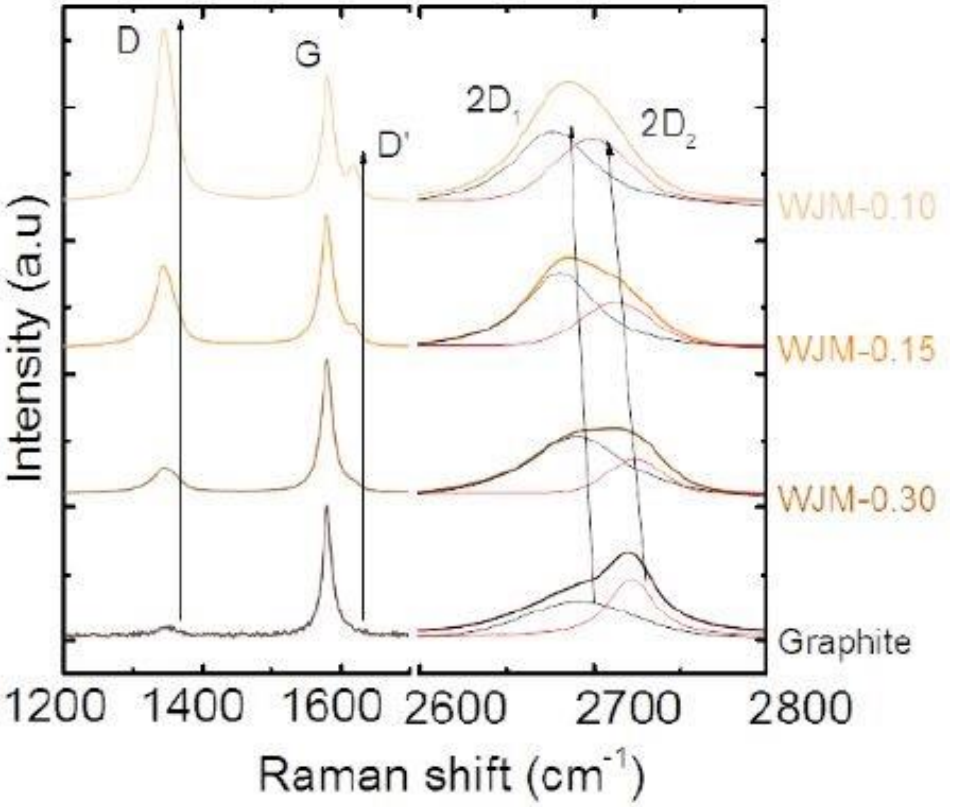


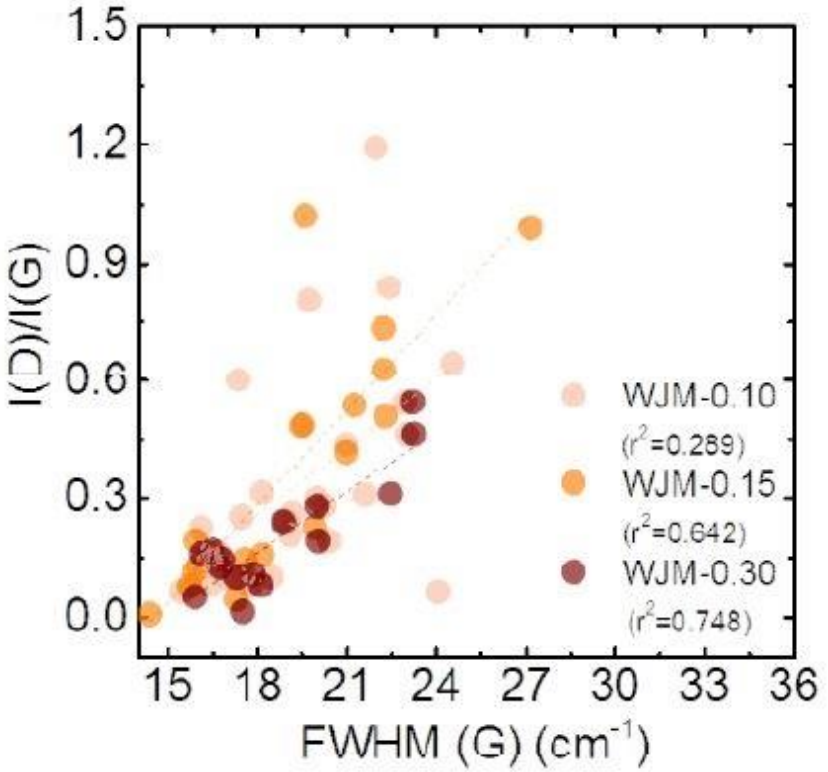
Castillo A. E. D. R., et al (2018), arXiv preprint arXiv:1804.10688.

Ink characterization

Crystalline integrity

(Raman Spectroscopy)

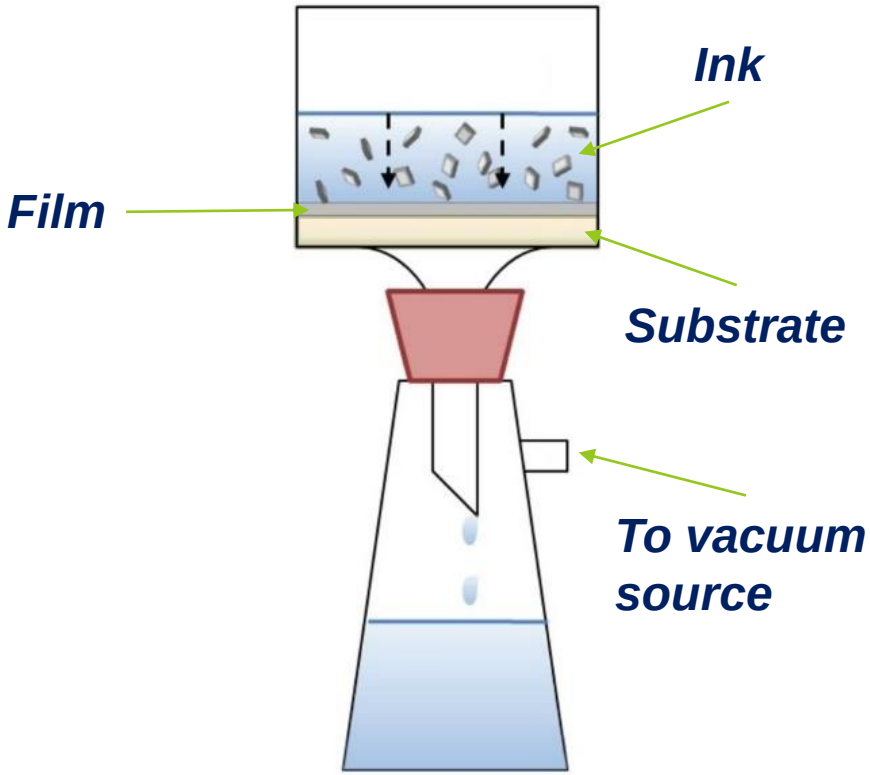




Castillo A. E. D. R., et al (2018), arXiv preprint arXiv:1804.10688.

Super – C fabrication

Graphene-based self-standing, binder and metal-free electrodes



CNT in NMP

Debundling by sonic tip

50:50% w – G:CNT

Vacuum filtration

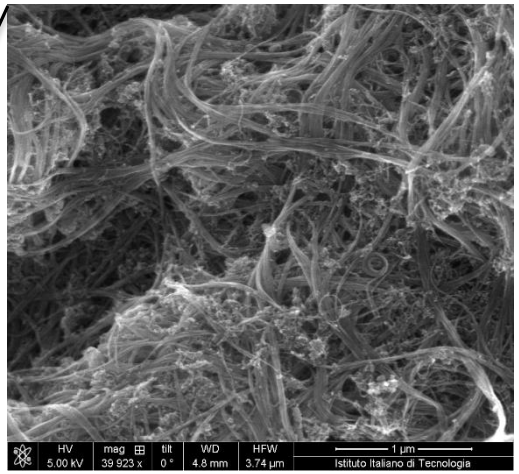
Sheath P., & Majumder M. (2016), Phil. Trans. R. Soc. A, 374(2060), 20150028.

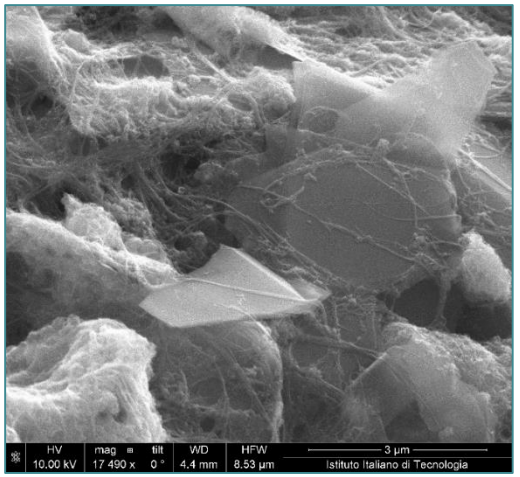
Super – C fabrication

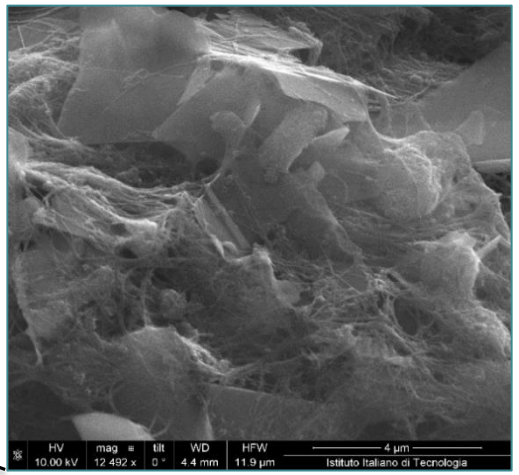
Taking a look inside the self-standing binder-free flexible electrodes by SEM

Reference CNT

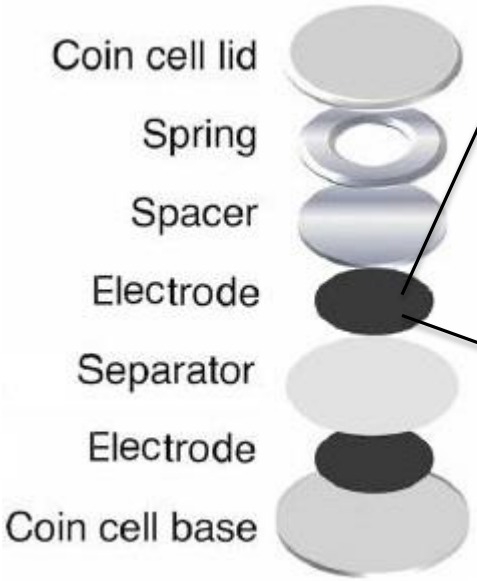
Graphene + CNT







Assembly in coin cells



Electrolyte – $TEABF_4$ in PC

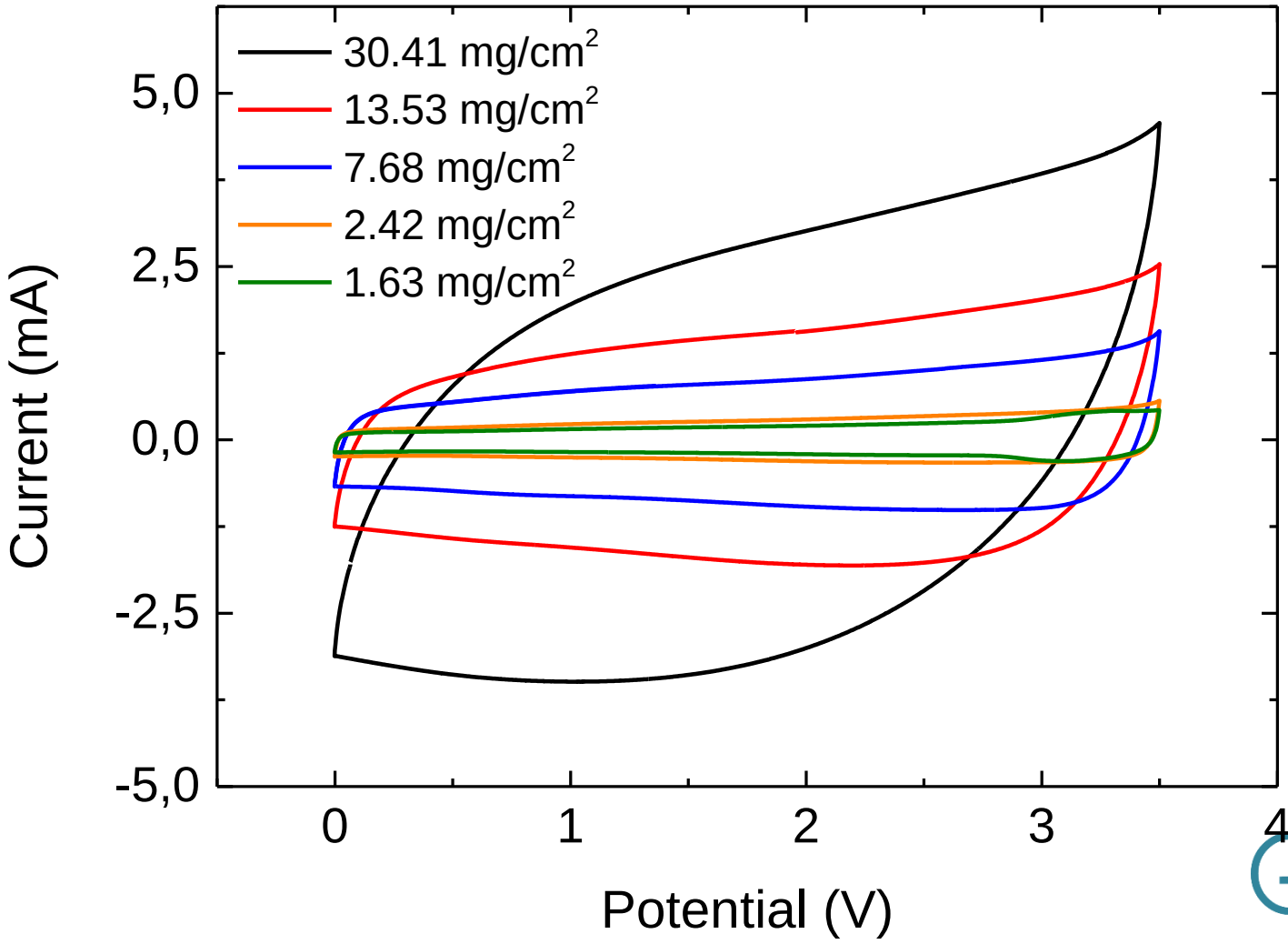
Birkl C. R., et al (2015), J. of Elect. Soc. 62(12), A2271-A2280.

Electrochemical characterizations

Cyclic Voltammetry

0 – 3.5 V , 100 mV/s

Nearly rectangular shape

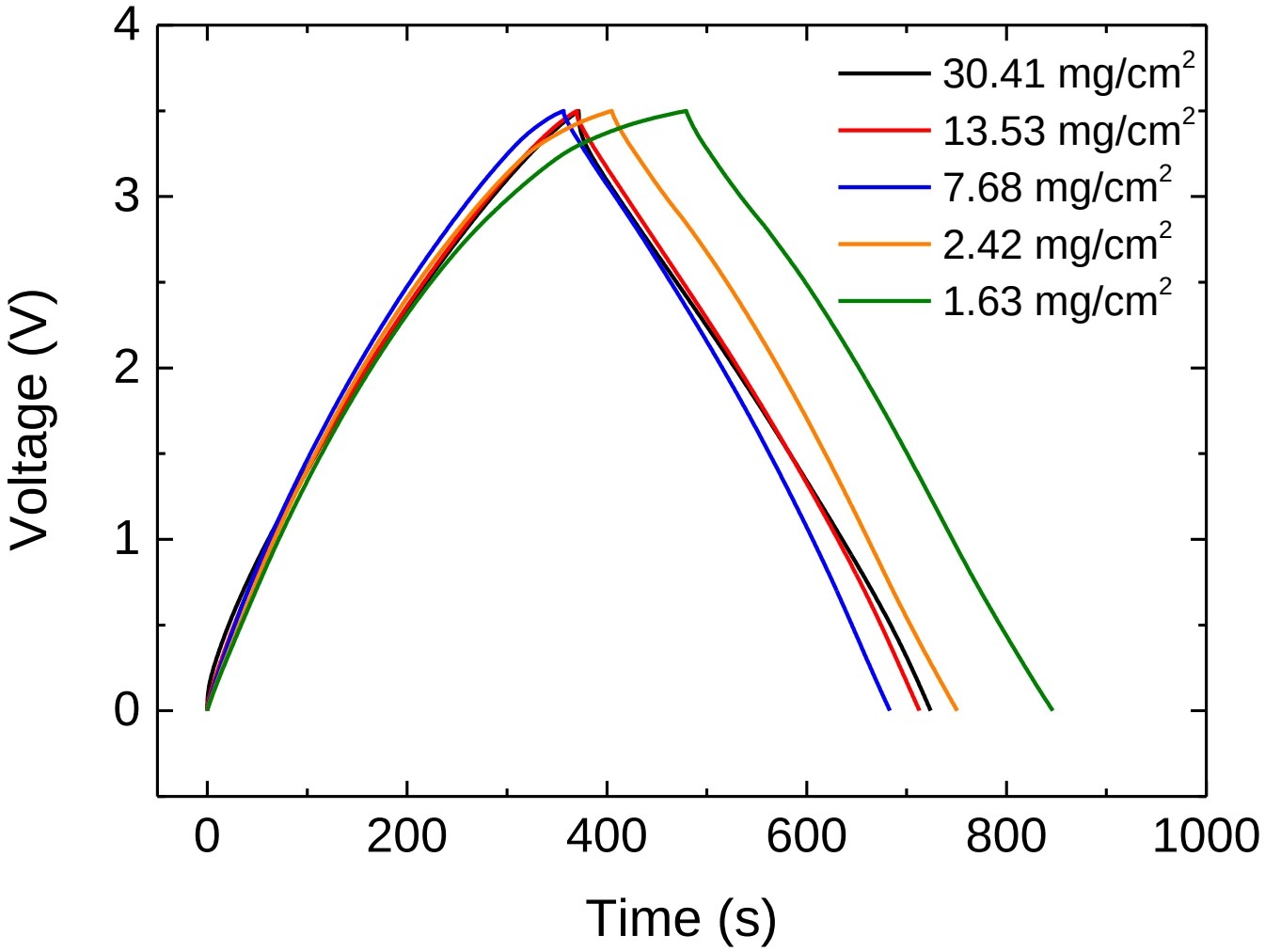


Electrochemical characterizations

Galvanostatic charge-discharge

0 – 3.5 V , 0.1 mA/mg

Nearly triangular shapes

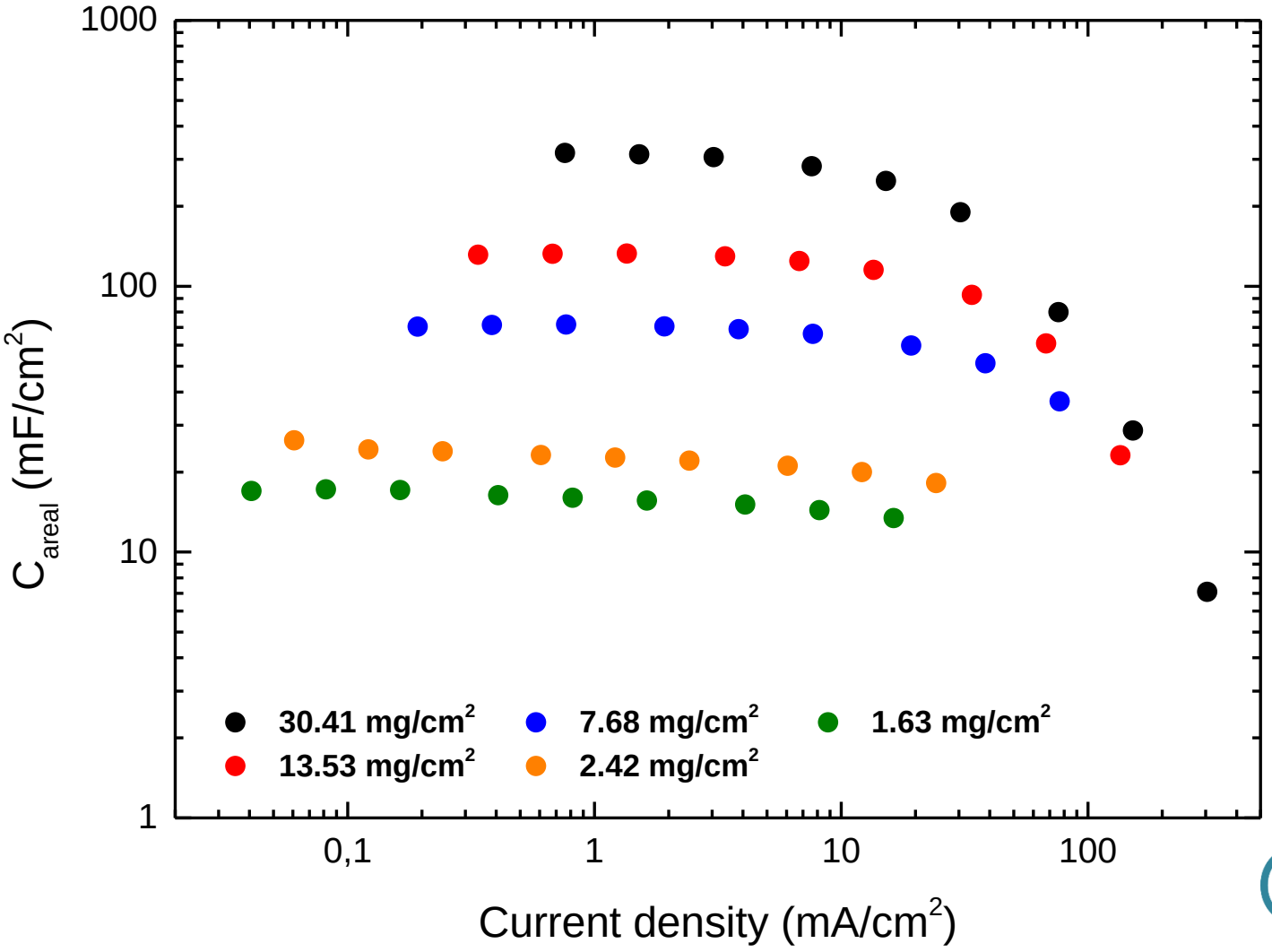


$$C = \frac{i \cdot \Delta t}{\Delta V}$$

Performance characterizations

Areal Capacitance

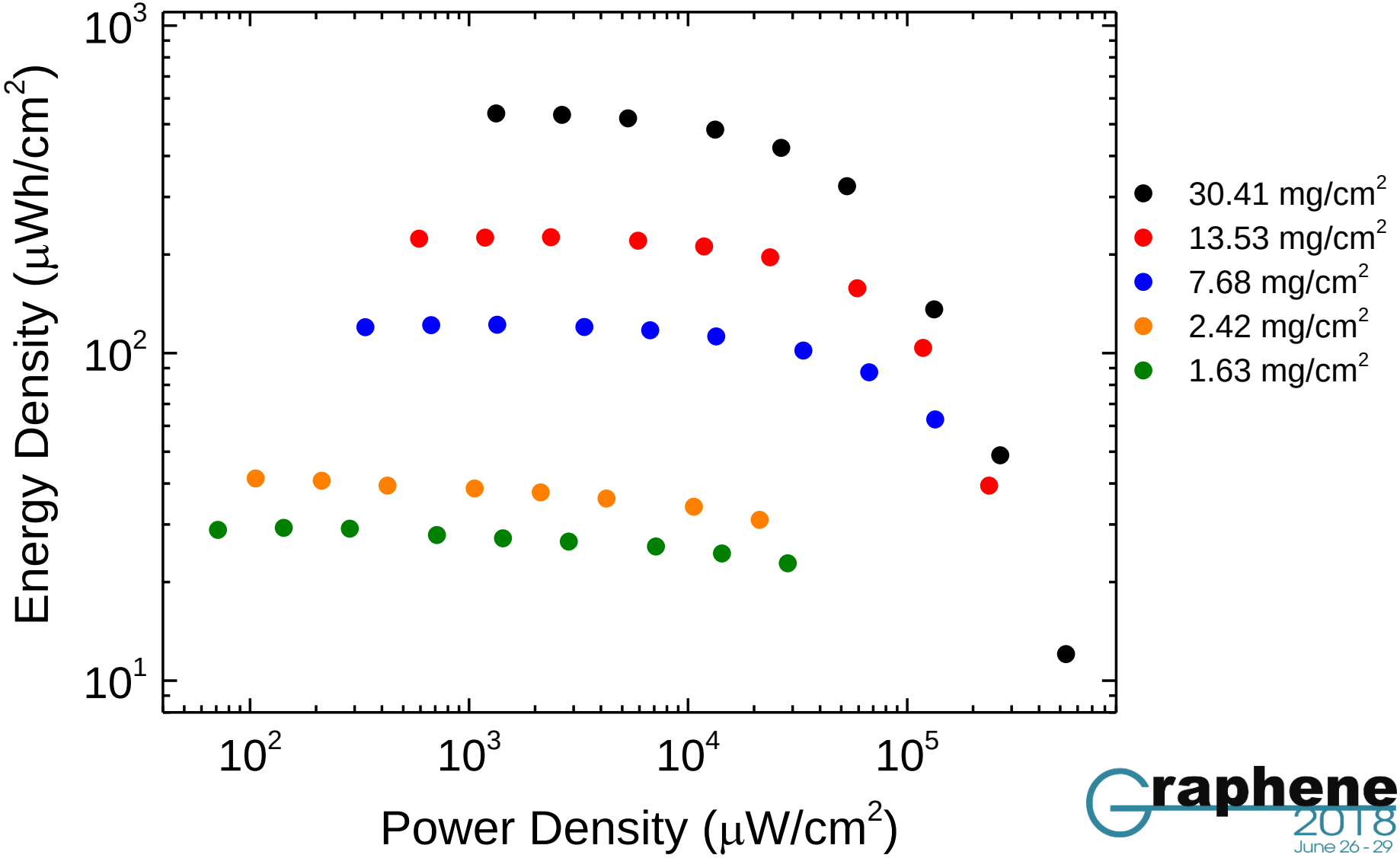
Good C_{areal} values for high mass loadings
High rate capability for low mass loadings (≈ 74%)



Performance characterizations

Ragone plot

High rate capability for low mass loadings (≈ 74%)



Conclusions

- Super C: binder free graphene – CNT hybrid (50:50)
- High yield production of graphene by wet-jet milling (2 L/h, c = 10 g/L ; $S = 0.1256\ \mathrm{cm}^2 \Longrightarrow$ more than 5000 super - C with mass loadings 30.41 mg/cm^2)
- Scalable electrodes fabrication procedure (vacuum filtration)
- Good areal performances values (wearable electronic applications)

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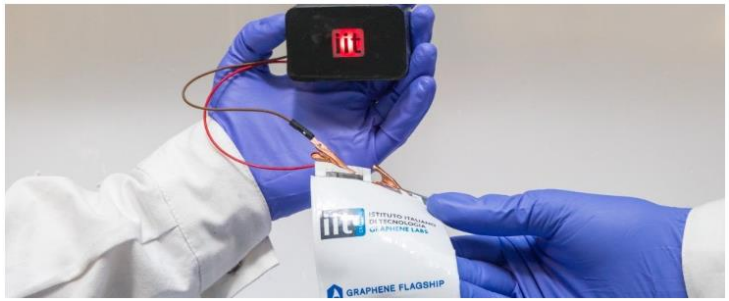
BARCELONA 26 FEB-1 MAR 2018



Graphene 2018
June 26 - 29
Dresden (Germany)

Acknowledgments

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Elisa Mantero
Luigi Marasco

Thank you for your attention!

BE DIMENSIONAL

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