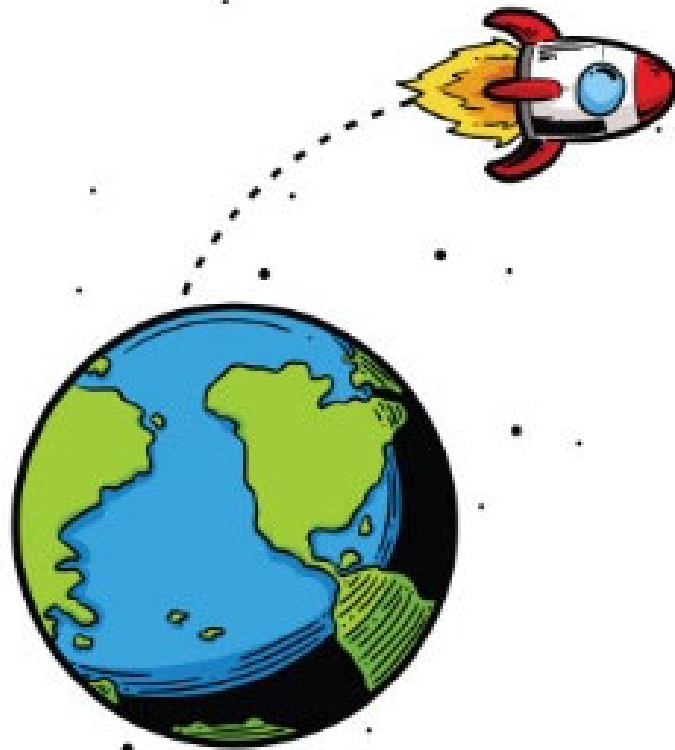


Exploring the Nano-flatlands:
How the world's thinnest materials can Revolutionise
Our Energy Storage Technologies

Prof. Valeria Nicolosi

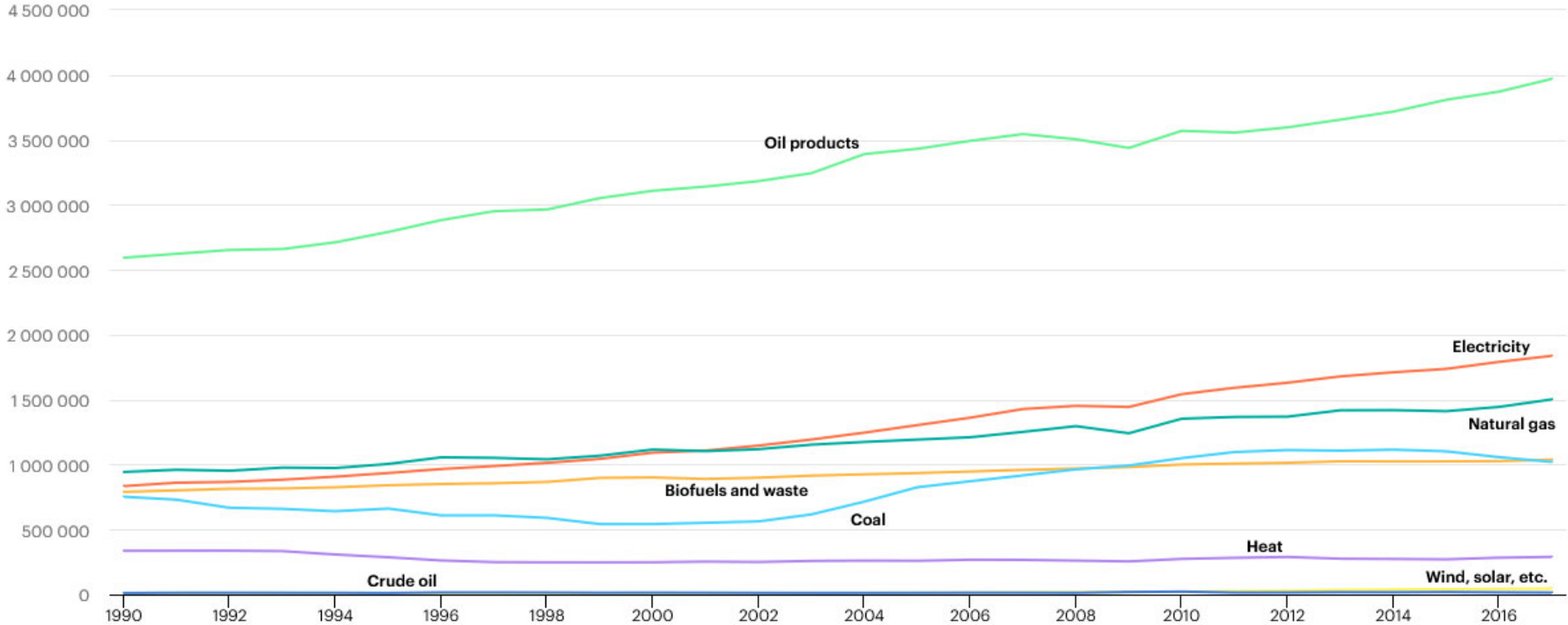
nicolov@tcd.ie



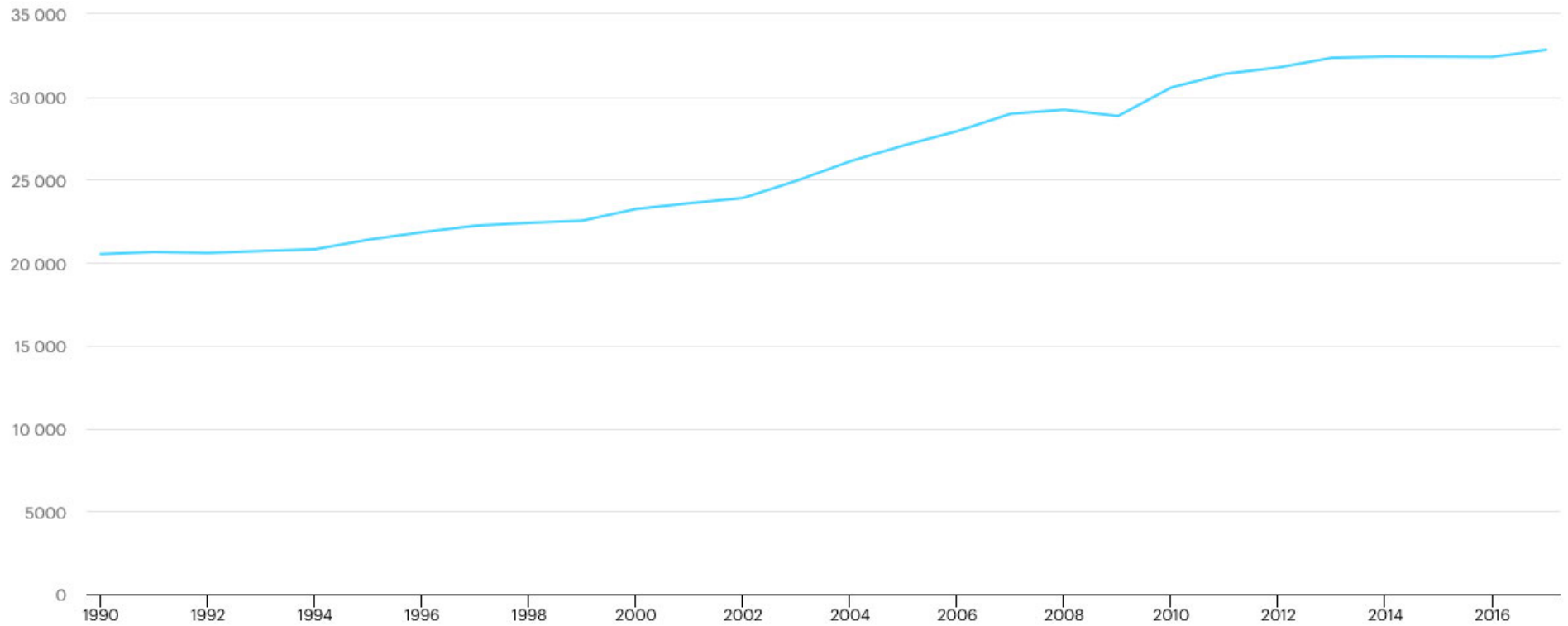
**THERE
IS NO
PLANET.B**

SAVE THE WORLD

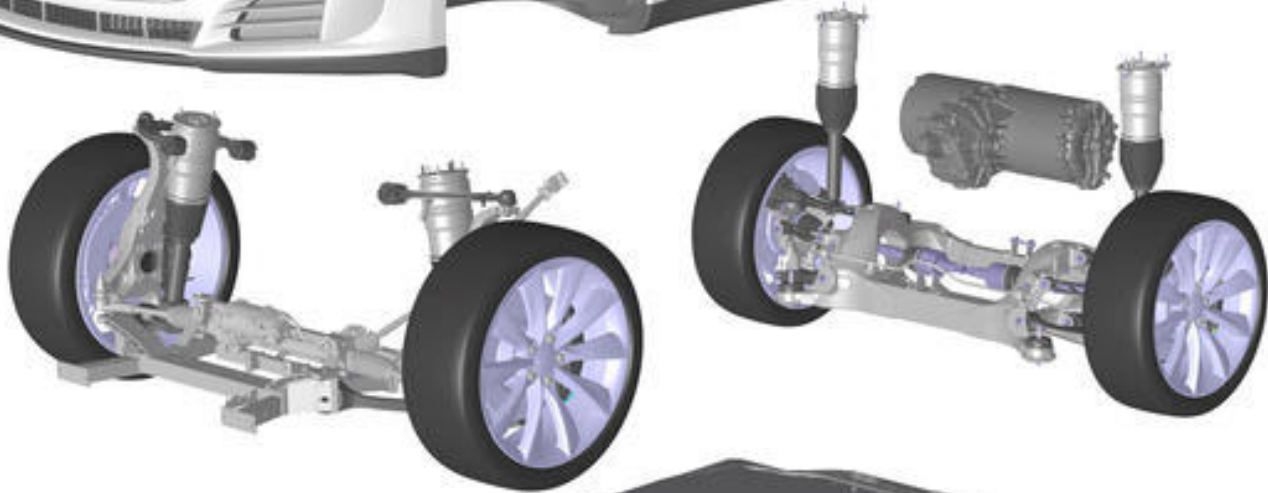
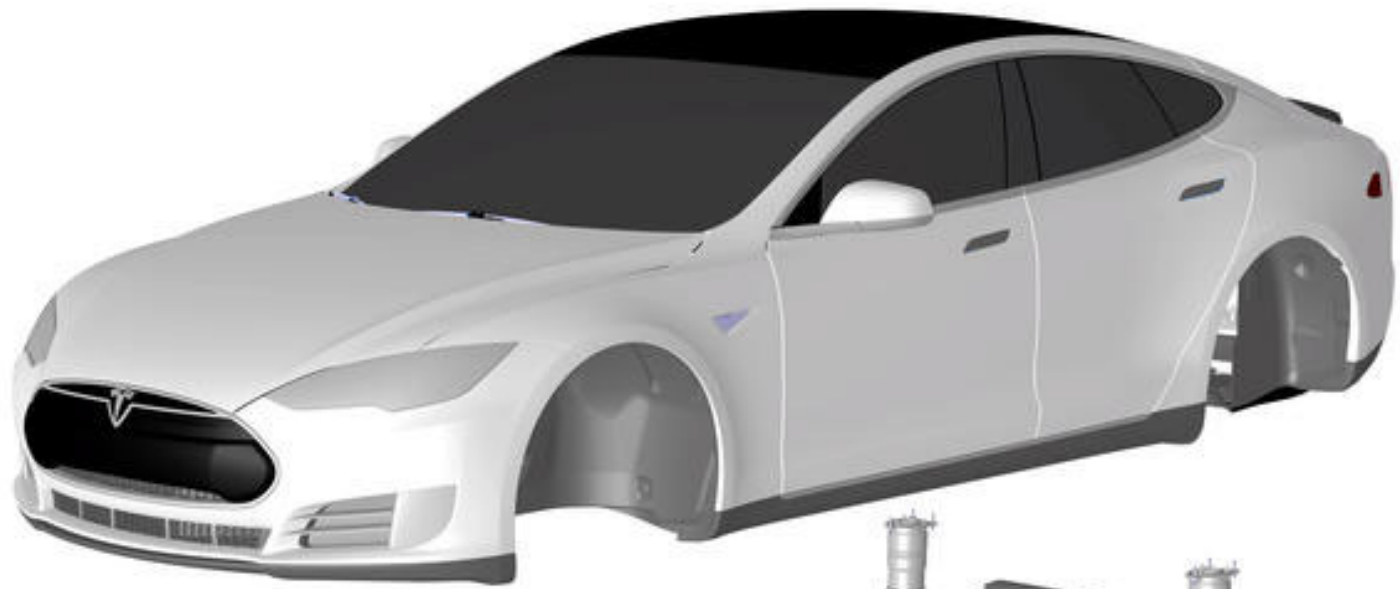
Total final consumption (TFC) by source, World 1990-2017

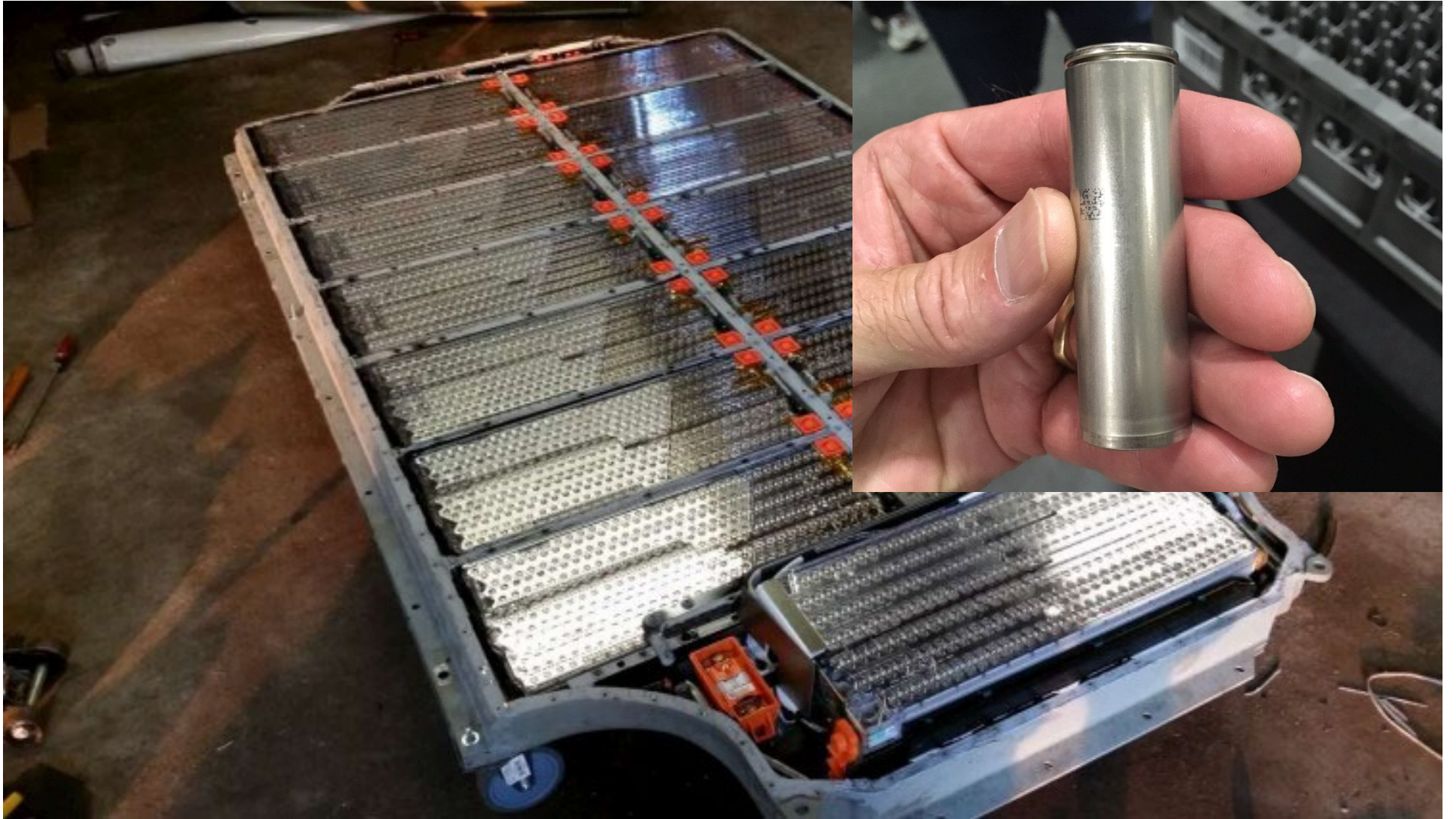


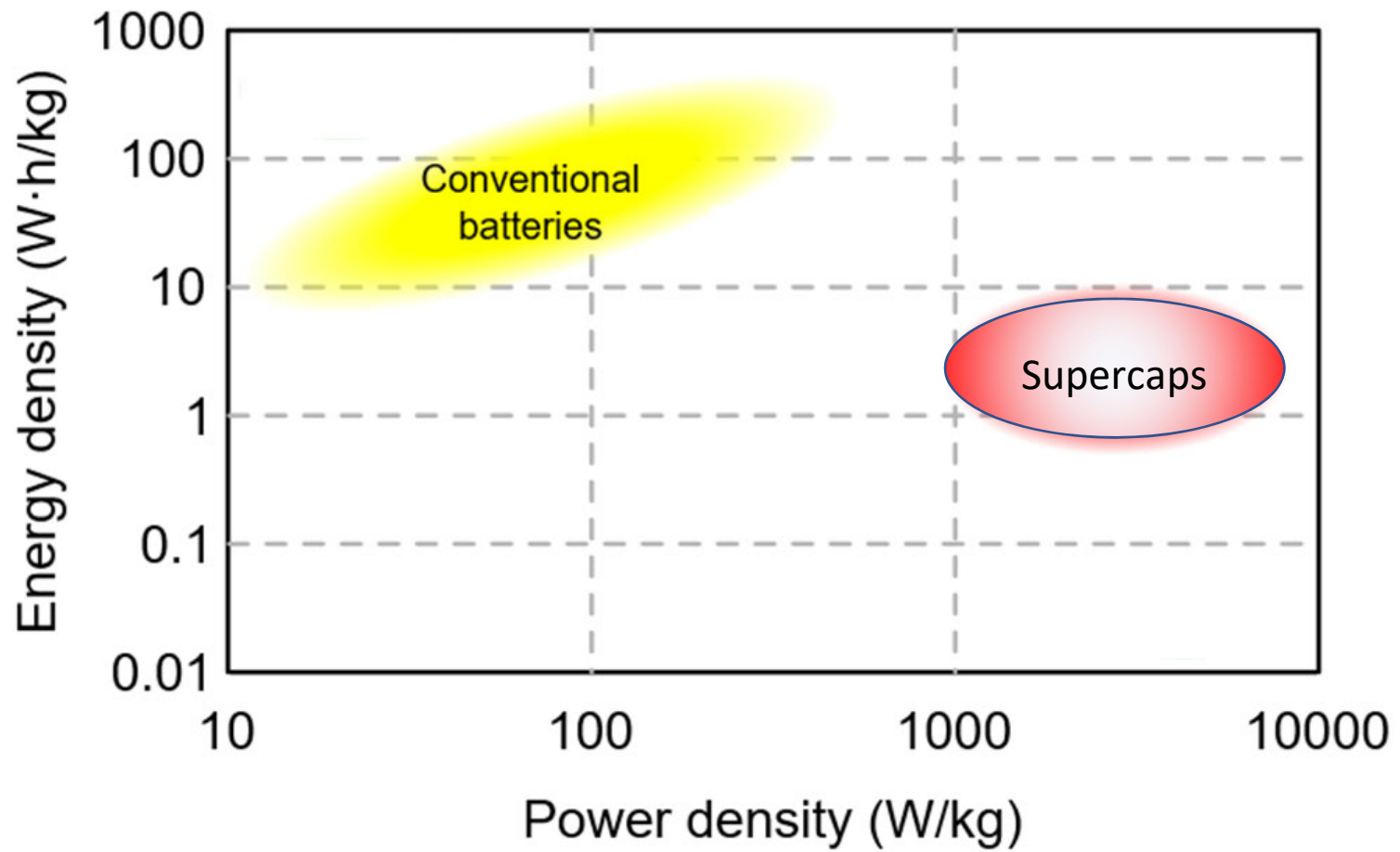
Total CO₂ emissions, World 1990-2017

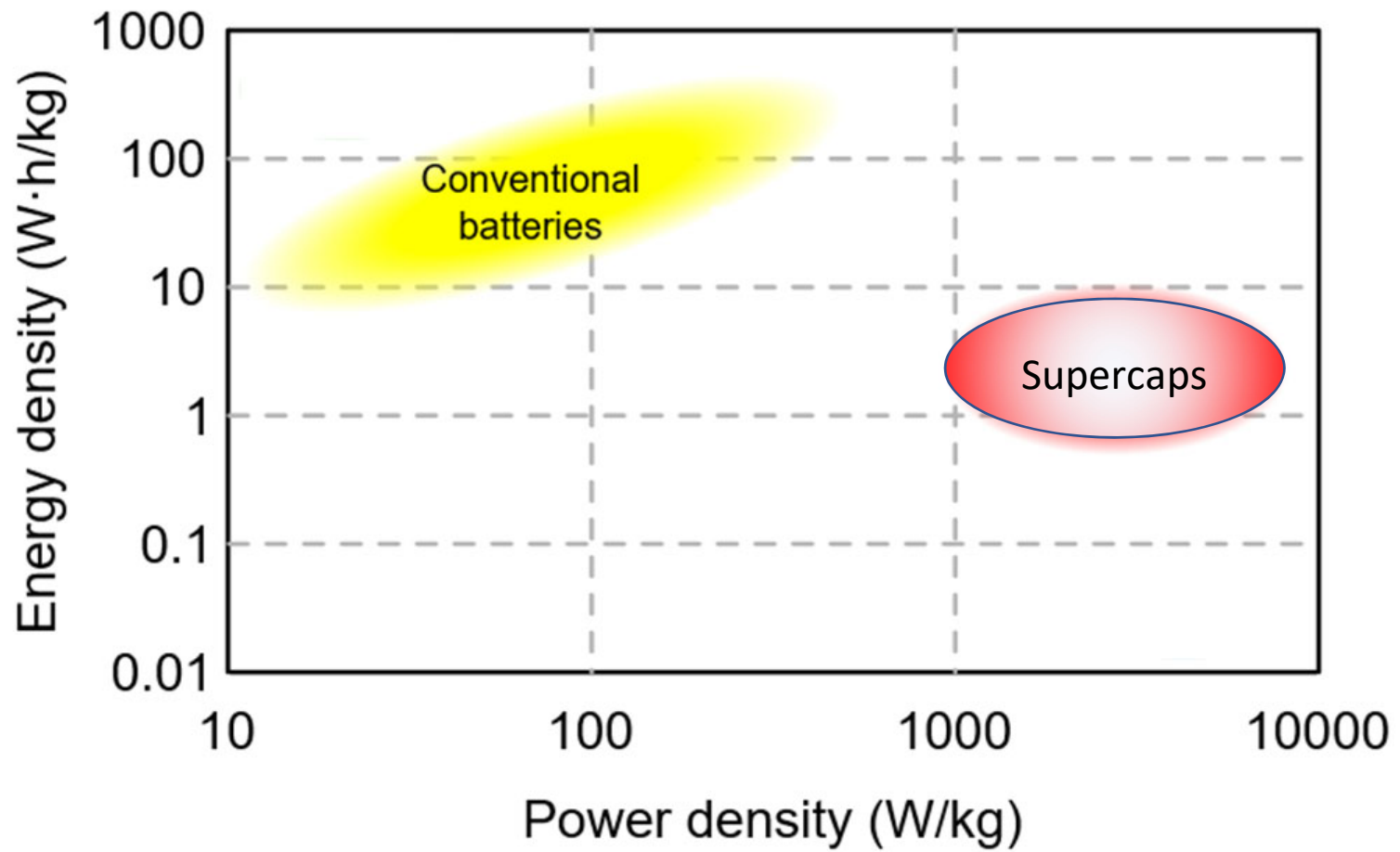


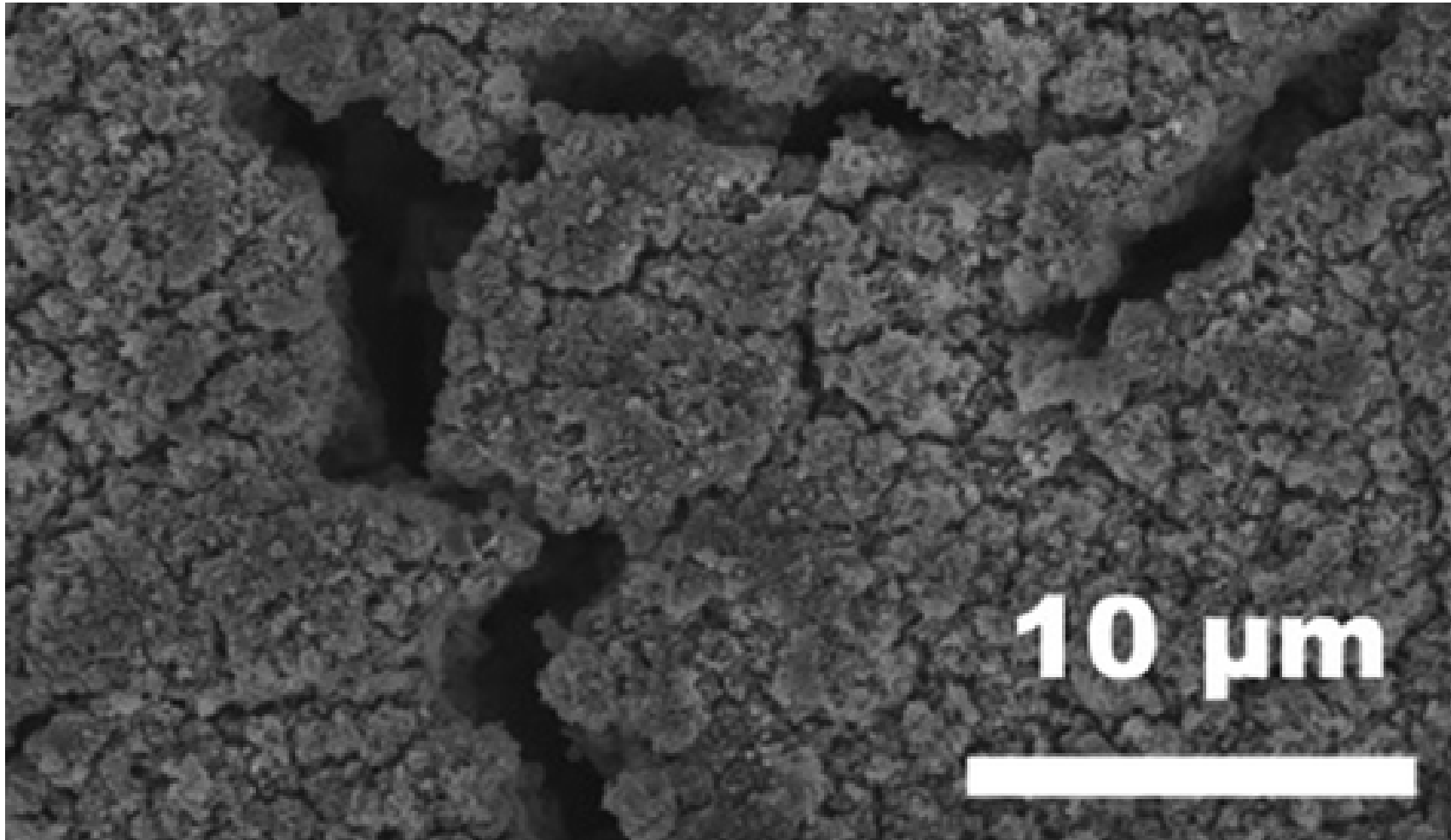














Graphene!

The thinnest,



lightest,

strongest



object ever obtained...

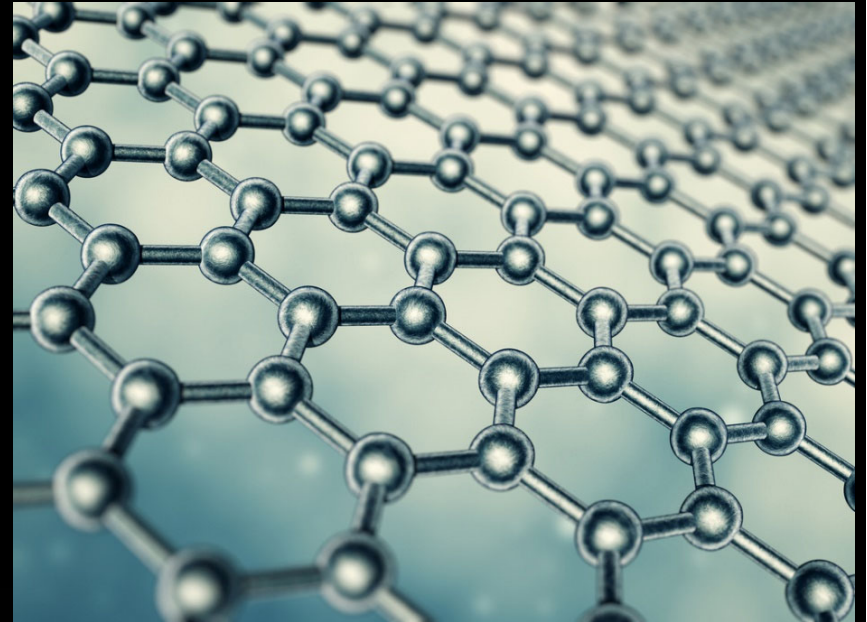
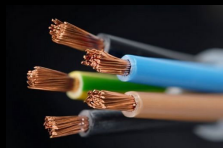
harder than



300 times stronger than



It conduces electricity
better than copper



transparent, flexible and bendable..

Rai 1





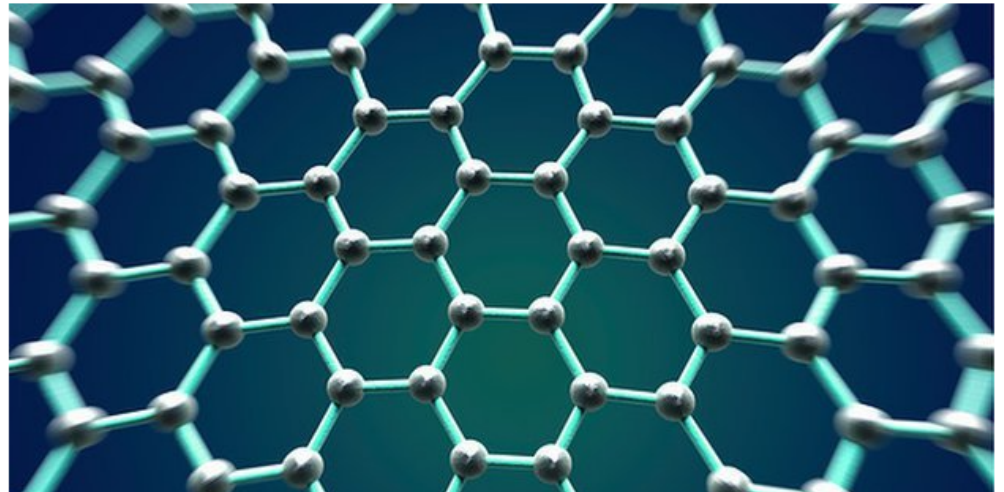
Make Sure Your Credit Is Ready
Get Your Latest Credit Report & Score
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22 April 2014 Last updated at 09:03 ET

Share   

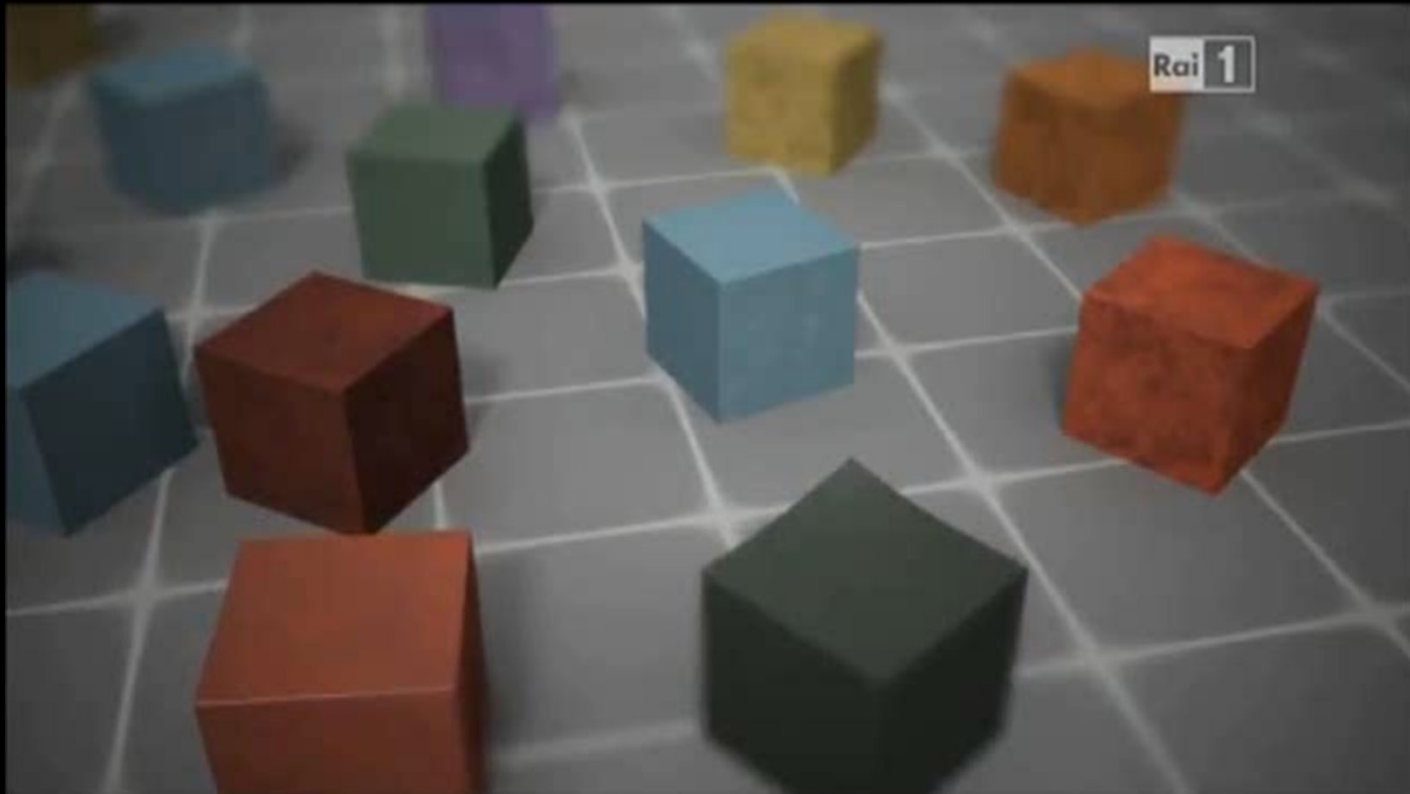
Graphene 'wonder material' made with kitchen blender



THOMAS SWAN





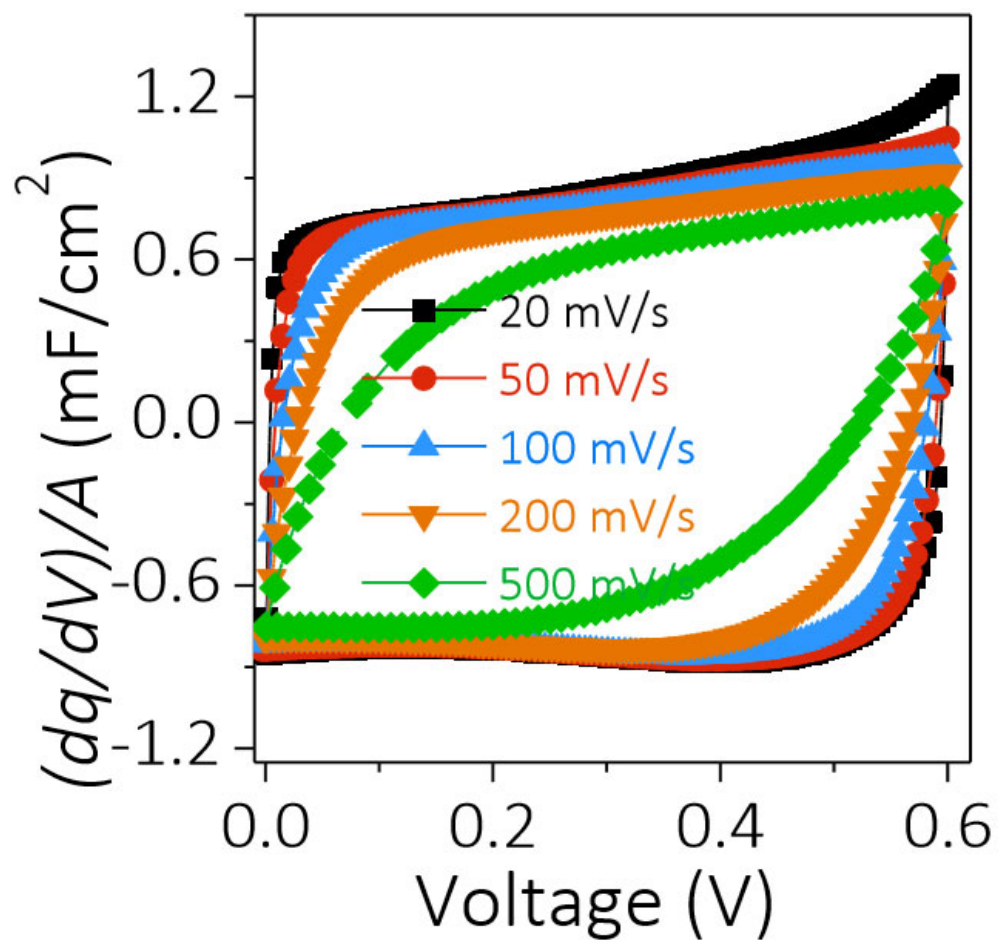


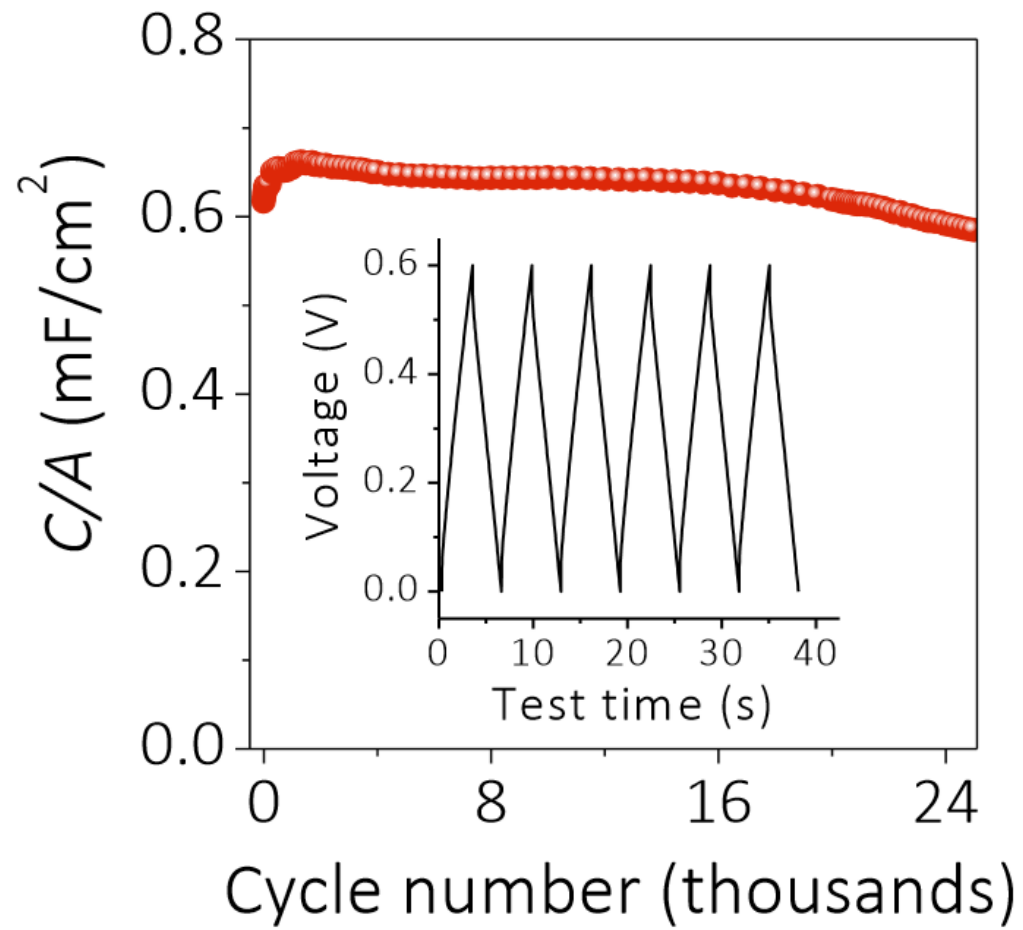
- Metals
- Semiconducting
- Insulators
- A variety properties...



Supercapacitors based 2D nanomaterials inks:







Stamped Micro-Supercapacitors

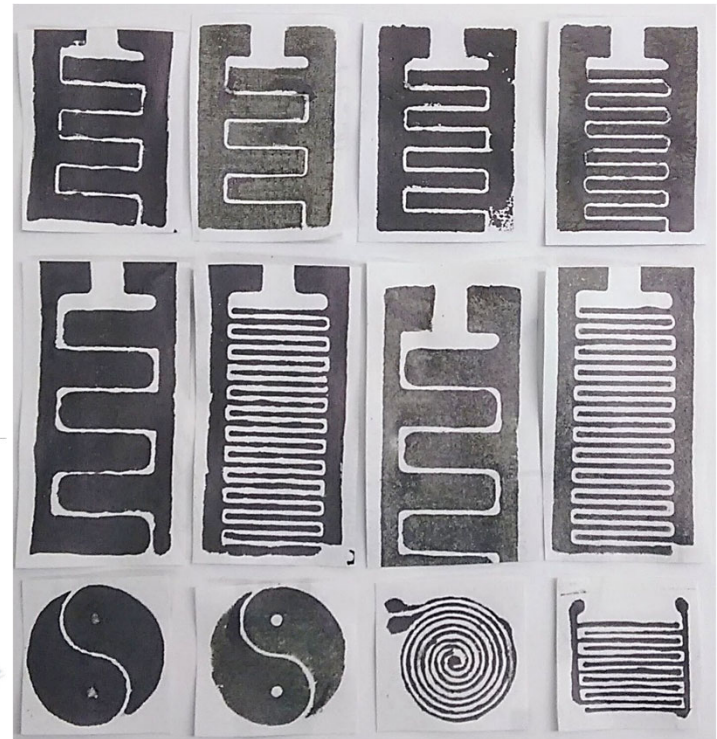
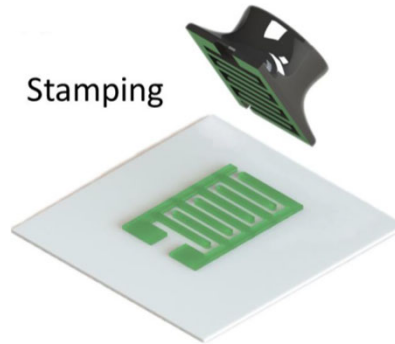


Rapid production

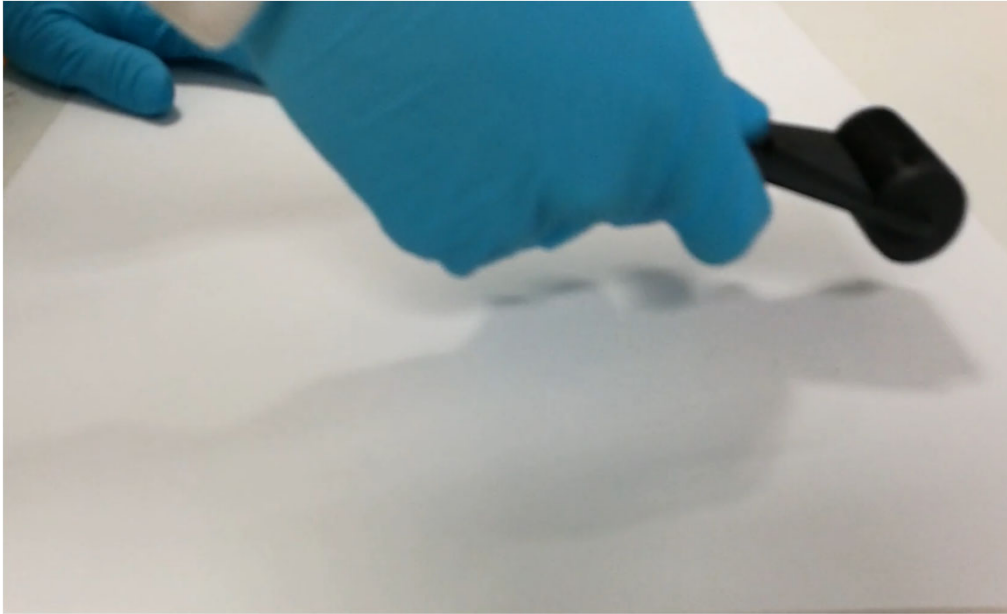
“Stamping”



Stamping



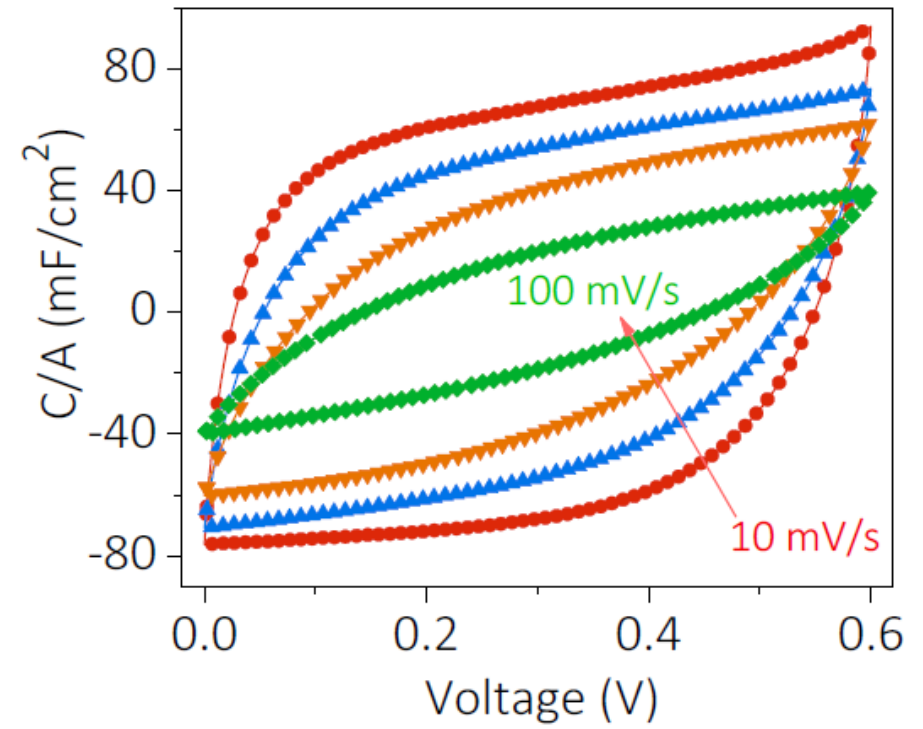
Stamped Micro-Supercapacitors



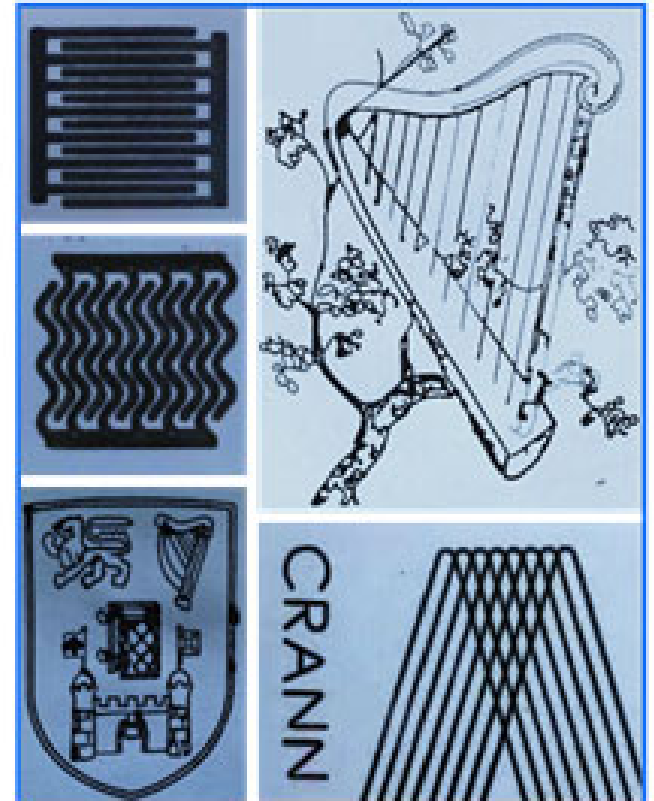
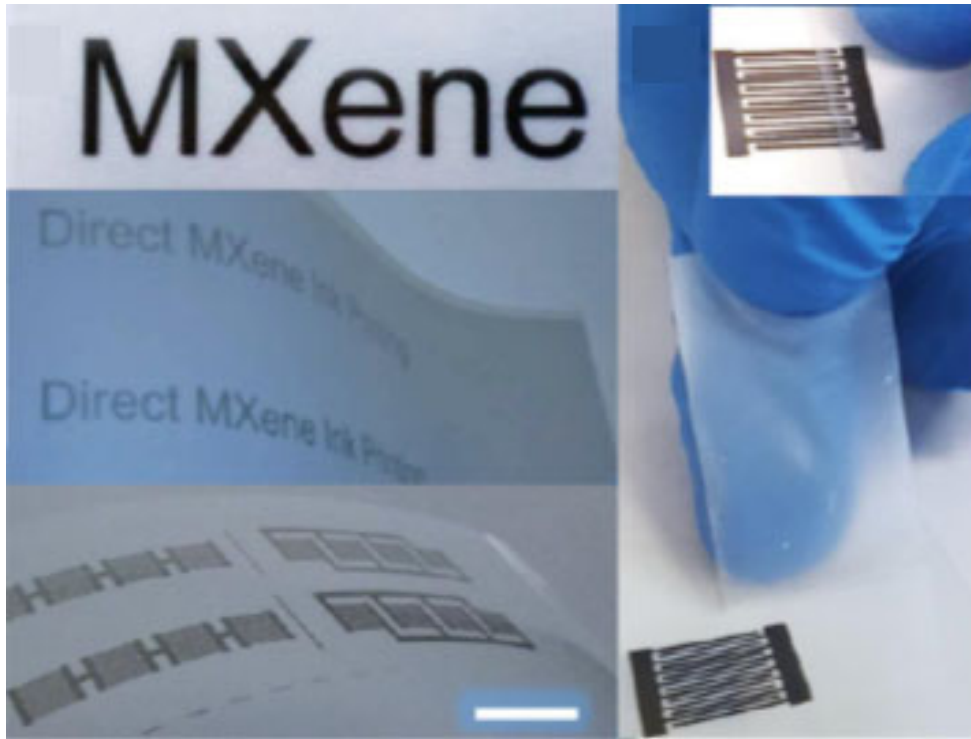
Old Babylonian cylinder seal, c.1800 BCE

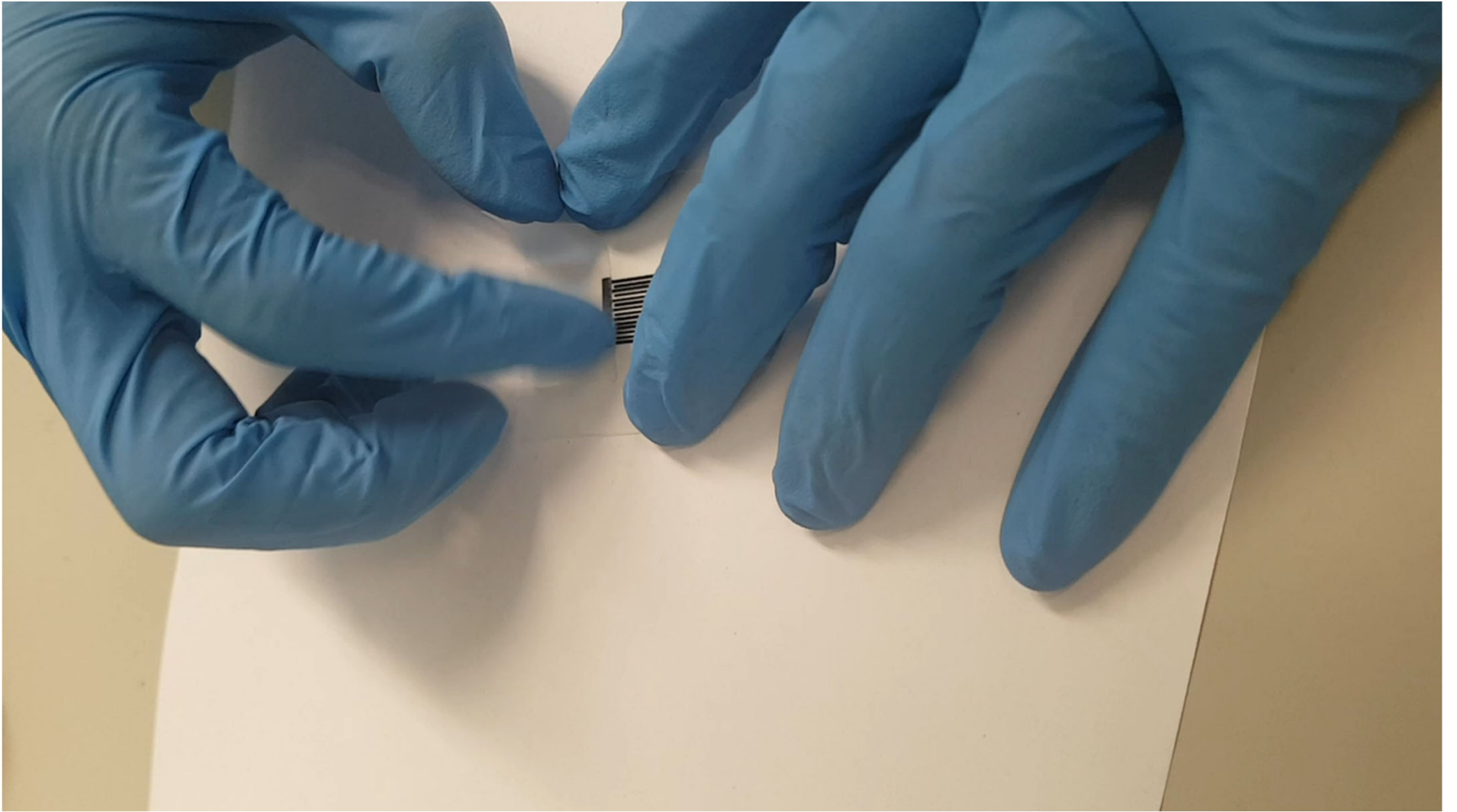


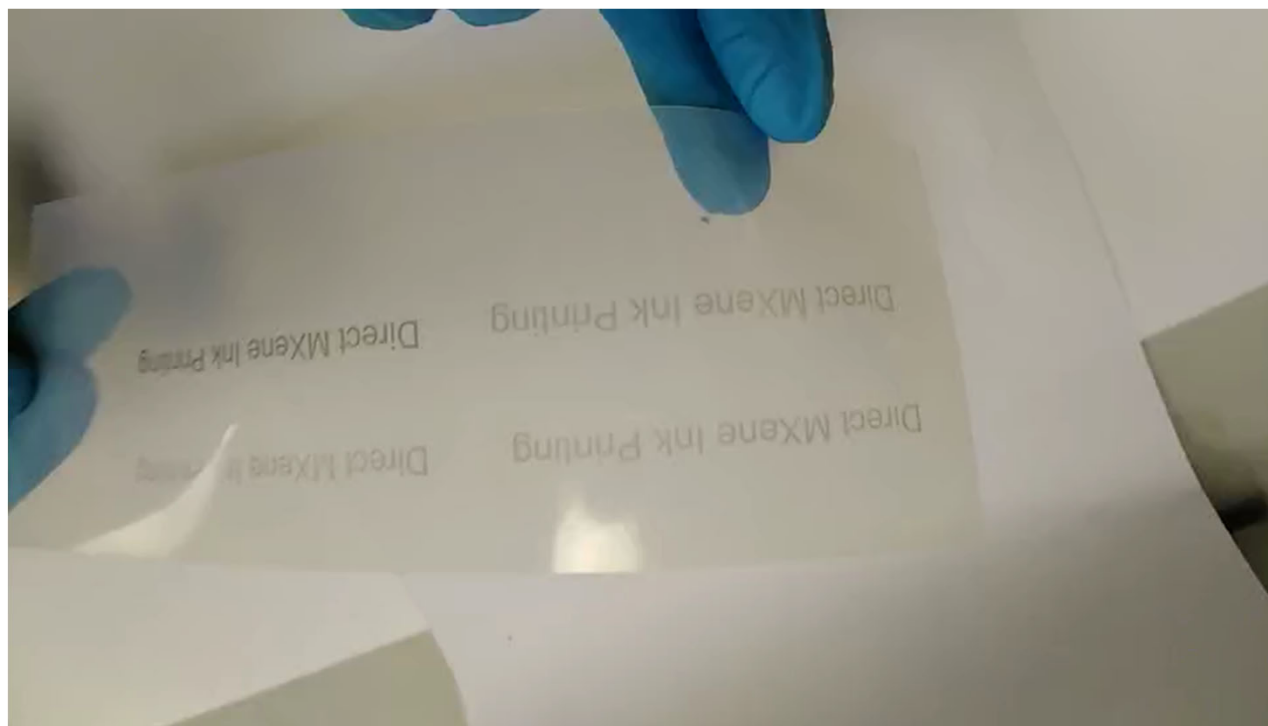
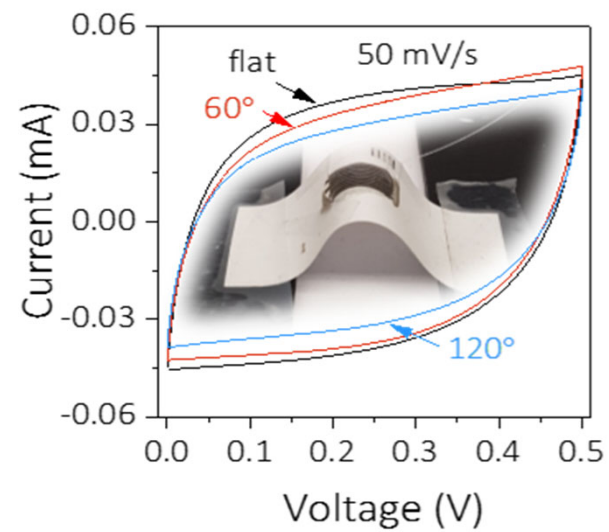
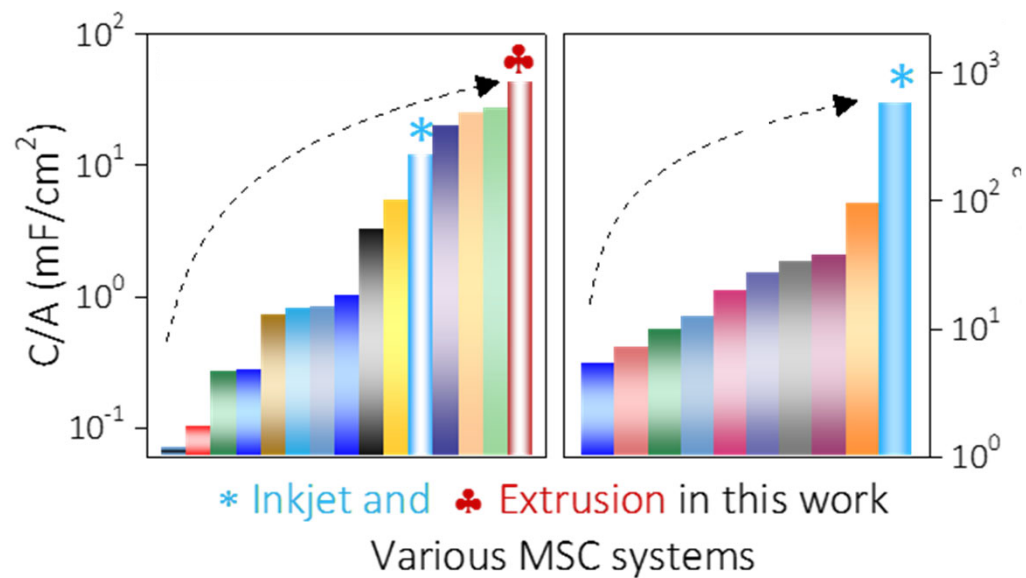
Stamped Micro-Supercapacitors



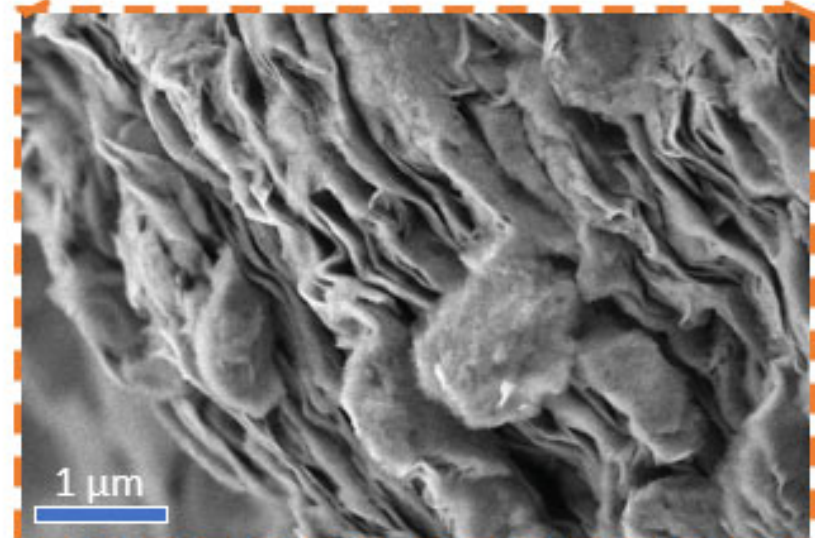
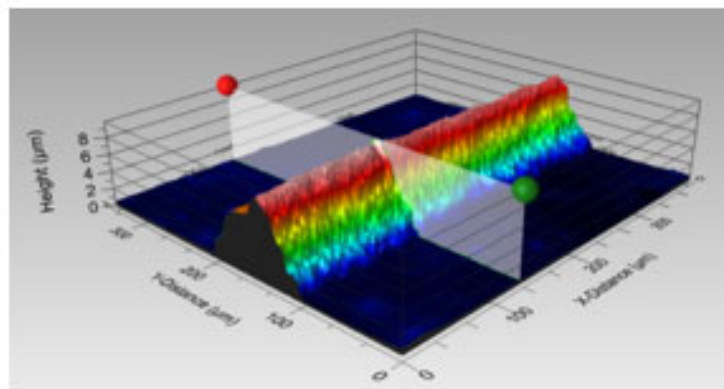
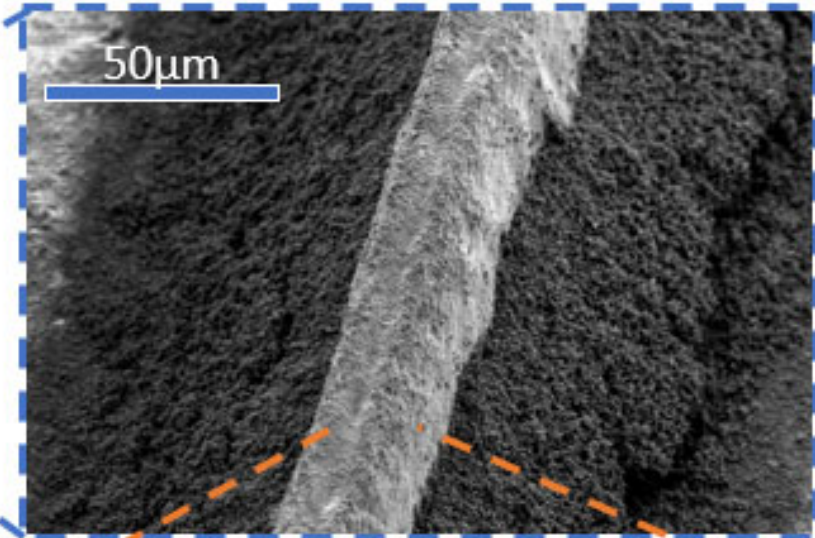
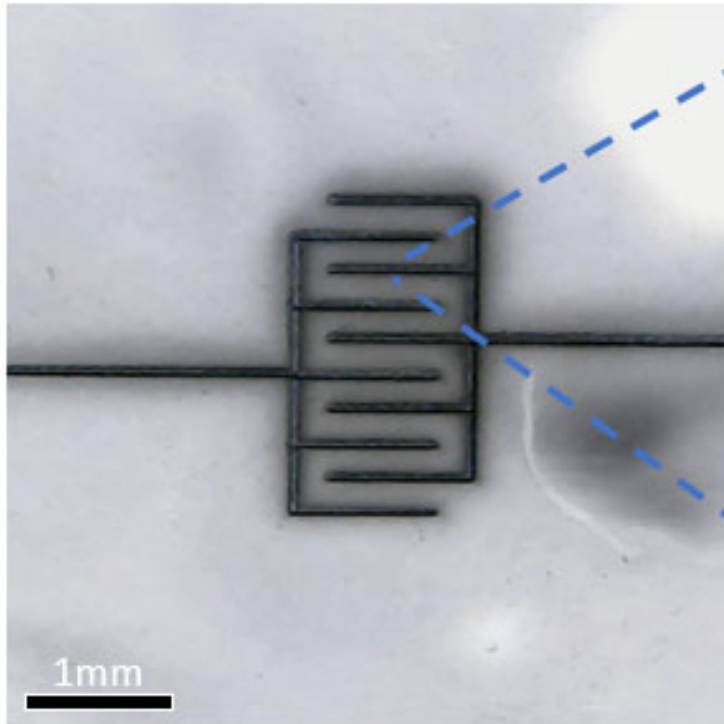
Ink-jet printed microsupercaps





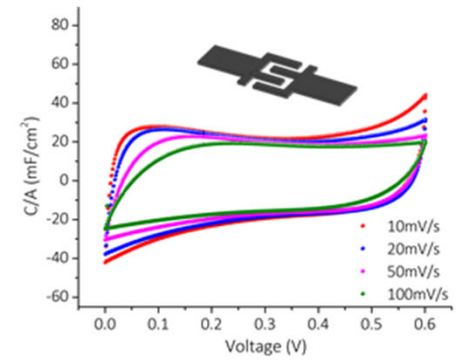
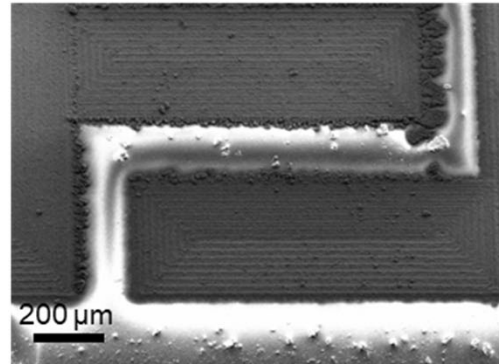
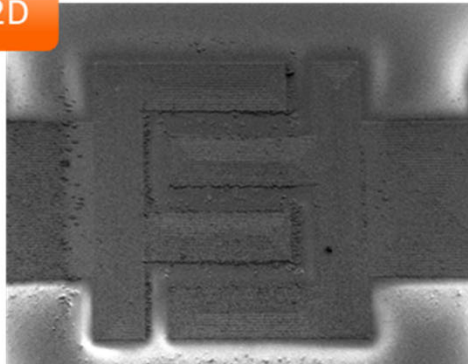


3D printing of supercaps

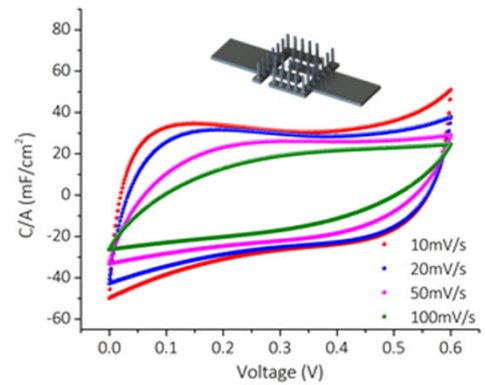
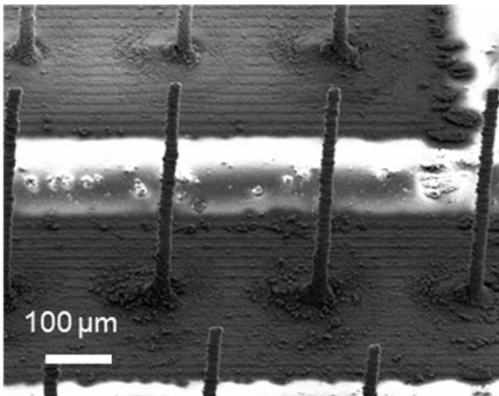
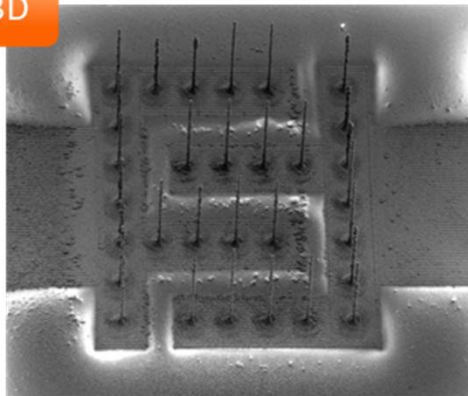


Going from 2D to 3D Supercapacitors

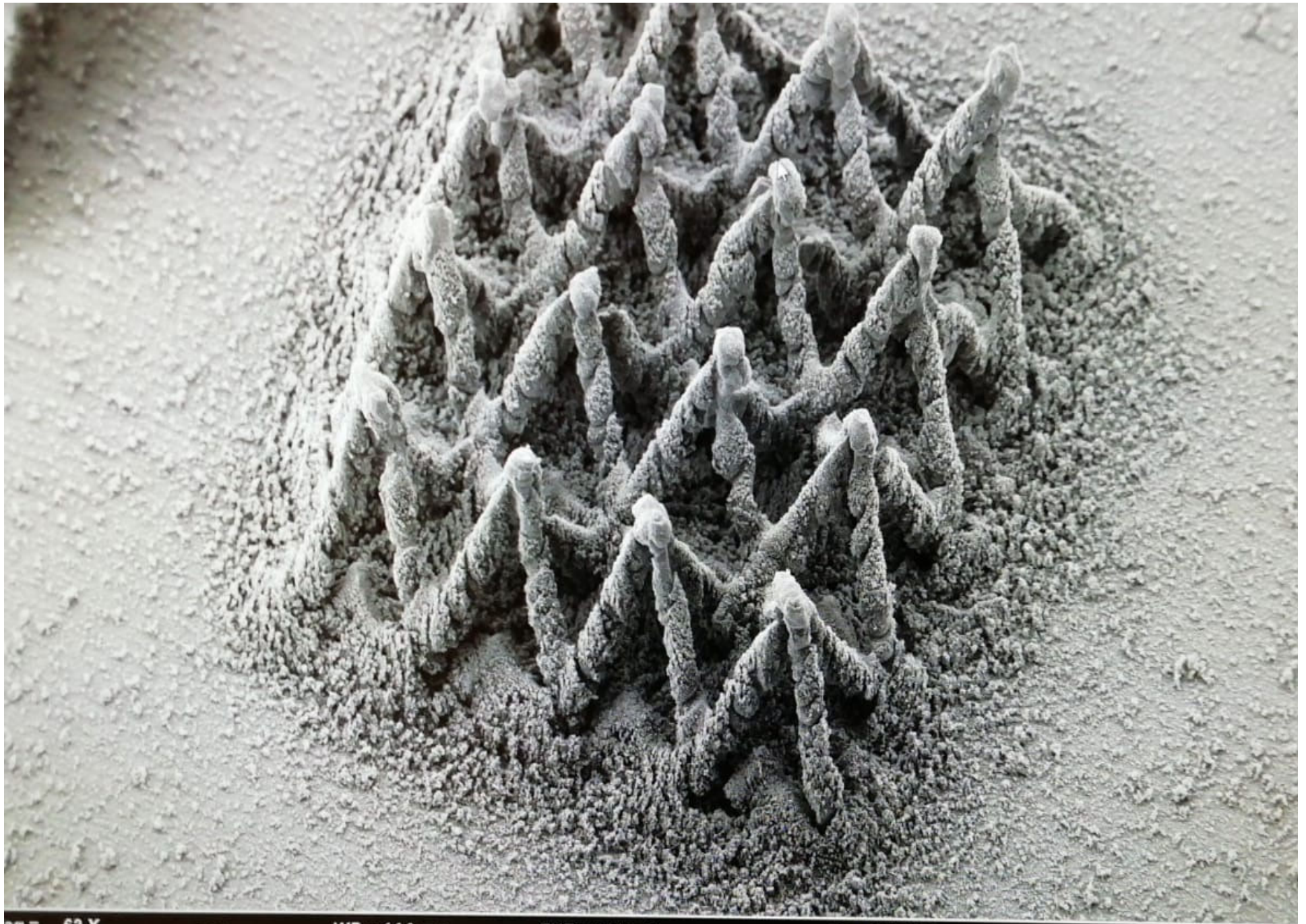
2D



3D



C/A +29%



Mag = 62 X

200 μ m

WD = 14.9 mm

EHT = 5.00 kV

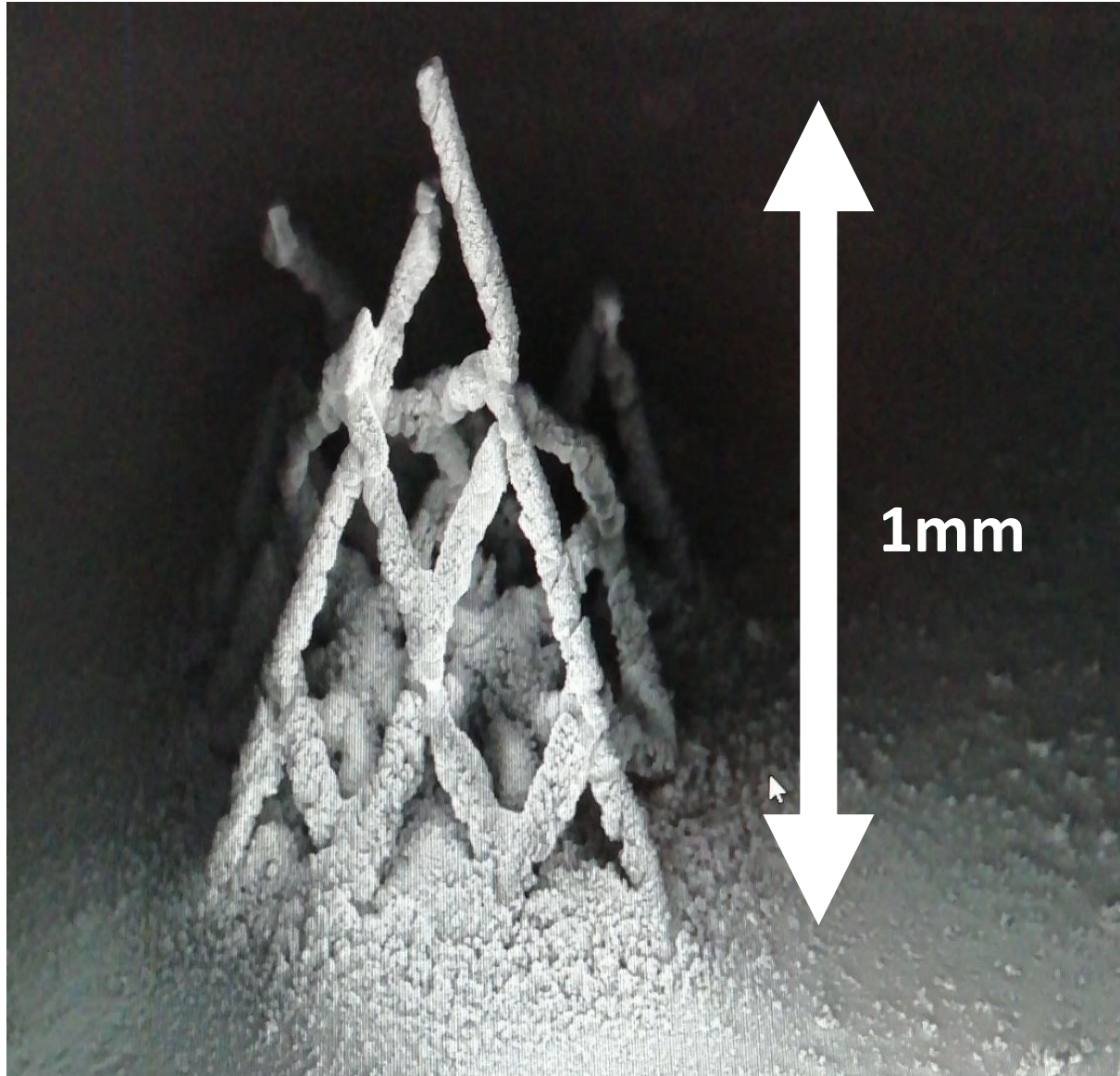
Signal A = SE2

Date :19 Nov 2019 Time :14:12

ULTRA PLUS-40-38

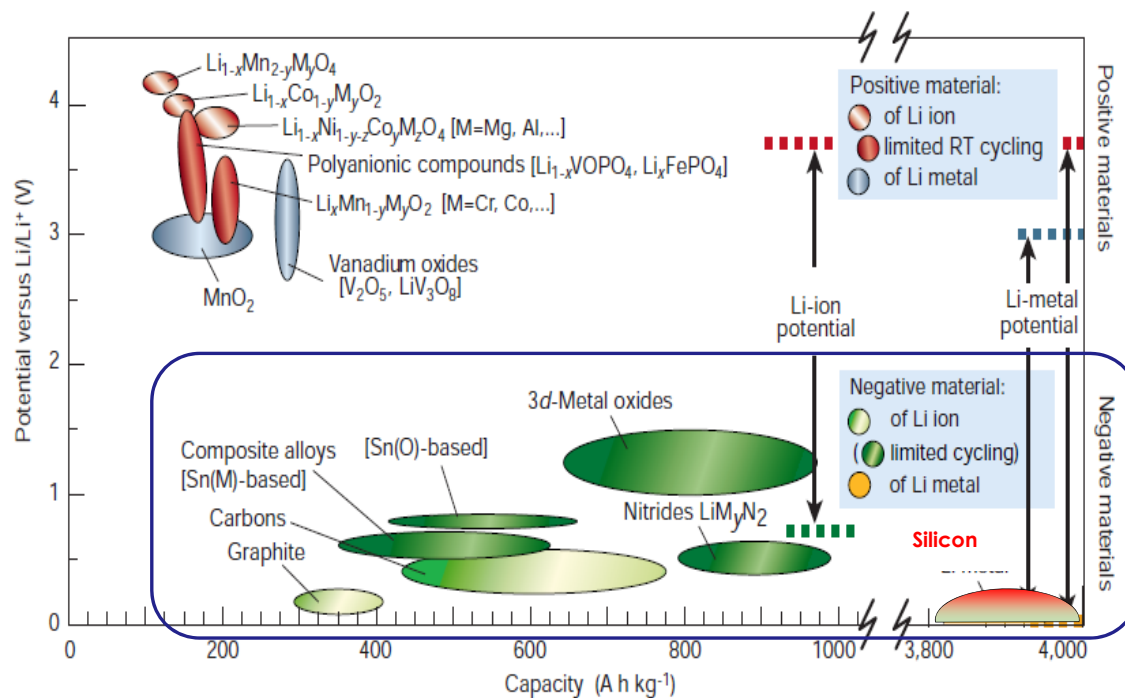
Noise Reduction = Line Avg

3D-Supercapacitors



What about batteries?

- Smaller - higher volumetric performance
- Longer lasting - better cycling performance



Electrode Materials for Li ion Batteries

Silicon anode material

- Highest theoretical capacity of $\sim 4200 \text{ mAh/g}$
 (Conventional graphite anode : 372 mAh/g)

- Abundant & cheap

How about Batteries?

Improve conductivity **AND mechanics** of electrodes

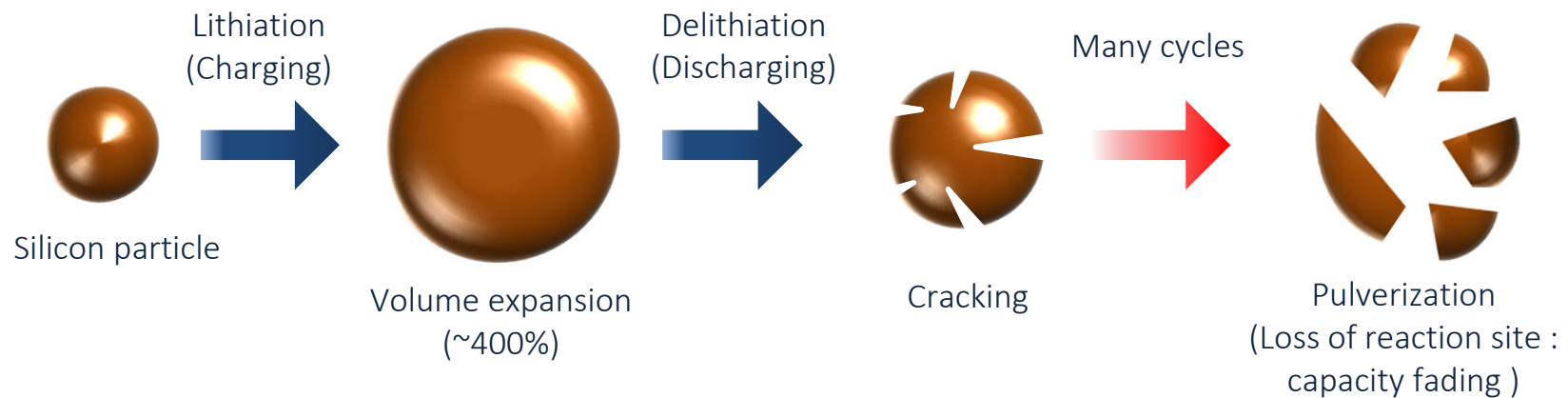
1. Conductivity -> charge delivery
2. **Mechanics -> stability....and....thickness**

The **critical crack thickness** depends on mechanics



Silicon anodes are projected to replace graphite anodes in Li-ion batteries with a huge impact on the amount of energy stored.

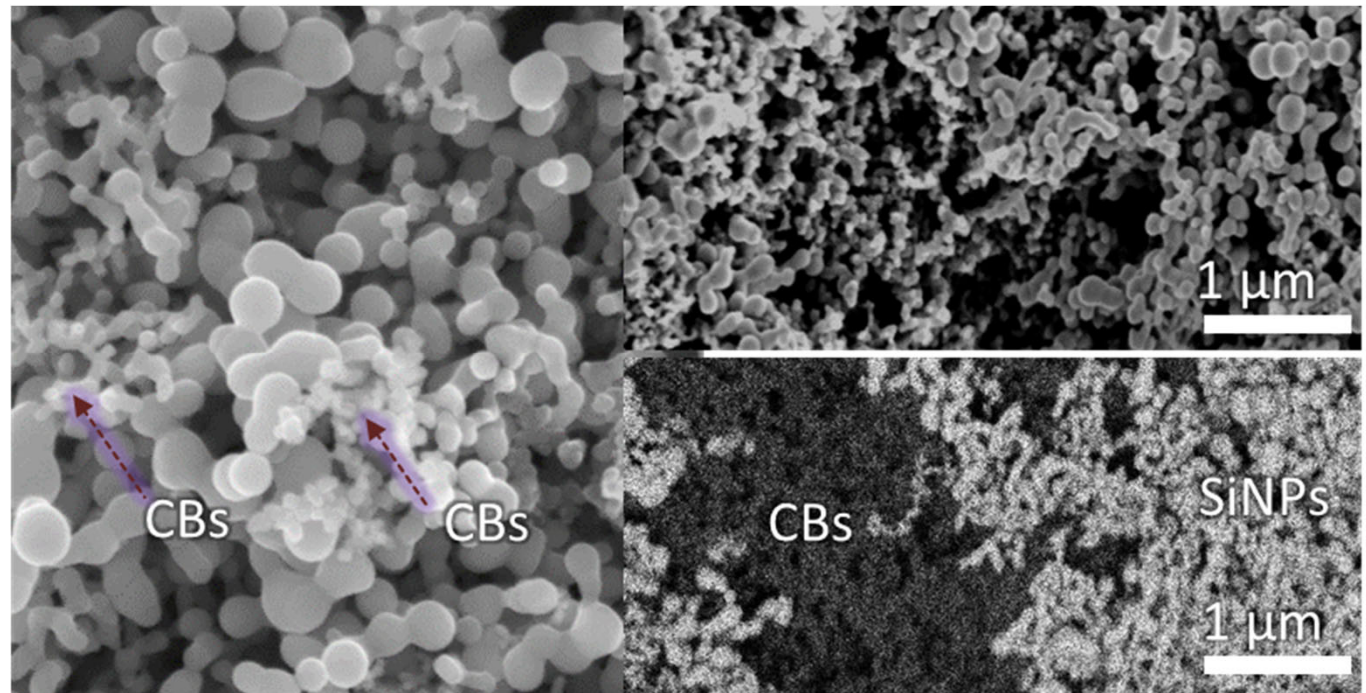
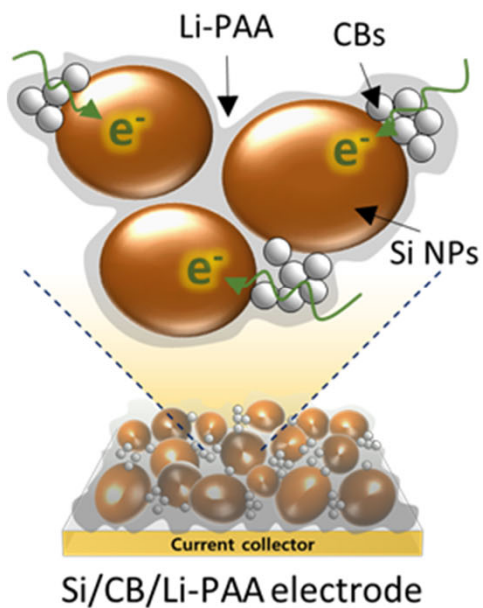
Silicon anodes can accept up to four lithium ions, while in graphite anodes take in just one lithium.

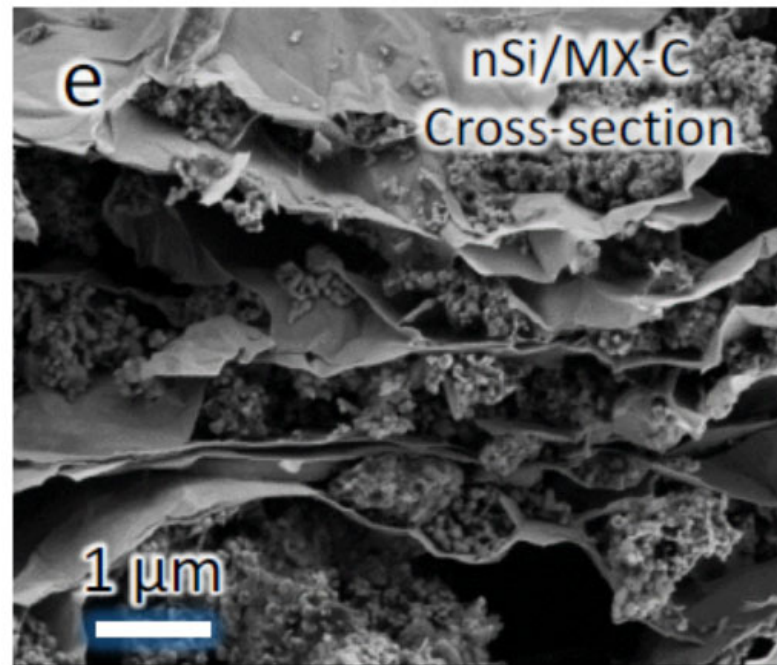
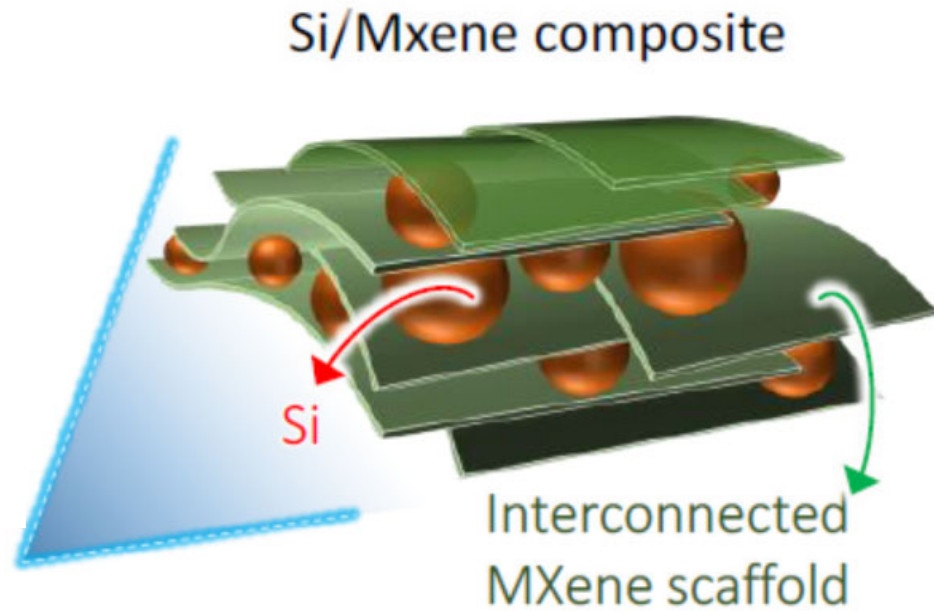
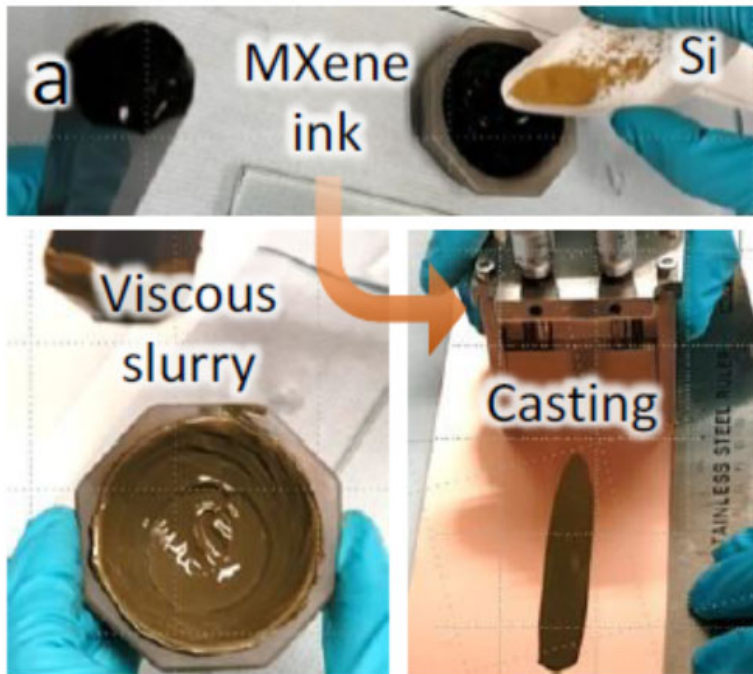


Improve conductivity **AND mechanics** of electrodes

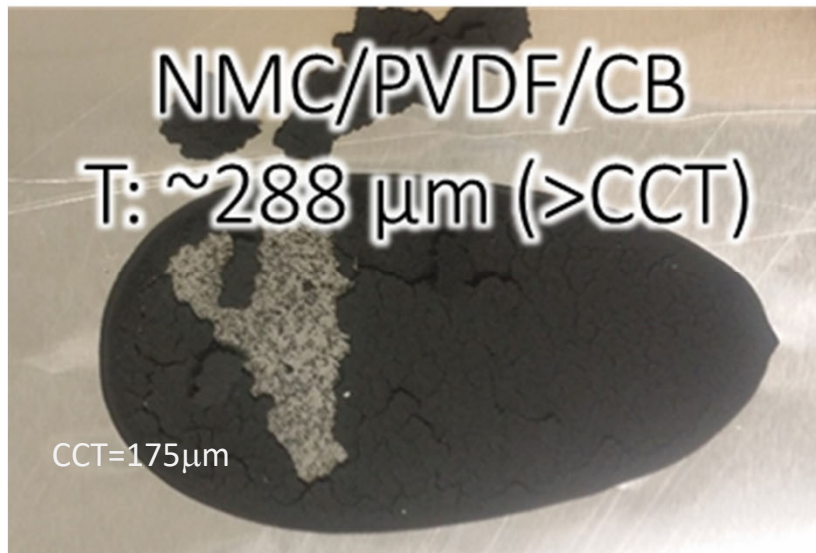
Conventional system (Tri-component electrode)

1. Si NPs : active material
2. Carbon black (CBs) : conductive agent
3. Polymeric binder (Li-PAA)

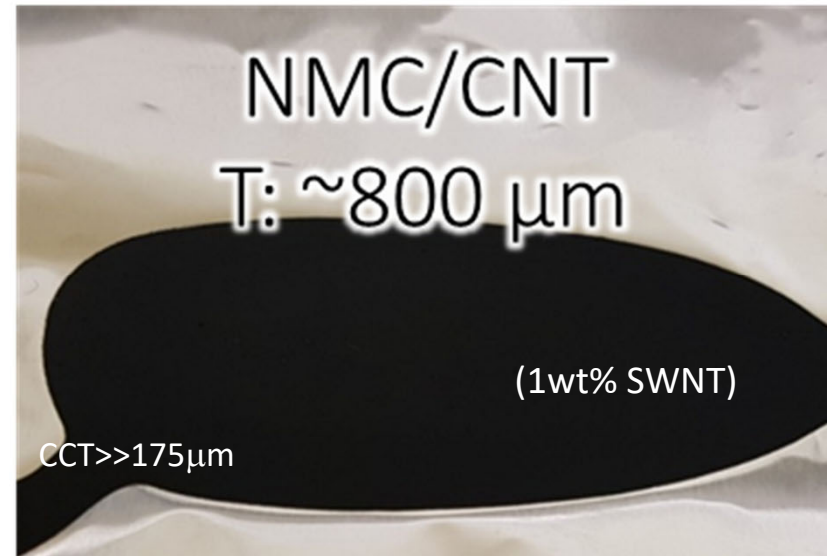




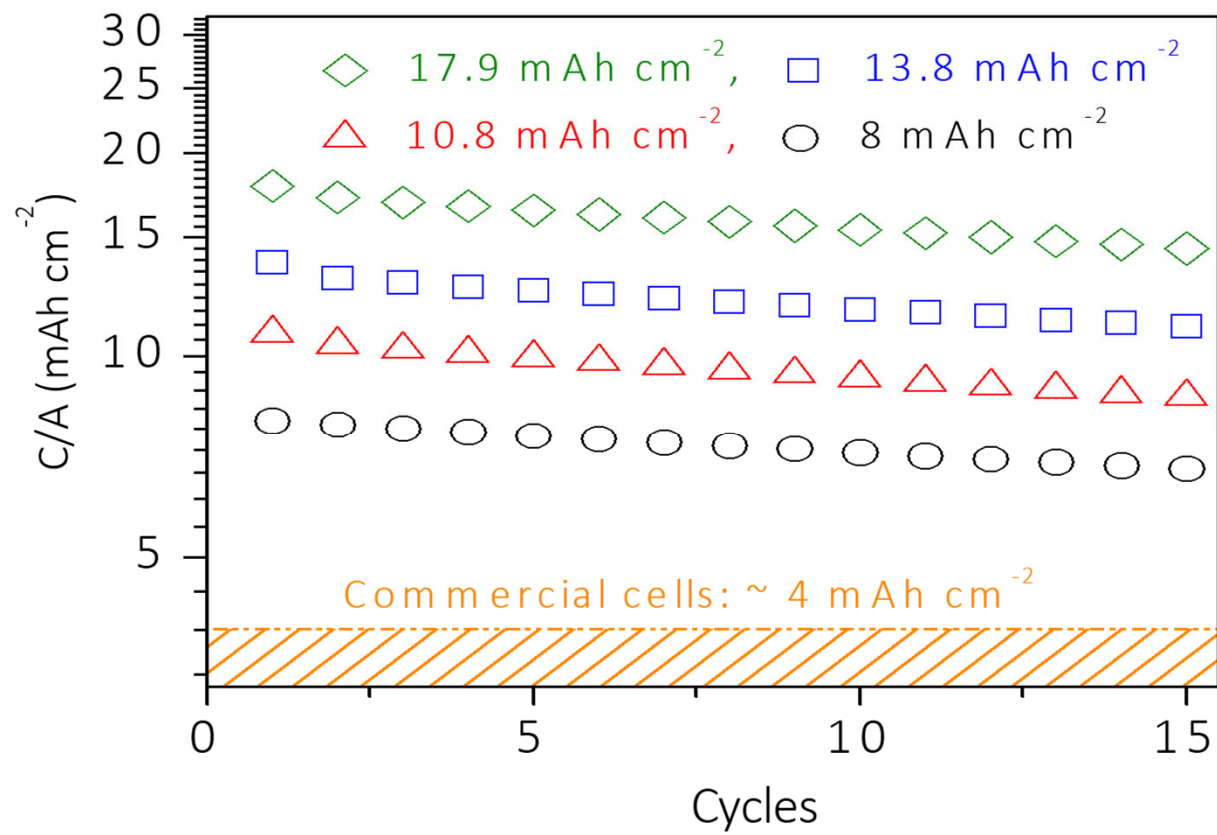
Mechanical enhancement allows thick electrodes



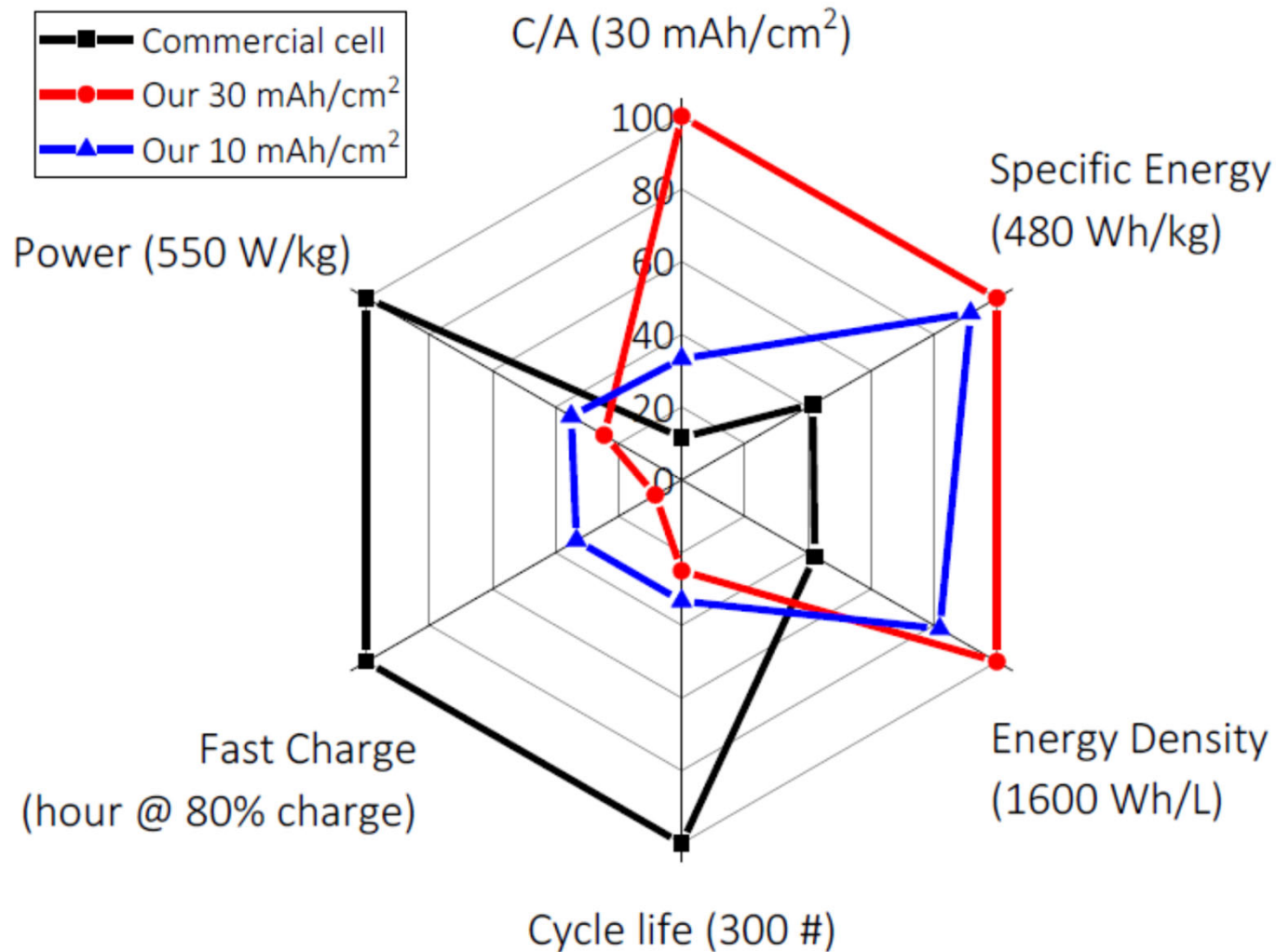
Nickel Manganese Cobalt oxide Cathodes



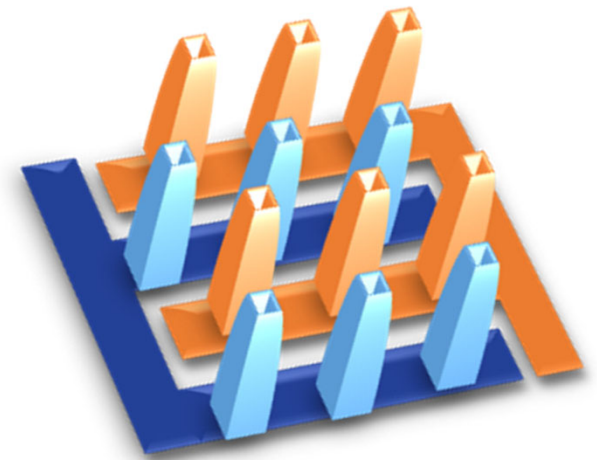
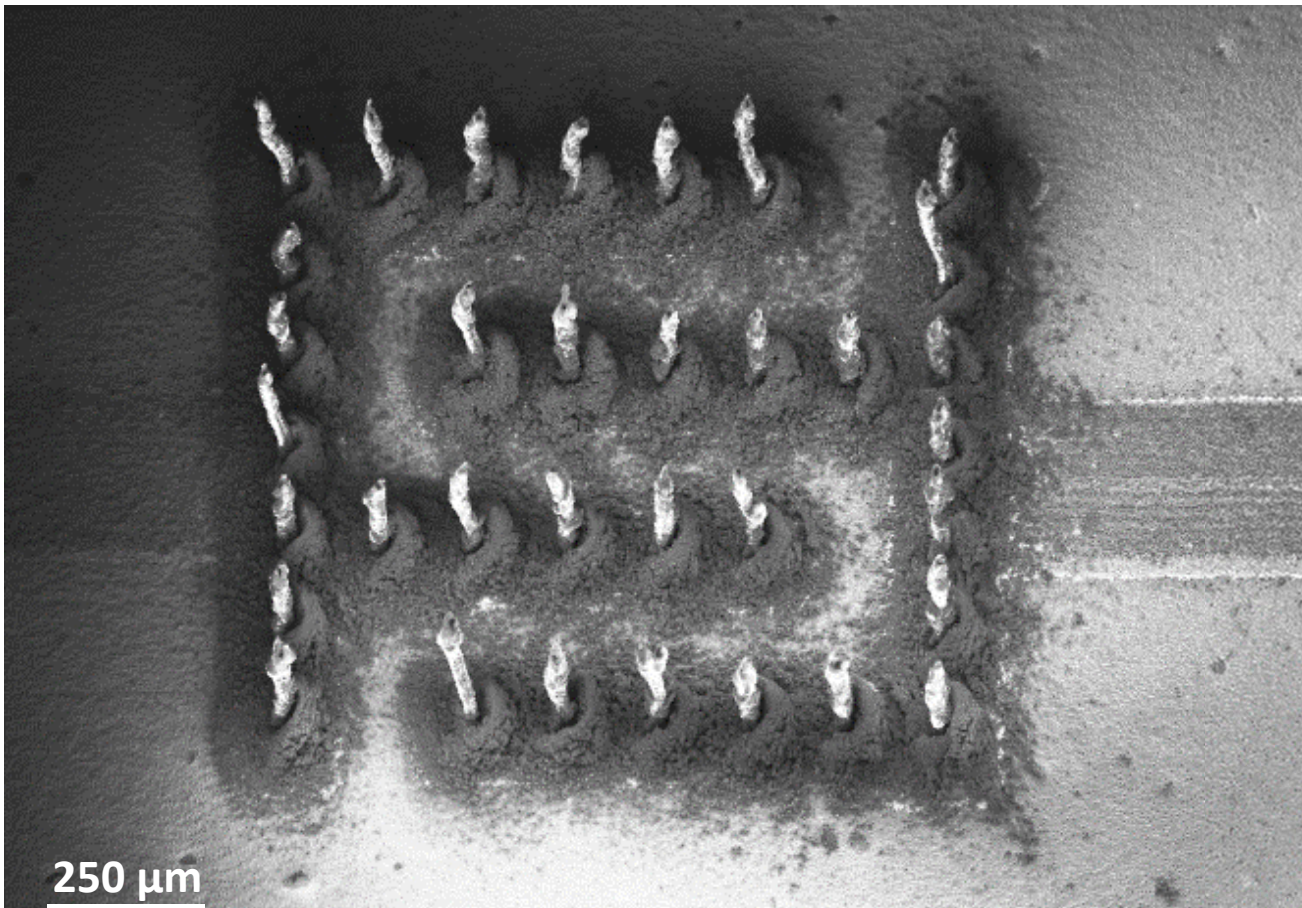
Record thickness



Where we are and what is coming next...

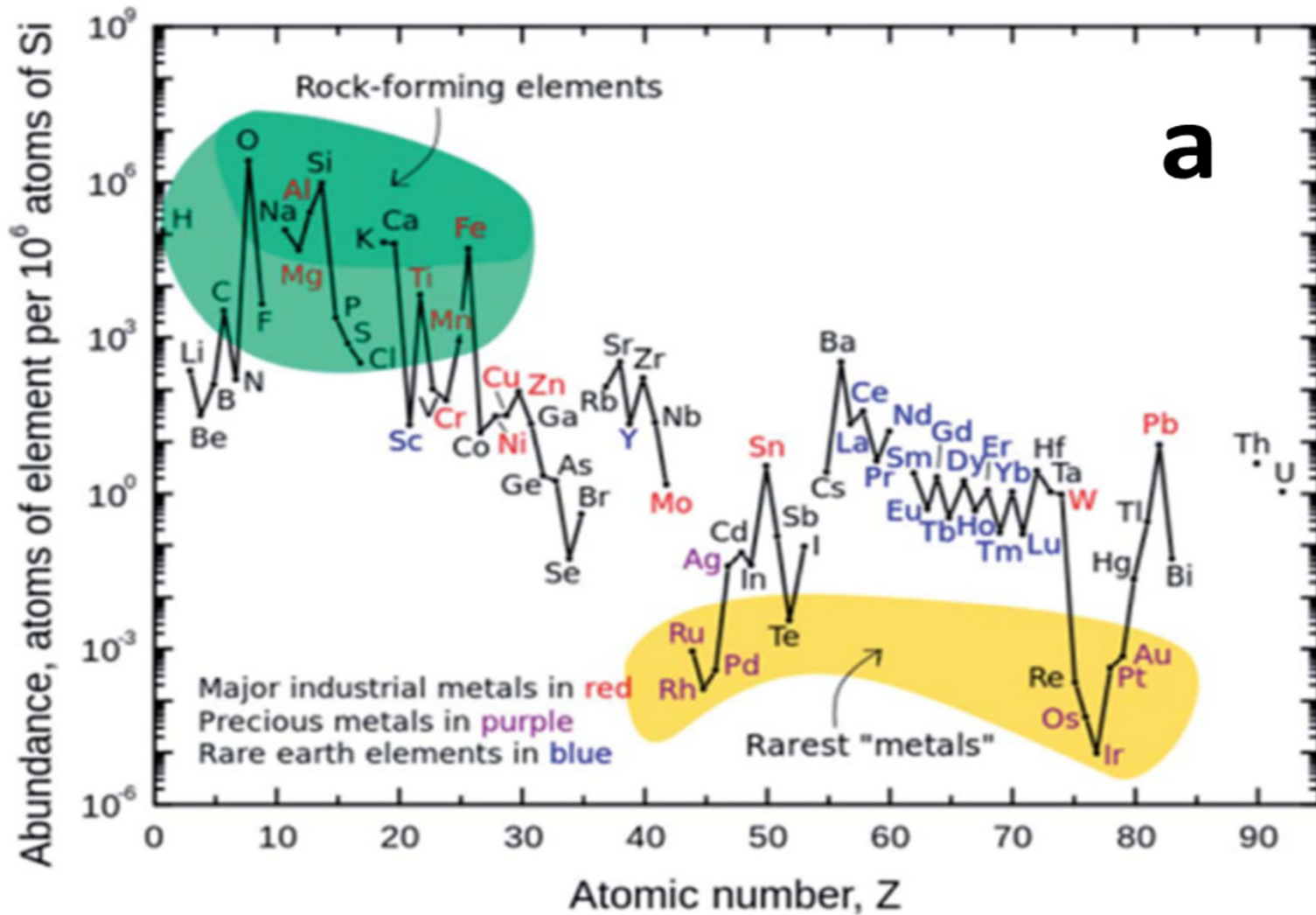


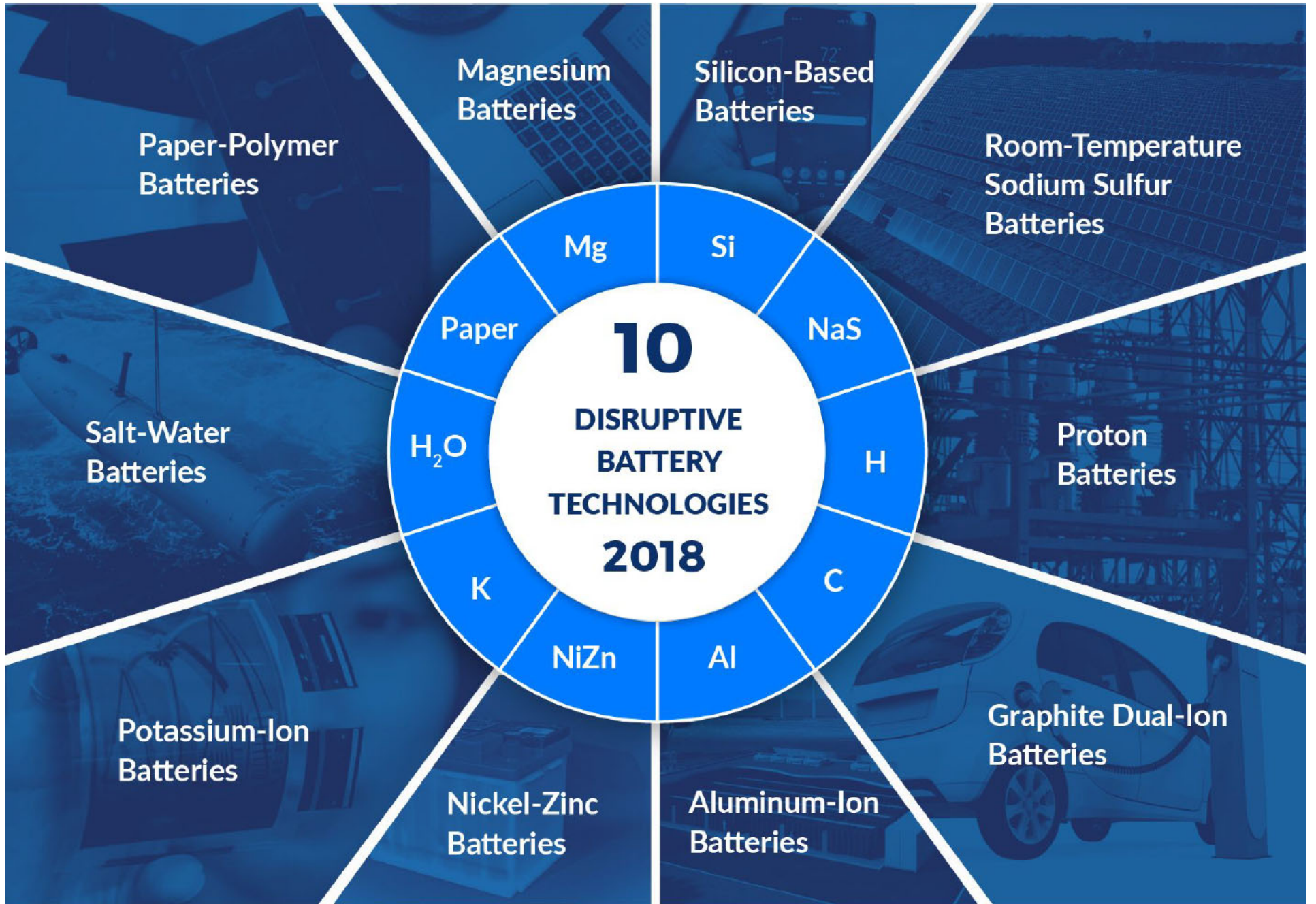
3D printing Batteries



Beyond Lithium ion batteries...

Abundance of elements in the earth's crust





Summary of Characteristics of Each Battery Technology

Battery Type	Phase	Cost	Performance	Capacity	Rechargeable	Applications
 Silicon-Based	Prototype	++	+++	+++	✓	Small electronics (e.g. smartphones, smartwatches), automotive
 Room-Temperature Sodium Sulfur	Research	++	++	+	✓	Large-scale (like renewable energy grid storage), utility-scale load leveling
Proton	Research	+	++	+	✓	Automotive, infrastructure grid scale storage
Graphite Dual-Ion	Research	+	++	+	✓	Industrial, portable electronics, cars, grid-level applications
Aluminum-Ion	Research	+	+++	+++	✓	Grid-scale storage
 Nickel-Zinc	Prototype	+	++	+++	✓	Automotive, renewables, electronics, telecom, marine
 Potassium-Ion	Prototype	+	+++	+	✓	Flexible and bendable devices, grid-scale energy storage
Salt-Water	Prototype	++	+	++	✓	Utility-scale use, underwater autonomous vehicles, stationary energy storage systems
Paper-Polymer	Prototype	+	+	+	✗	Biosensors
 Magnesium						
Mg-Metal	Prototype	++	+++	+	✓	Electronics, EVs, Grid-scale storage, etc.
Solid-State Mg	Research	+++	+++	+	✗	

+++ HIGH ++ MEDIUM + LOW

