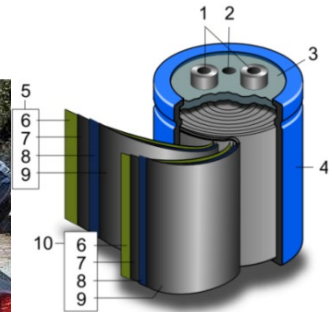
Microscale Energy Storage Devices

Presenter: Javen Lin

07/29/2014

Why Microsupercapacitors?

Large-scale Devices



Wikipedia

http://campus.albion.edu/

Advantages:

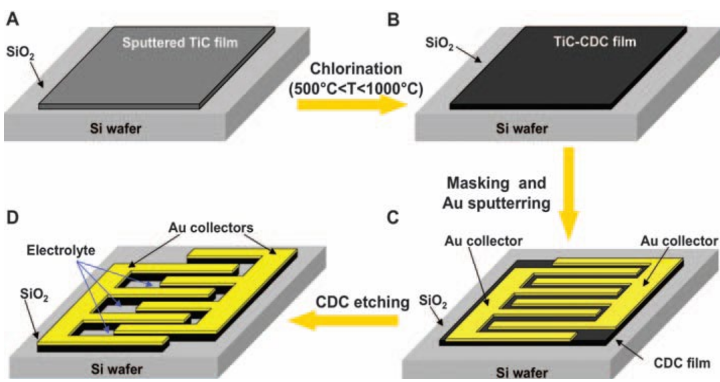
- In-plane structure without separator
- Compatible with MEMS and microchips

Wearable Electronics

- **Demands:** Emerging wearable microelectronic devices
- **Applications:** PC chips, wearable electronics

http://www.eteknix.com/

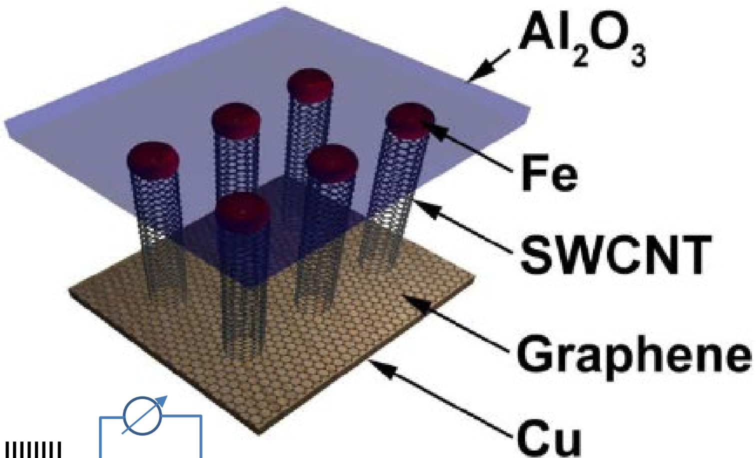
Microscale Devices

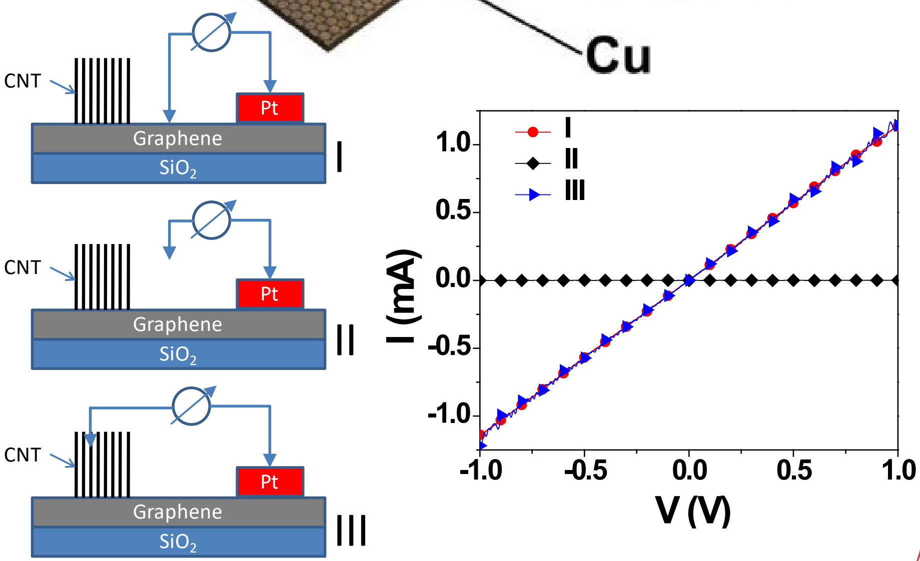


Y. Gogotsi *et al.*, **Science** 2010, 328, 480

3D Graphene/CNTs for Microsupercapacitors

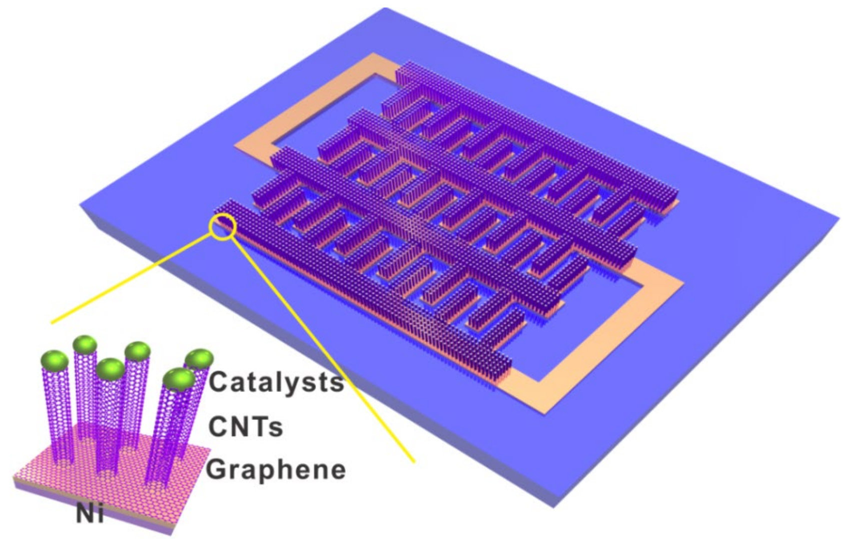
Past work: 3D Graphene/CNTs hybrid materials





Y. Zhu, et al. **Nat. Commun.** 2012, 3, 1225

Current work: Microsupercapacitors



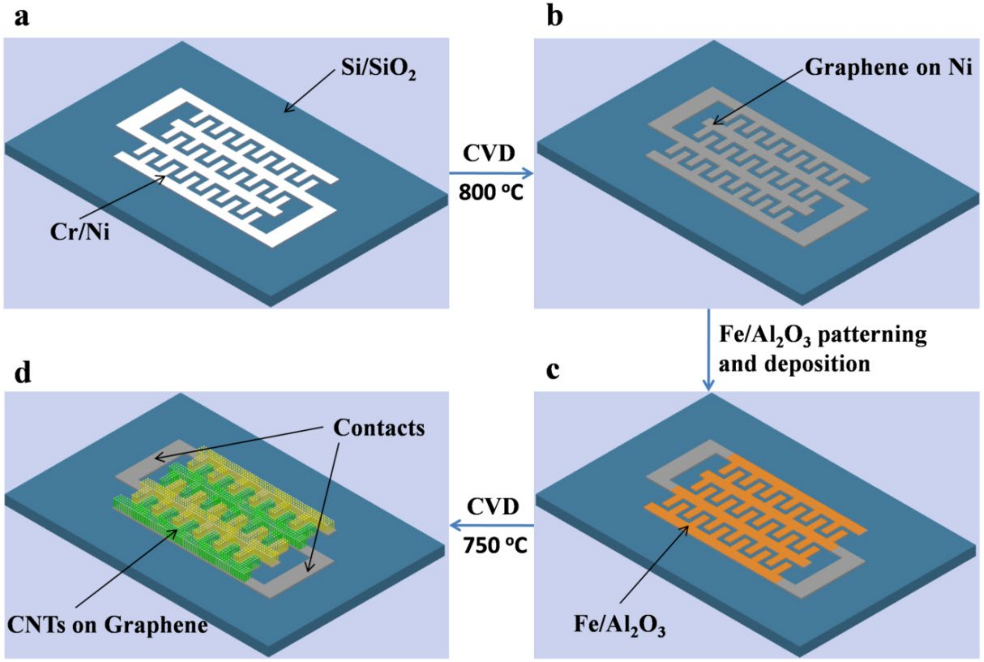
J. Lin, *et al*. **Nano Lett.** 2013, 13 (1), 72-78

Properties of 3D G/CNTs hybrid materials:

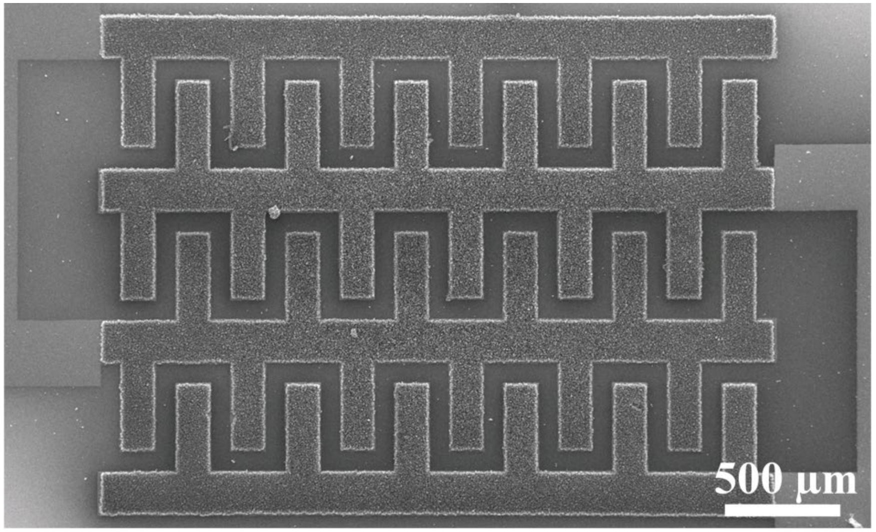
- High surface area, > 2000 m^2/g
- High electrical conductivity
- Ohmic conduction between graphene and CNTs

Microsupercapacitors Fabrication

a) Fabrication Process

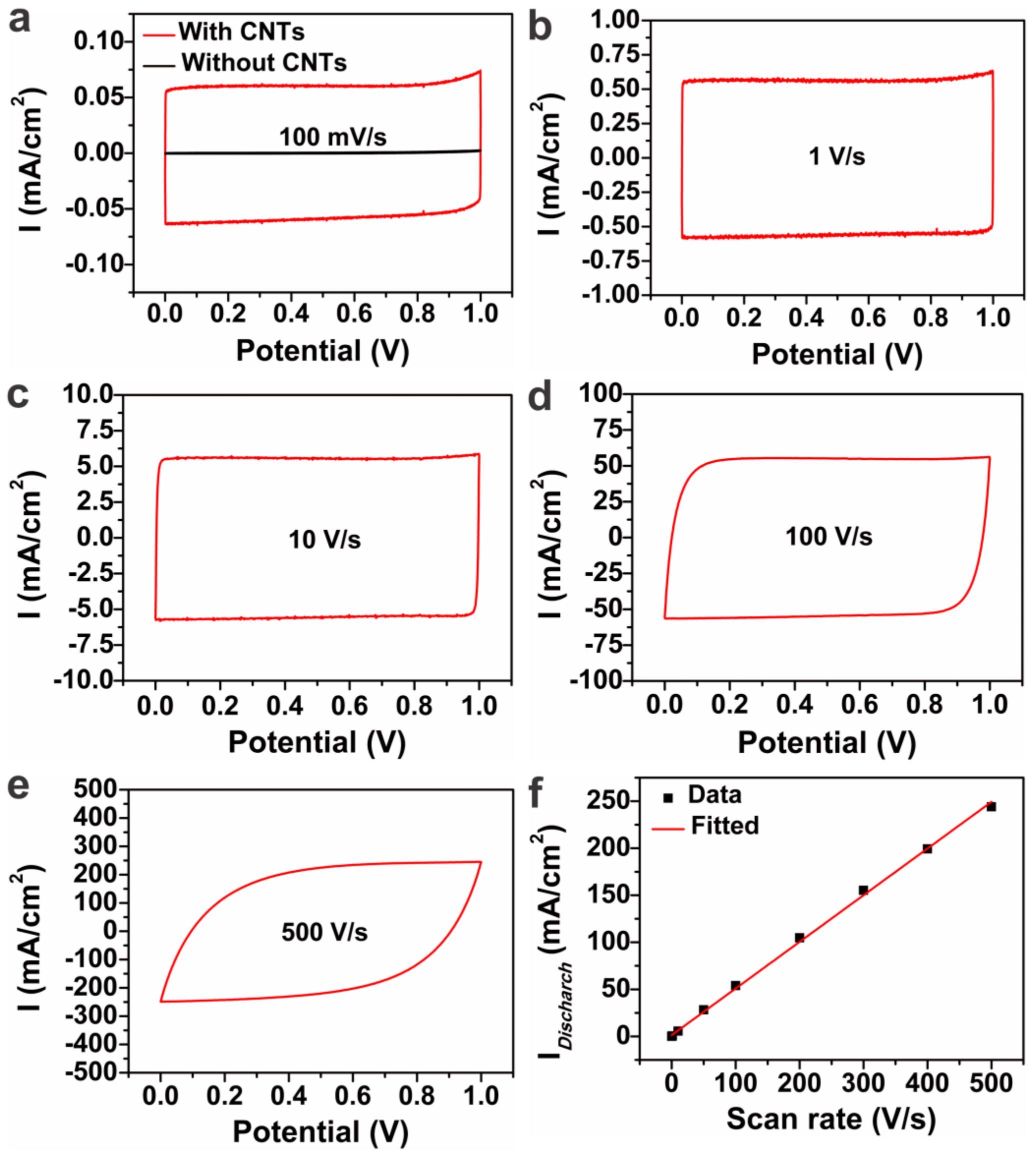


b) Results: A Fabricated Microdevice



J. Lin, *et al*. **Nano Lett.** 2013, 1, 72-78

Rate Capacity of 3D G/CNTs Microsupercapacitors (G/CNT-MCs)

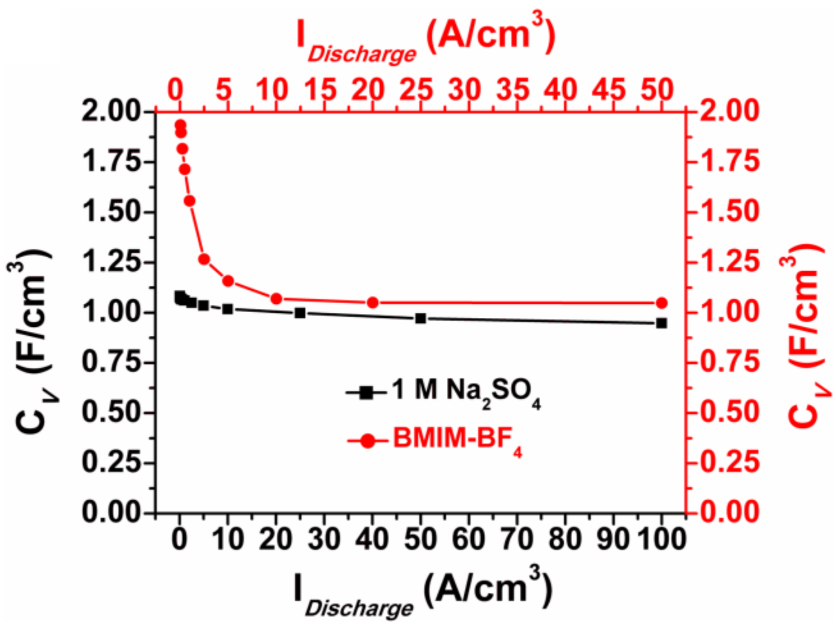


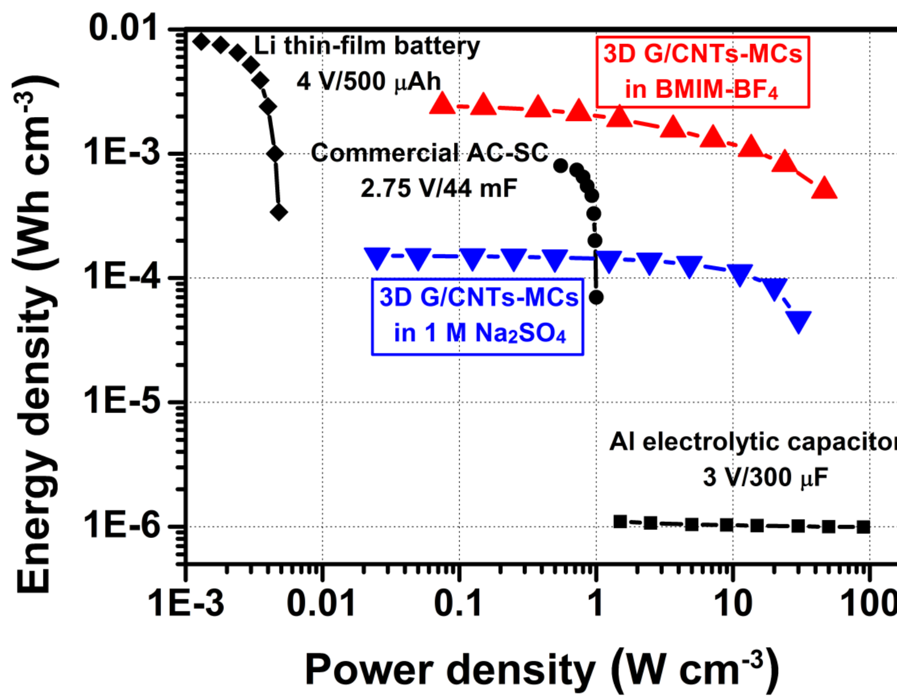
Results:

- Rectangular shape of CV curves up to **400 V/s**: ideal double layer capacitors
- Ultrahigh rate of **500 V/s** was achieved in G/CNCs-MCs.

J. Lin, *et al*. **Nano Lett.** 2013, 13 (1), 72-78

Comparison of Electrochemical Performance of 3D G/CNTs MCs in Aqueous and Organic Electrolytes





$$C_V = \frac{I}{S \times h \times (dV/dt)}$$

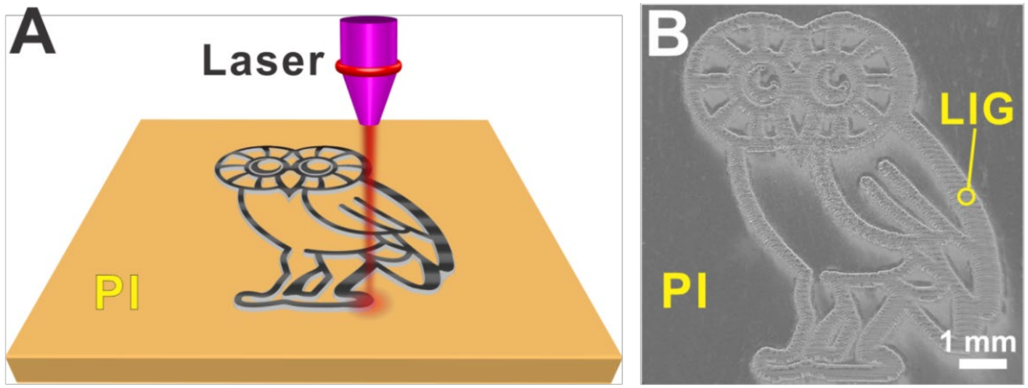
$$E_V = \frac{C_v V_i^2}{2} \times \frac{1}{3600} \qquad P_V = \frac{E_V}{\Delta t}$$

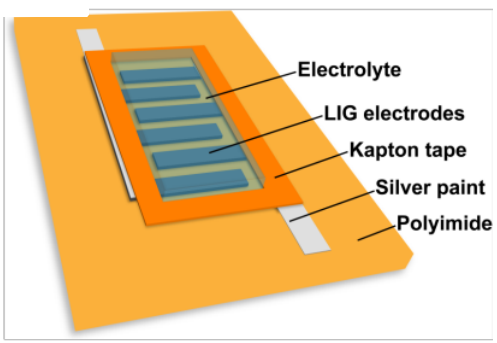
~ 10^3 times higher than commercial aluminum electrolytic capacitor in terms of energy density

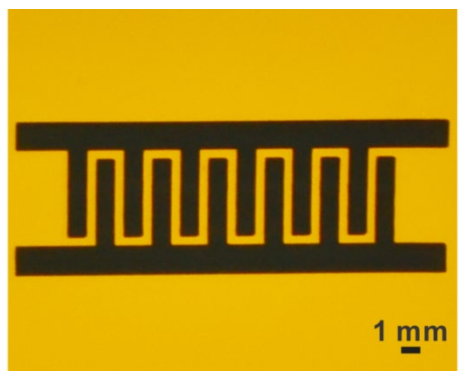
J. Lin, *et al*. **Nano Lett.** 2013, 13 (1), 72-78

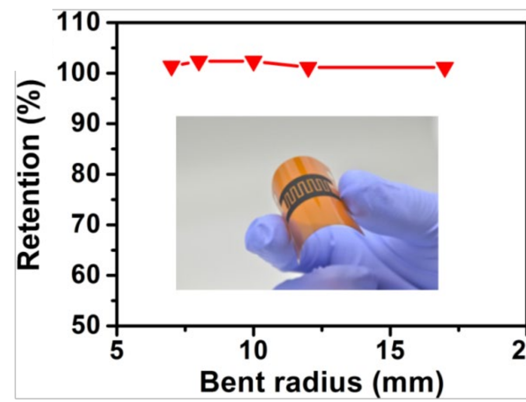
RICE Unconventional Wisdom

Laser-induced Porous Graphene (LIG) from Polymers for Microsupercapacitors



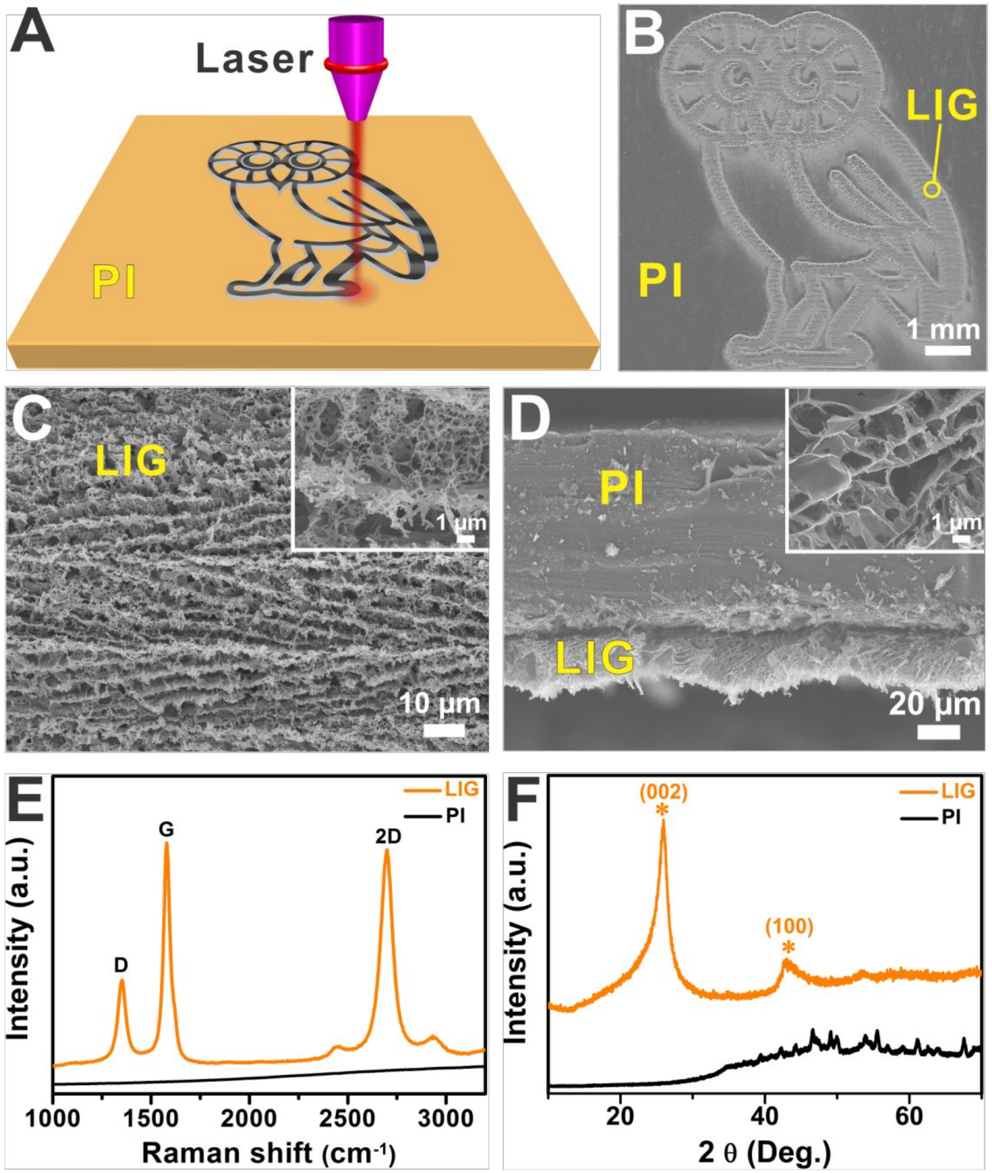






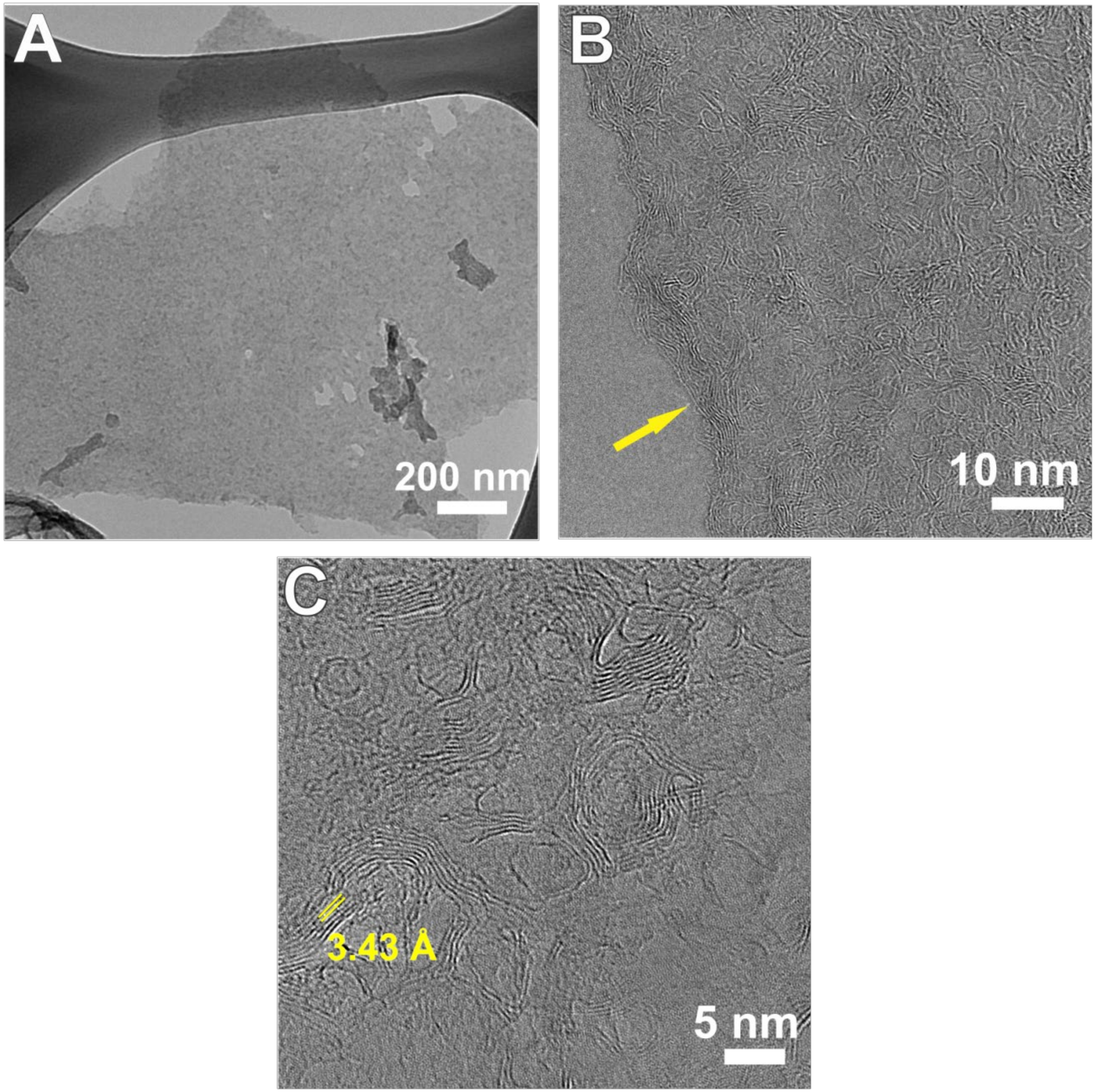
J. Lin *et al*., 2014, under review
Z. Peng*, **J. Lin*** *et al*., 2014, to be submitted
Z. Peng, *et al*., 2014, to be submitted

LIG: High Porosity and Good Quality



J. Lin *et al*., 2014, under review

LIG: Highly Wrinkled and Mesoporous Structures



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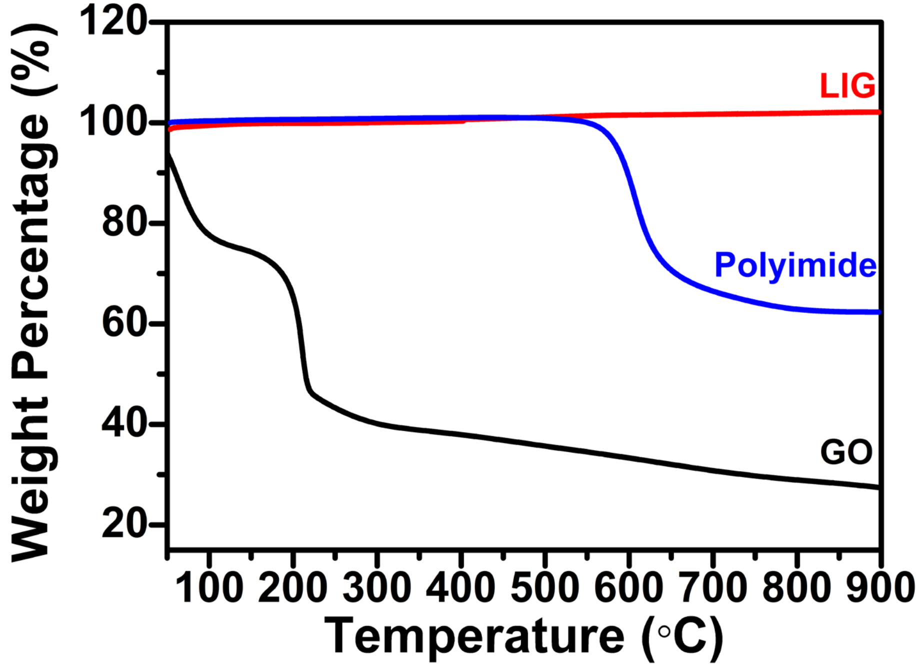
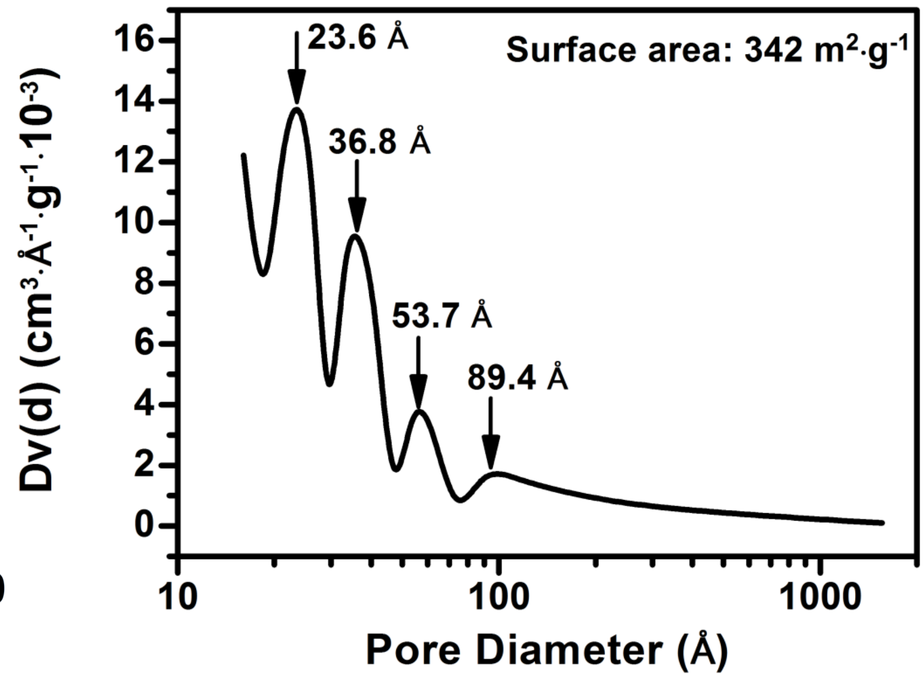
Stable LIG with Small Pore Size and High Surface Area

TGA (in Ar)



BET

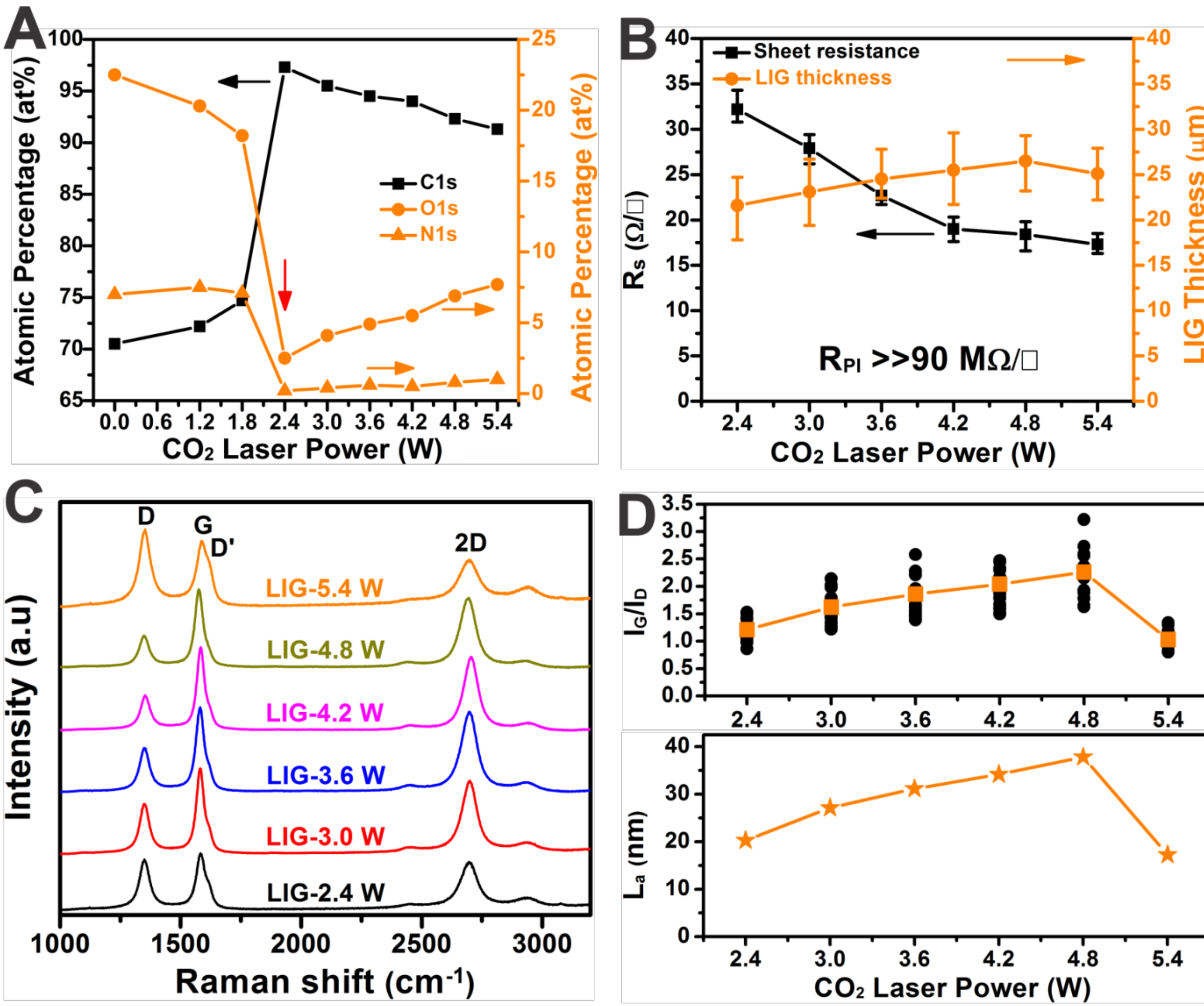


Stable at over 900 °C, while GO starts to decompose at 190 °C.

Pore size less than 9 nm

J. Lin *et al.*, 2014, under review

Quality Control of LIGs with Different Laser Power



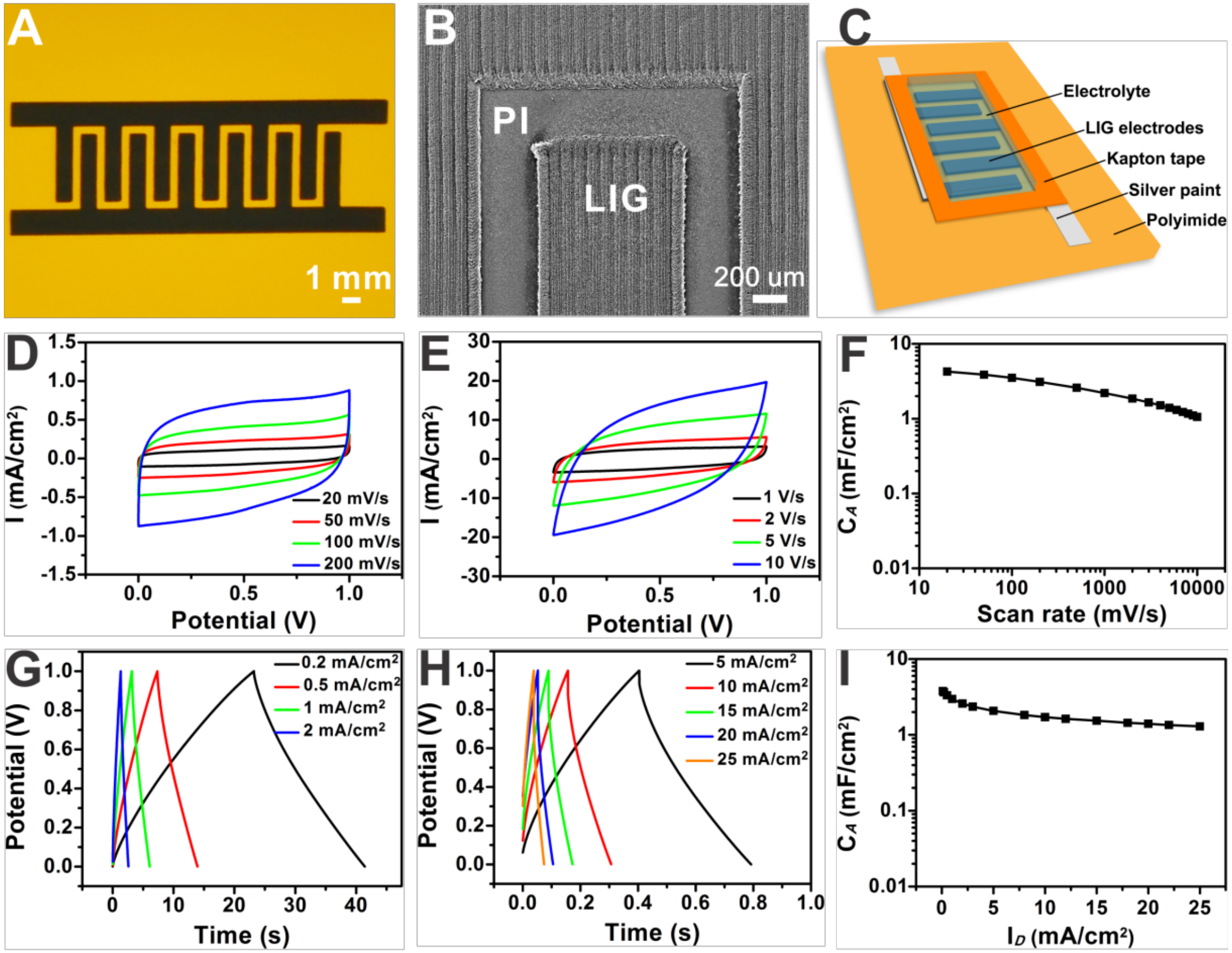
$$L_a = (2.4\times10^{-10})\times\lambda_l^4\times\left(\frac{I_G}{I_D}\right)$$

Results:

- Threshold laser power: **2.4** W
- rGO: R_{rGO} > **100** Ω/□)
- crystalline size along a-axis: from 20 nm to 40 nm.

J. Lin *et al.*, 2014, under review

Electrochemical Performance of LIG Microsupercapacitors



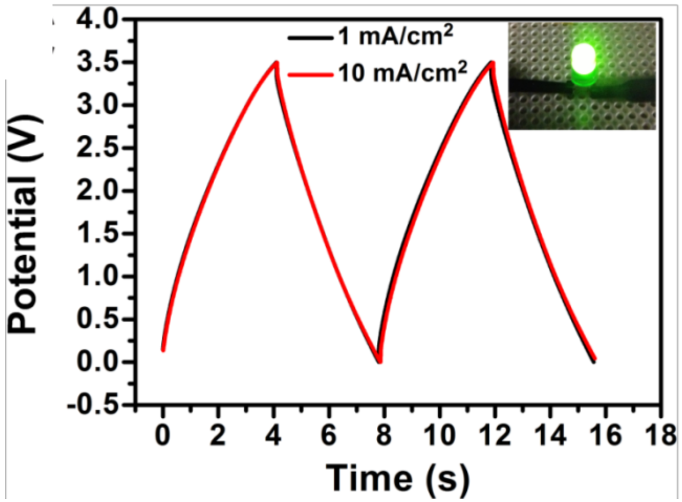
Results:

- Over 4 mF/cm^2 at scan rate of 20 mV/s, higher than laser-scribe GO based microsupercapacitors (~2.4 mF/cm^2 from Ref. "Nat. Commun. **2013**, 4, 1475")
- Maintain good capacitive behaviors at $I_{discharge}$ of 25 mA/cm^2.

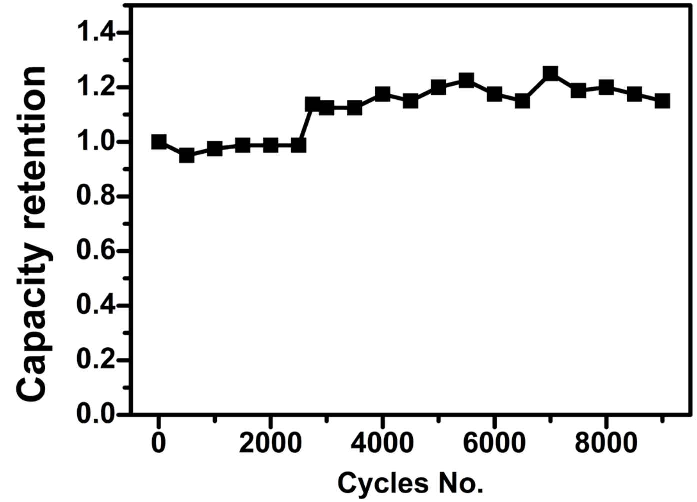
J. Lin *et al.*, 2014, under review

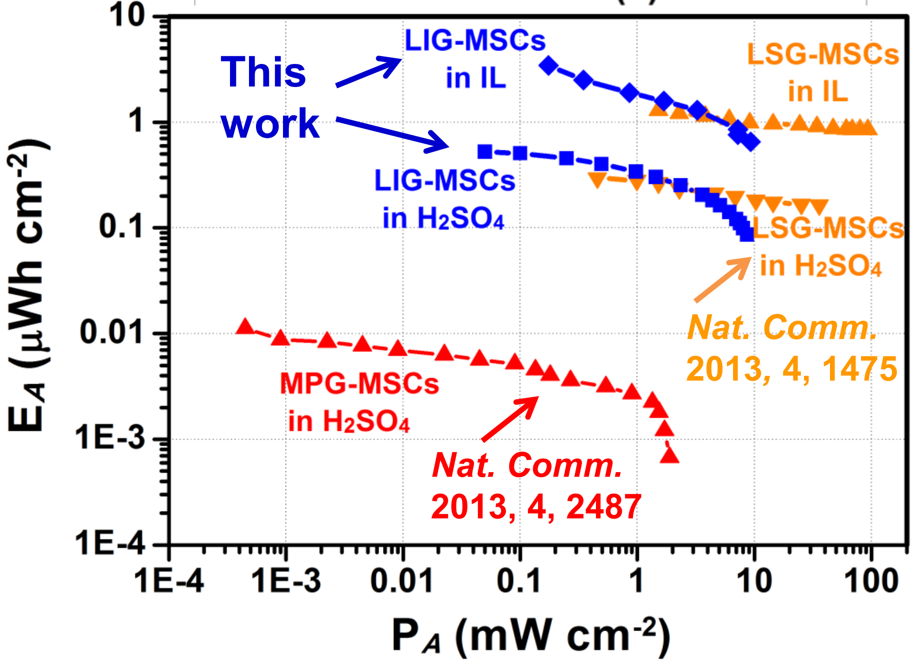
Other Electrochemical Performance

Parallel configuration



Cycling performance



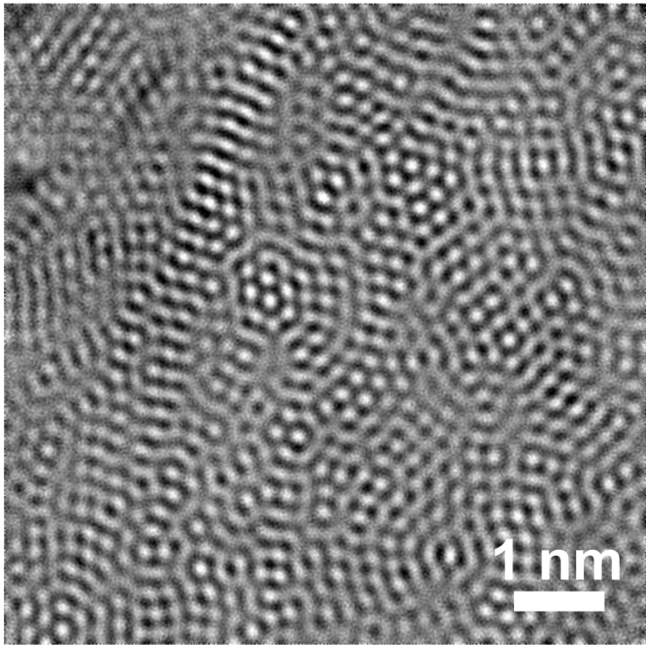


Ragone Plots of Energy Storage Devices

J. Lin *et al.*, 2014, under review

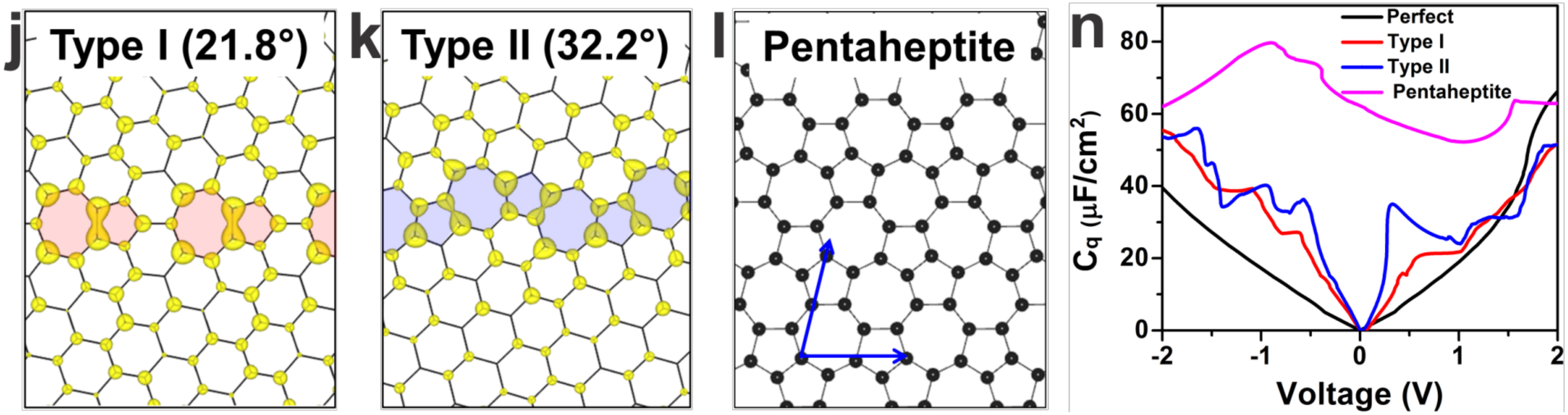
Relation of Structures and Electrochemical Performance

Aberration-corrected TEM image



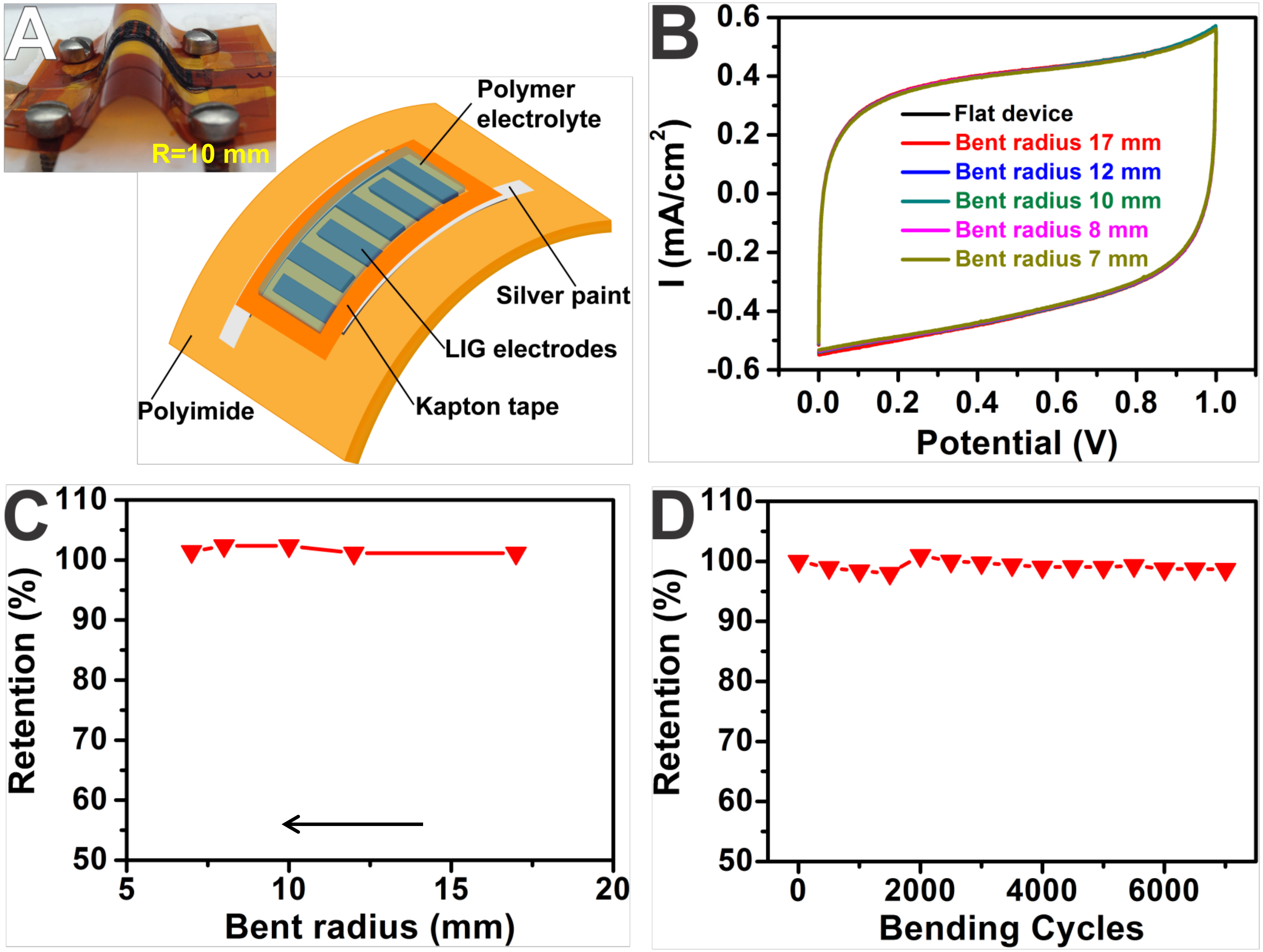
Ultra-nanocrystalline features

Density function theory calculation:



J. Lin *et al*., 2014, under review

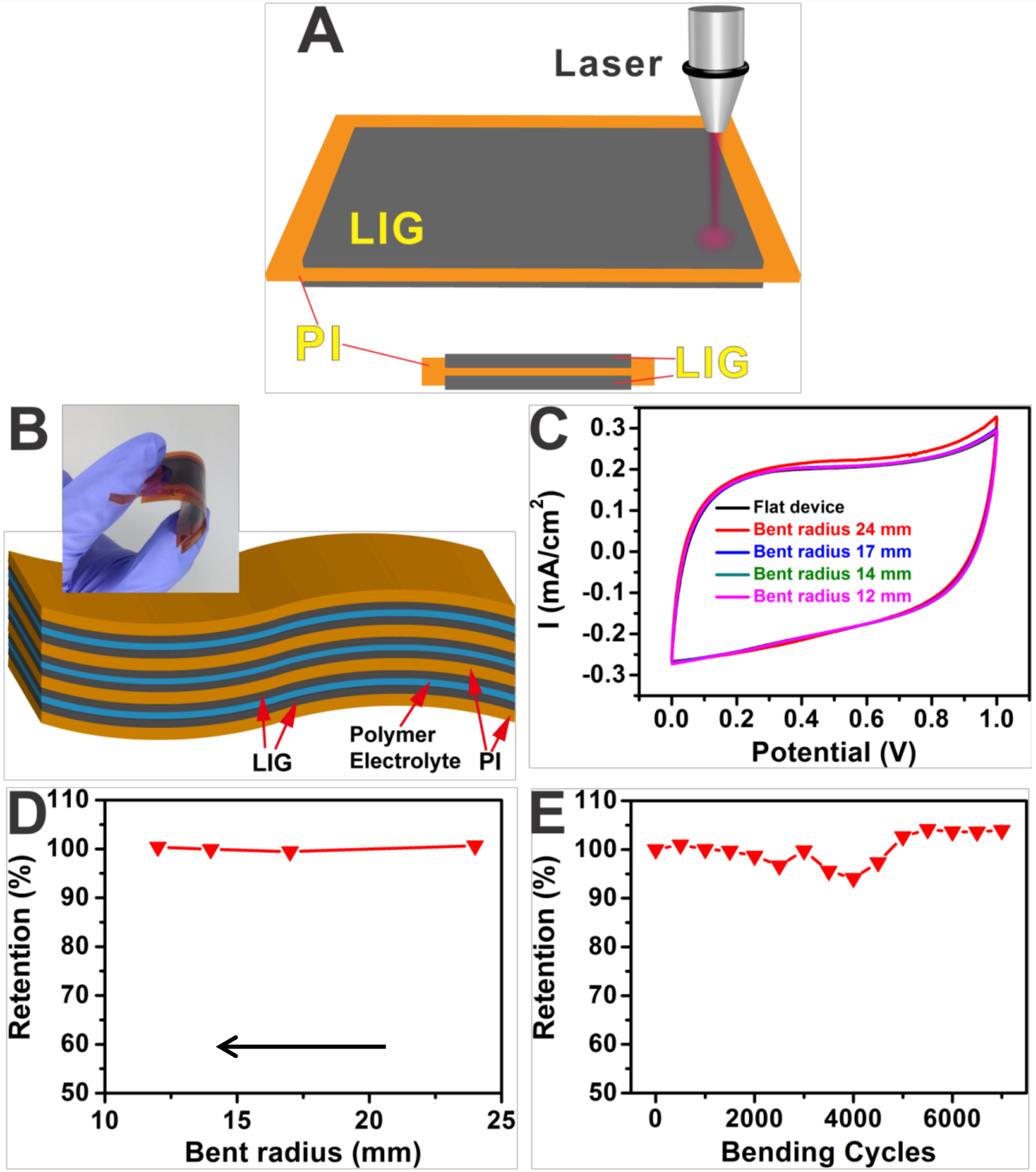
Solid-state and Flexible Microsupercapacitors



Z. Peng*, **J. Lin*** *et al.*, 2014, to be submitted

Solid-state and Flexible Supercapacitors—Sandwiched Structure

3D stacking structures



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