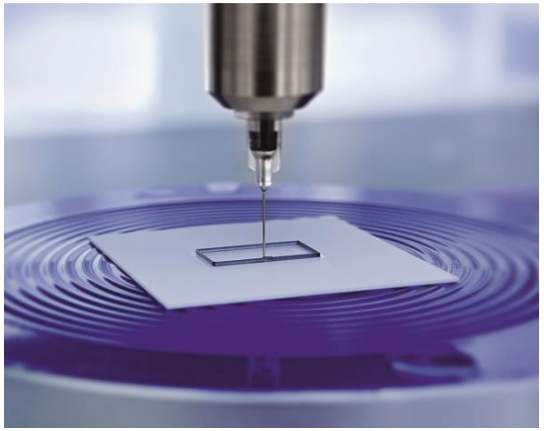
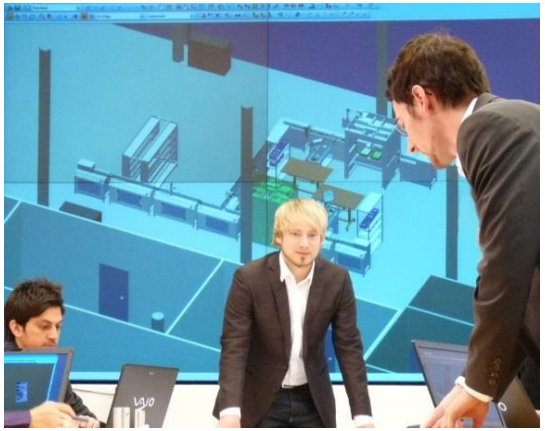
FRAUNHOFER IPA

INSTITUTE FOR MANUFACTURING ENGINEERING AND AUTOMATION

In cooperation with the University Institutes ISW and IFF





We produce future

Innovative. Interdisciplinary. Sustainable.

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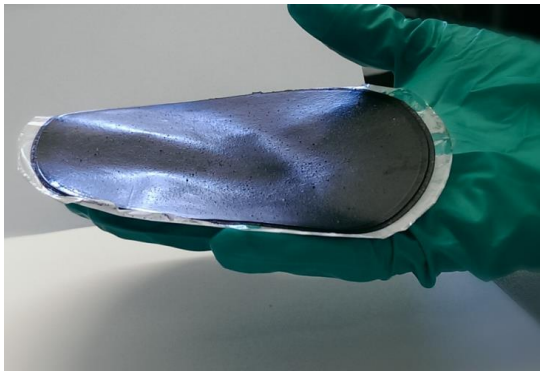
Nanocarbons in Supercapacitor Electrodes

An approach to foster nanotechnology in electric power trains

Raphael Neuhaus[1]
Researcher
Dipl.-Ing. aerospace engineering
Dpt. of functional materials

1) Fraunhofer IPA, Stuttgart, Germany
2) HRI AIST, Ikeda, Osaka, Japan

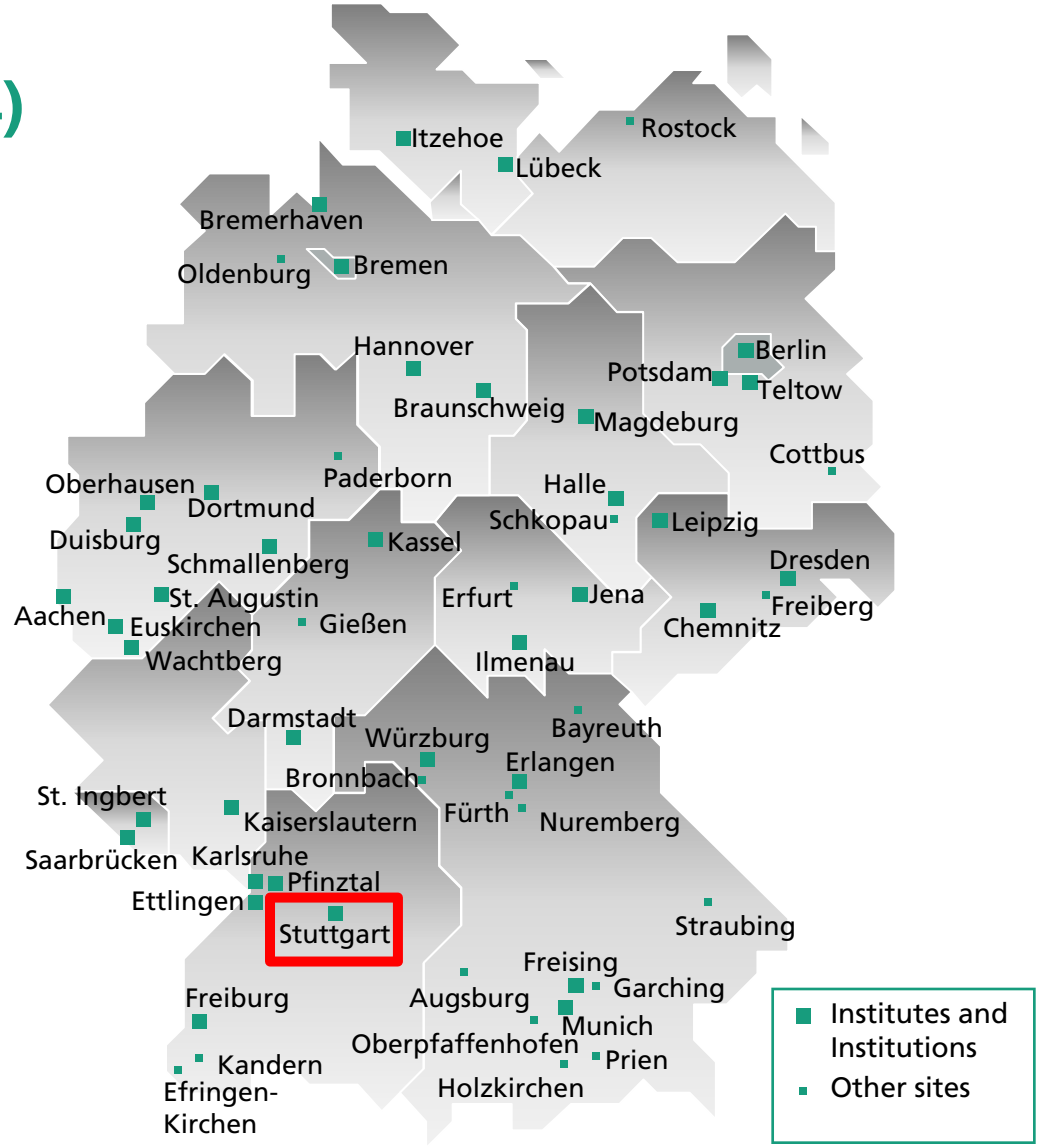


Co-authors: Carsten Glanz[1], Takushi Sugino[2], Ivica Kolaric[1], Kinji Asaka[2]

Fraunhofer Society -
Facts and Figures (2014)

- More than 24 000 employees
- € 2.0 billion budget
- 67 institutes

Largest Applied Research Organization in Europe!



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Fraunhofer IPA
Facts and Figures (2014)

Operational Budget (excluding investments):	51 Mio. €
Projects with industry:	22,2 Mio. €

Staff

researchers:	350
administration and specialists:	70
scientific assistants:	300

Partner Institutes at the University of Stuttgart

IFF, Institute of Industrial Manufacturing and Management:	50
ISW, Institute for Control Engineering of Machine Tools and Manufacturing Units:	50
GSaME, Graduate School for advanced Manufacturing Engineering:	50

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„Functional Materials“ at Fraunhofer IPA: Service Range

材料 MATERIAL	プロセス PROCESS	応用 APPLICATION	生産 PRODUCTION	サービス SERVICE
- グラフェン - 高性能SWNT - 高性能MWNT - アークジェット - アーク放電 - レーザー アブレーション - CVD	- ナノ複合材料の シミュレーション - 精製 - 機能化 - ナノコーティング - 分散 - 製粉	- ディップ コーティング - スクリーン印刷 - 焼結 - 押し出し - 無電解めっき - バー・コーティング	- 新しい合成・分散 技術の構想・開発 - 分散プロセスや 分散機器の開発 - 工程品質の検証	- 被害分析および 現場でのコンサル - 機能的なナノ材料 実現のための 戦略コンサル - 生産開発における 構想・コンサル
- Graphene - High-quality SWNT - High-quality MWNT - Arcjet - Arc-discharge - Laser ablation - CVD	- Simulation of nano compounds - Purification - Functionalisation - Nano coatings - Dispersing - Milling	- Dip coating - Screen printing - Sintering - Extrusion - Electroless plating - Bar coating	- Conception and development of new synthesis- and dispersion technologies - Development of dispersion processes and machines - Verification of process quality for customers	- Failure analysis & site consultancy - Strategy consultancy for successful implementation of functional nano materials - Concept development and consultancy in the field of production development

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Cooperation Partners

Fraunhofer Institute for Manufacturing Engineering and Automation (IPA)

Department Functional Materials

AIST Kansai National Institute of Advanced Industrial Science and Technology (AIST)

Research Institute for Cell Engineering

Fraunhofer IPA

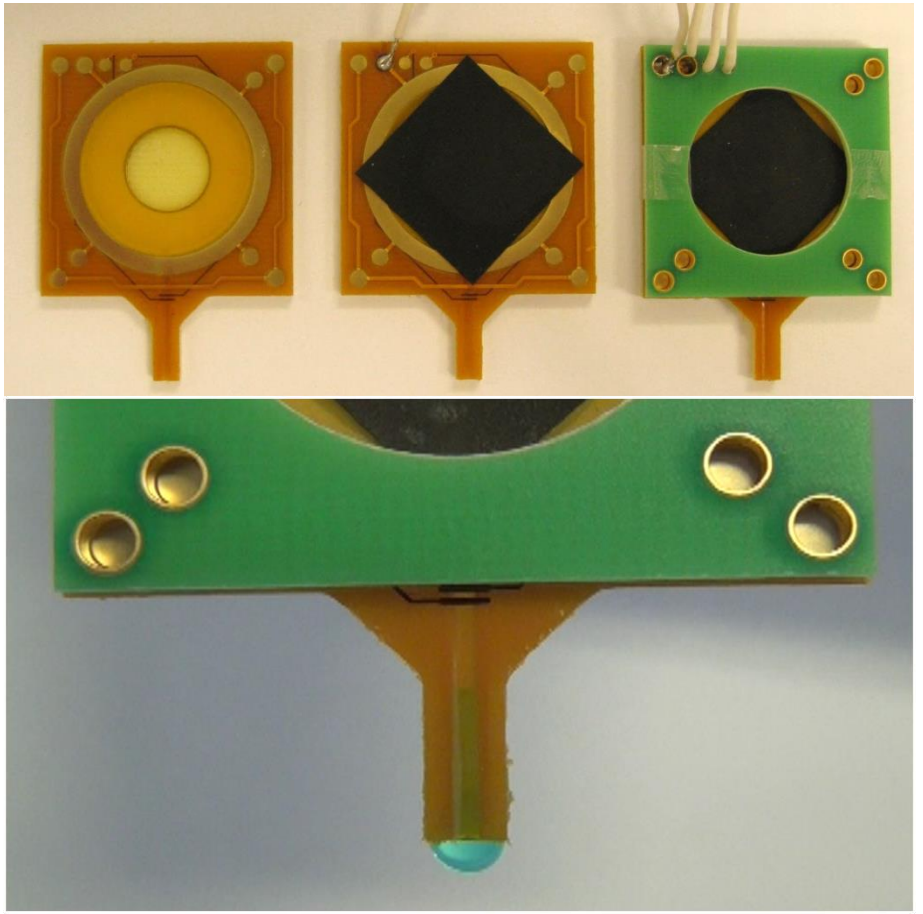
Picture source: http://cio-perspectives.com

AIST

Yesterday

German-Japanese Cooperation – First Joint Development 2012 – Pipette with CNT actuator

- Simulation of actuation and geometry
- Material development and processing
- Electrical contacting and system integration
- Construction and engineering of Pipette based on PCB board
- Showed at Nanotech 2013



The 12th International Nanotechnology Exhibition & Conference
nano tech 2013

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Bundesministerium für Bildung und Forschung

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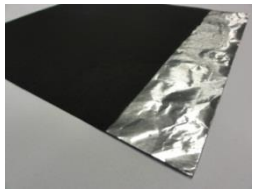
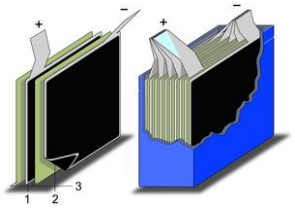
Today
SkiPper – a joint research project

- Three-year research and development cooperation in the field of functional materials and energy related applications.
- Development of nanocarbon based materials for energy storage devices
- Consideration of:
  - Development of electrodes for supercapacitor modules
  - Multifunctionality of materials and devices

Nanocarbons



High-performance electrodes



Supercapacitor cells

Supercapacitor modules

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Tomorrow

Fraunhofer Project Center (FPC) for EAP Applications at AIST KANSAI in Ikeda, Japan

- 3 years of continuing cooperation starting in Summer 2014
- Ca. 900 000 Euro financial contribution from BMBF
- Mutual exchange of scientific personnel (2 – 3 months)
- Focus on EAP technology (Electro Active Polymers)

- The worlds #2 in applied science (FHG) joins forces with #3 (AIST)

Artificial muscle ©SRI EPAM

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What is our goal ?

Use **supercaps** as

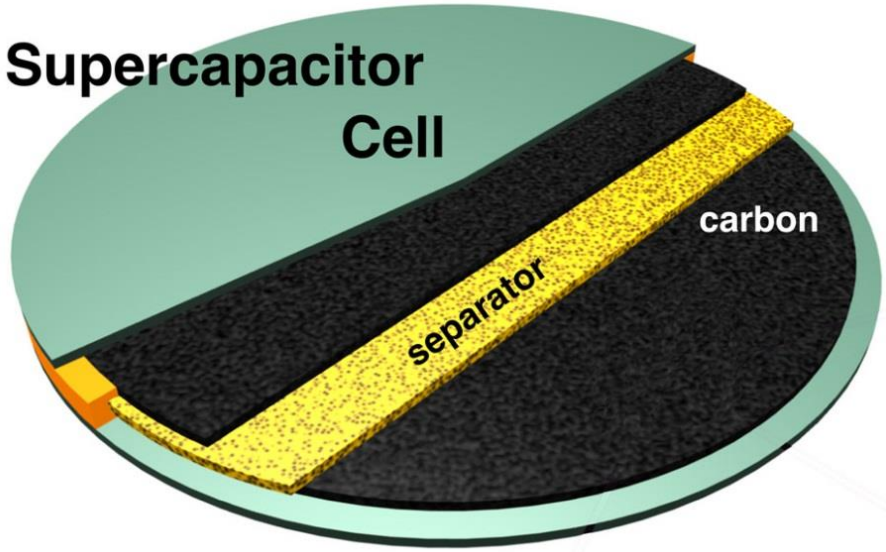
- fast,
- high power-density,
- temperature independent,
- temporary

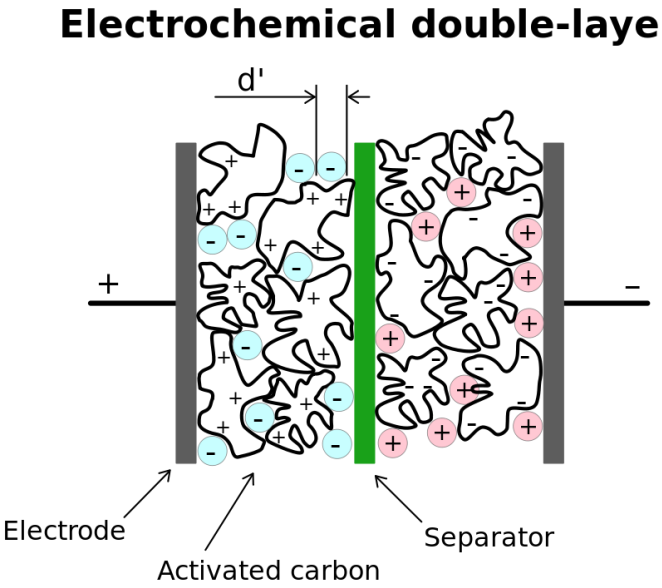
Energy storage system for automotive applications

What is a Supercap?

Fraunhofer
IPA

Supercapacitor cell
Working principle





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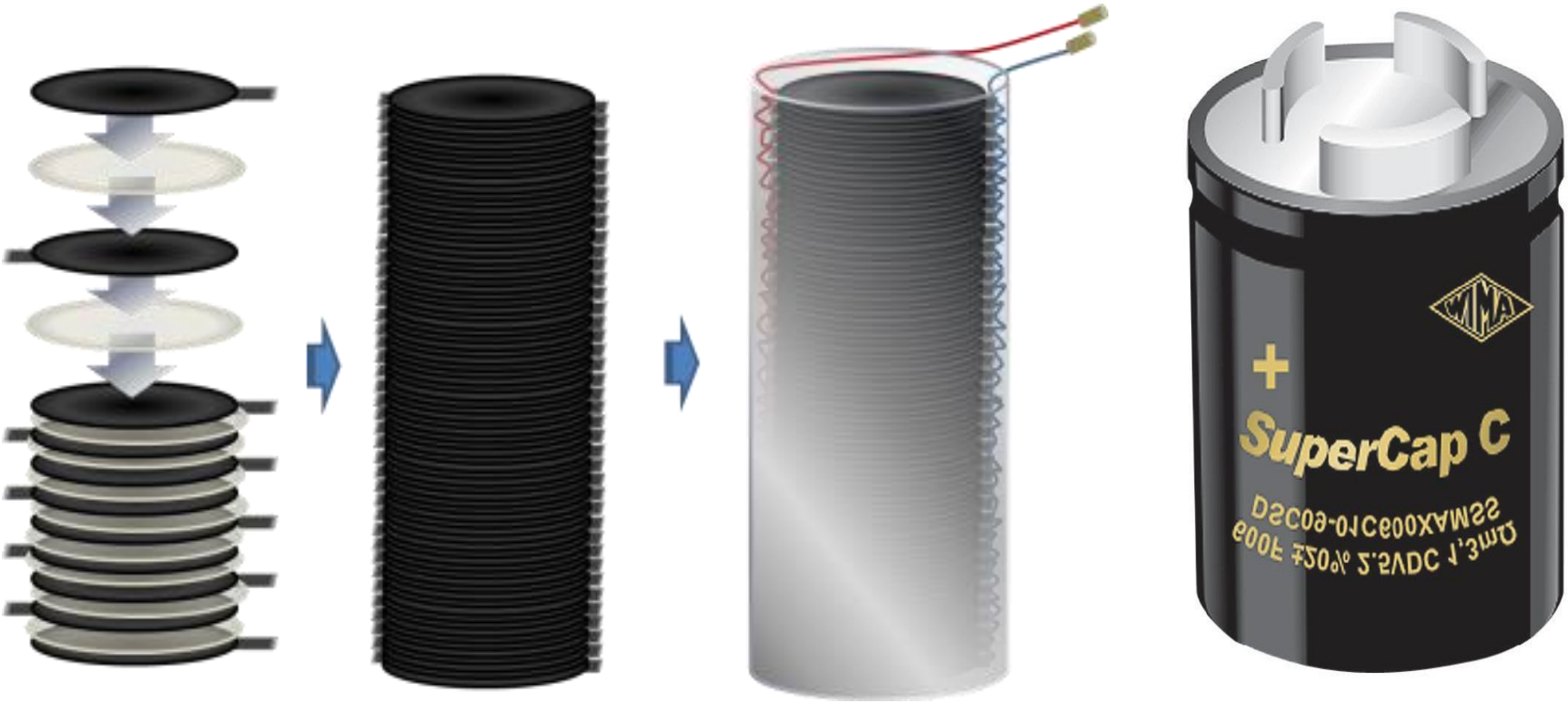
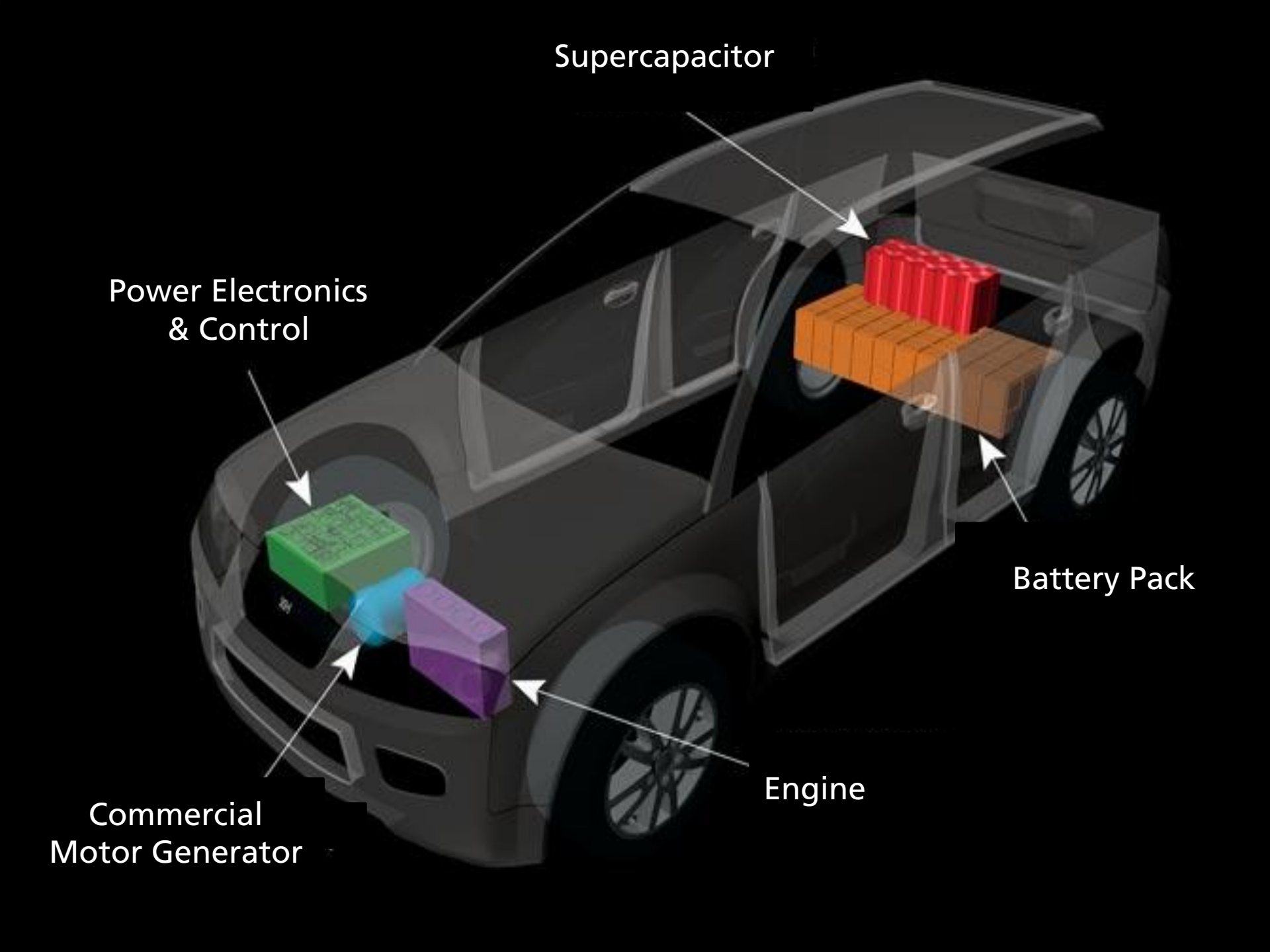
Supercapacitor

Stacking of electrodes to form cells



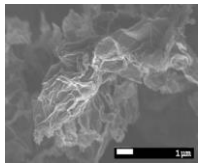

Supercapacitor
Power Electronics & Control
Battery Pack
Engine
Commercial Motor Generator

How do we make it better ?

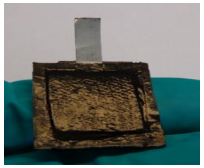
Scope

Make better and lighter electrodes

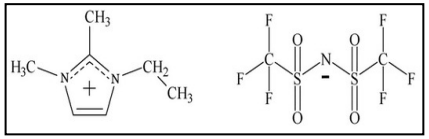
Graphene



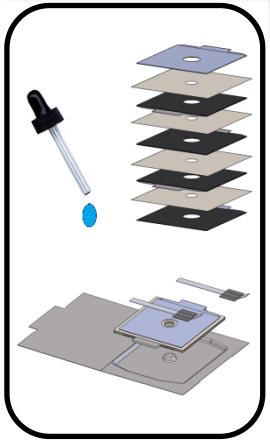
Electrodes



Electrolyte



Supercapacitor



Application

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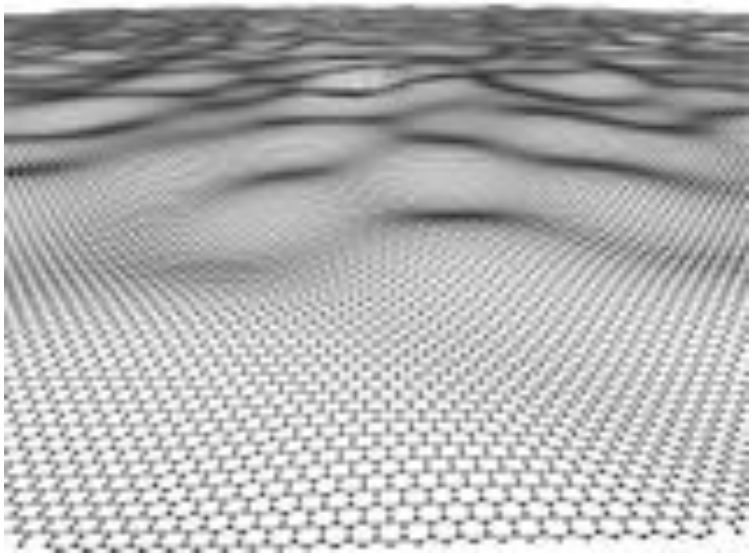
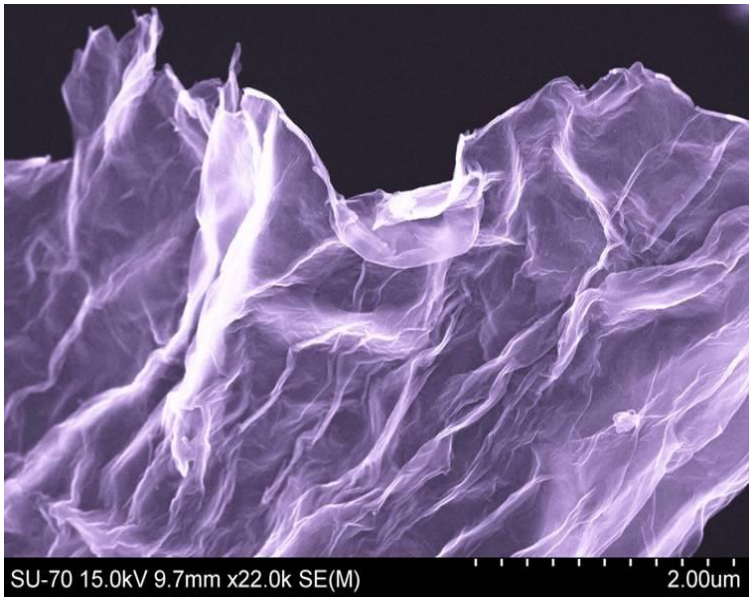
Graphene

- First “discovered” in the form of isolated thin sheets in 2004.
- One-atom-thick planar sheet of sp2-bonded carbon atoms that are densely packed in a honeycomb crystal lattice.



Mechanical and material properties

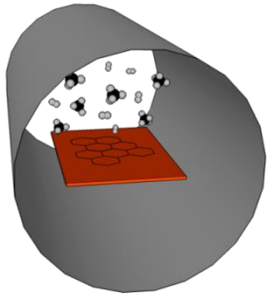
- As of 2009, graphene appeared the strongest material ever tested.
- Young’s modulus ~ 1,100 GPa
- Fracture strength 125 GPa
- Specific surface area 2,630 m^2/g



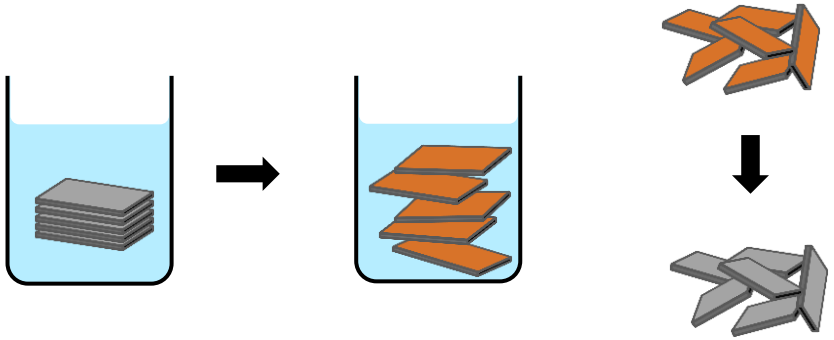
Graphene Synthesis at Fraunhofer IPA

3 different routes

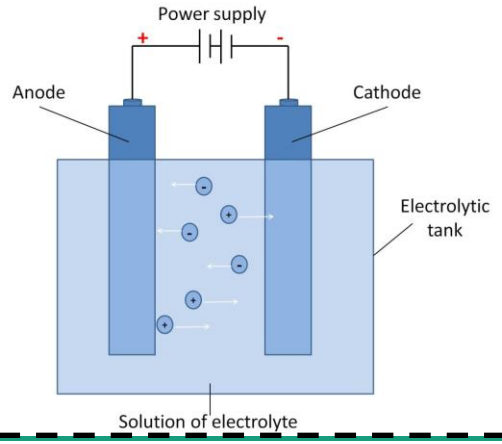
- Chemical Vapour Deposition (CVD)



- Reduction of Graphene Oxide



- Electrochemical exfoliation of graphite



GNP production at Fraunhofer IPA

Simplyfied electrochemical exfoliation setup

Electrode fabrication

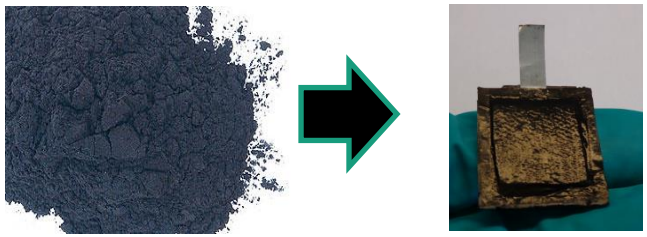
Challenges faced

1. Adhesion

2. Conductivity

3. Porosity

GNP to electrodes



4. Geometrical constraints

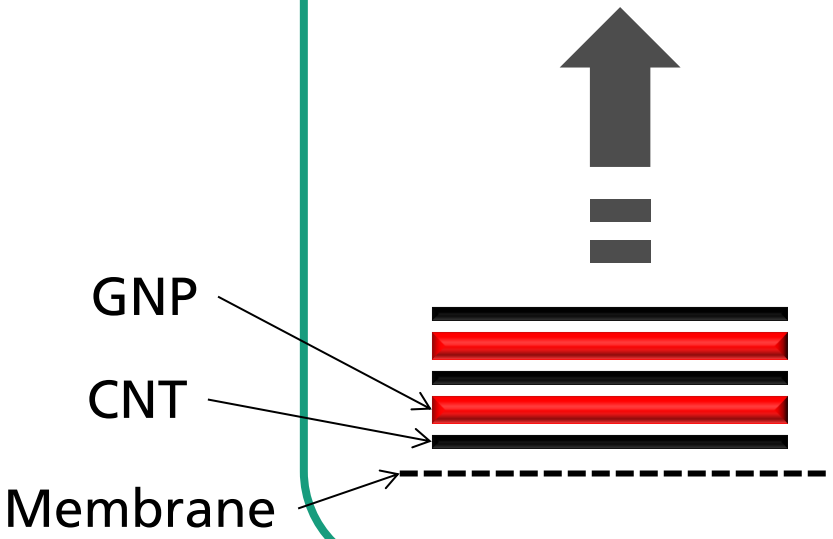
5. Structural expansion

Electrode fabrication

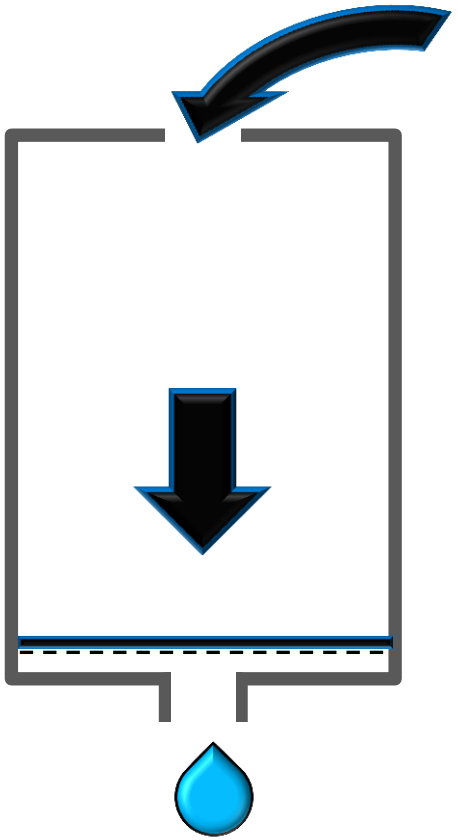
Lab scale

Film filtration

Build up of coating layers



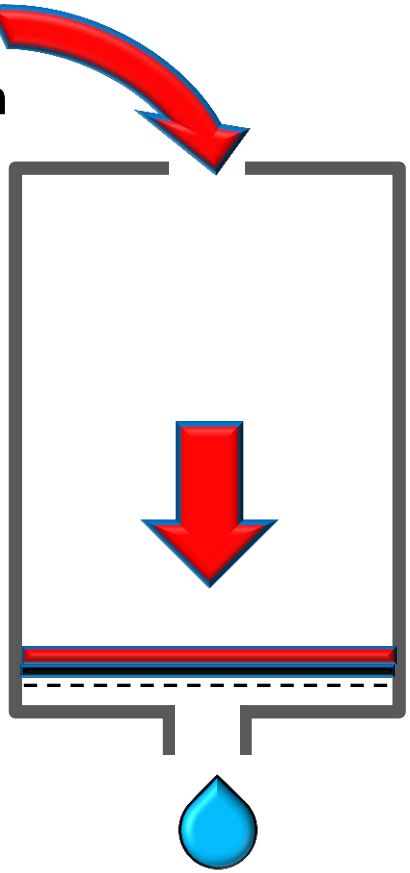
Filtration process



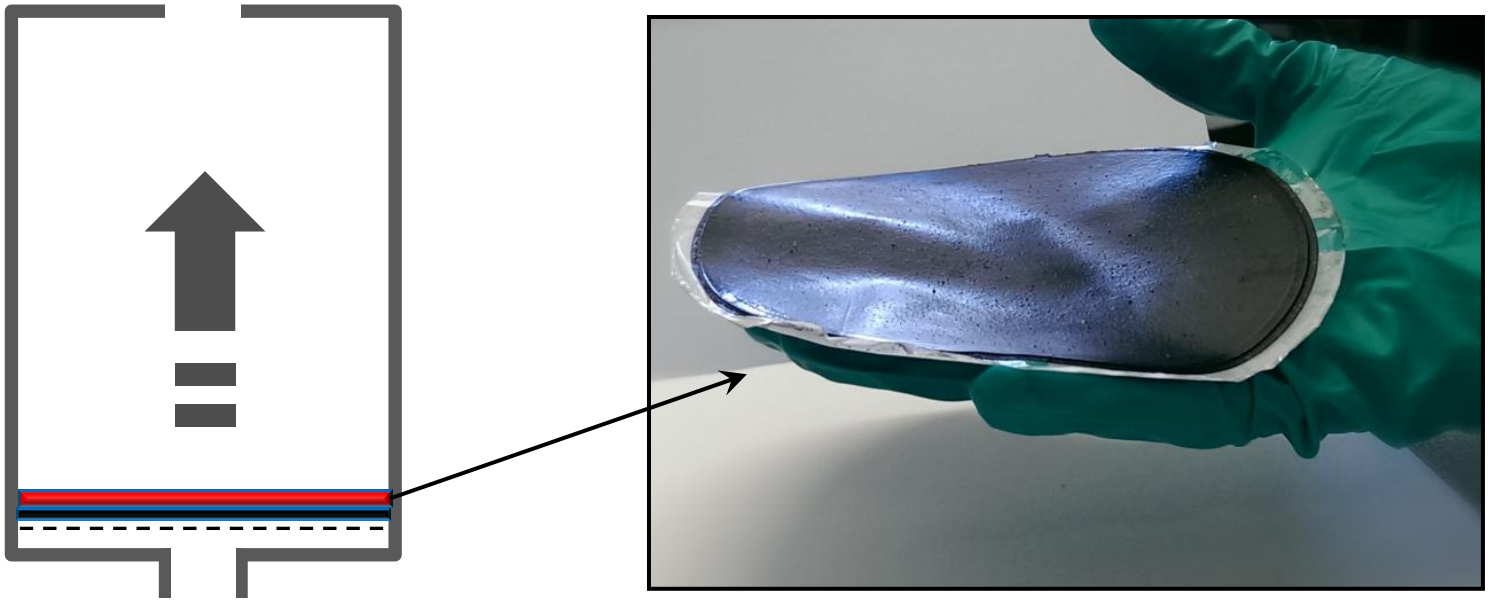
CNT Dispersion

Filtration process

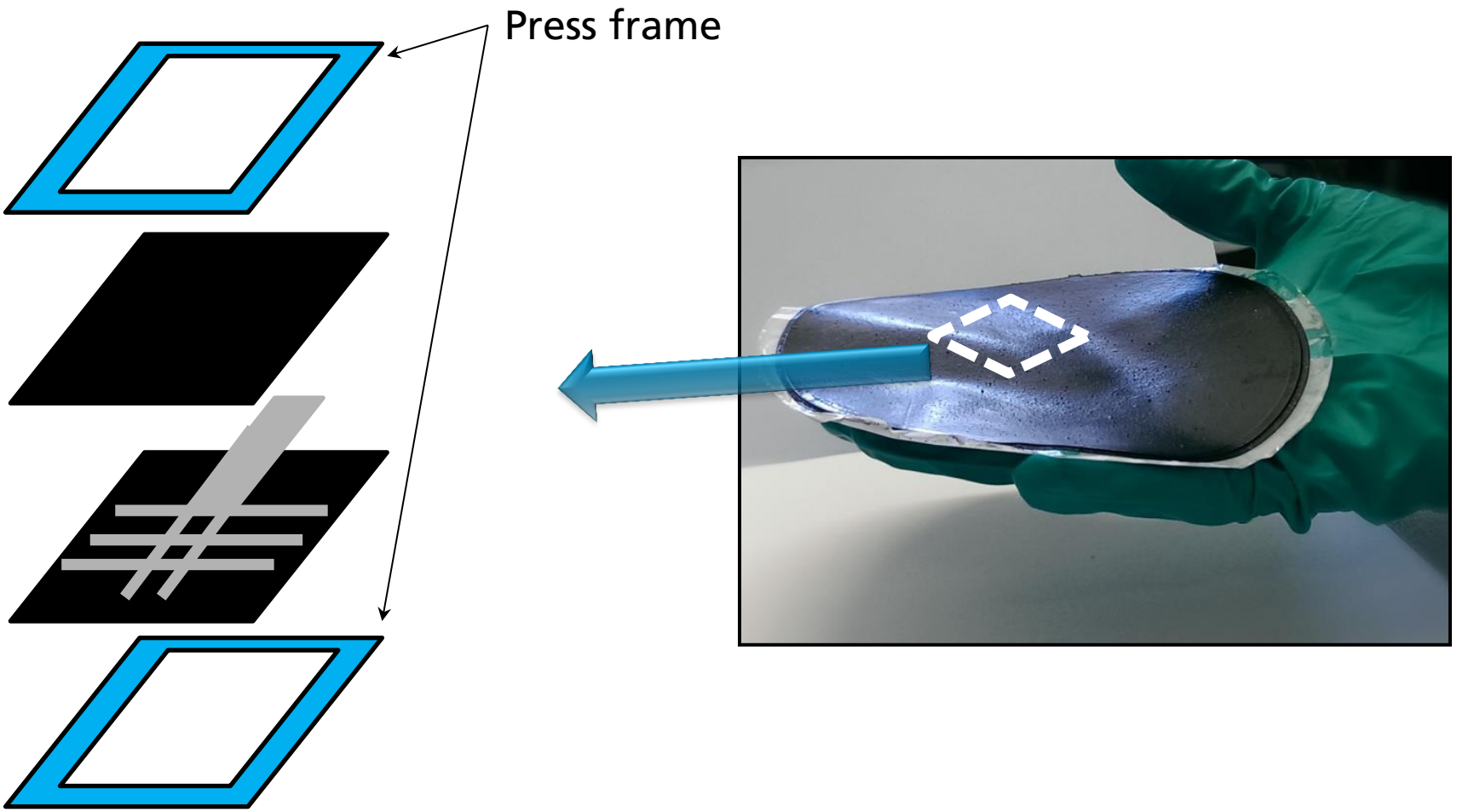
GNP
Dispersion



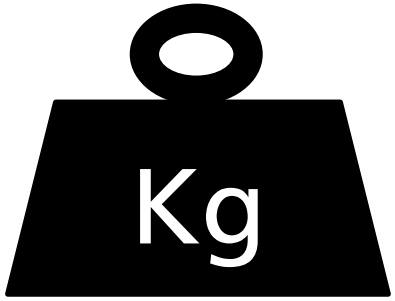
Filtration process

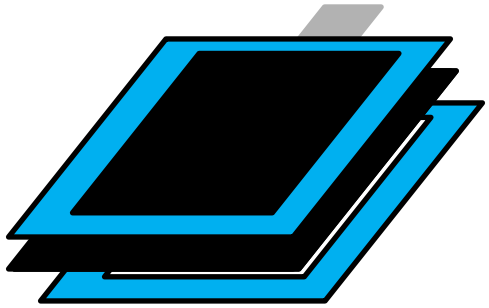


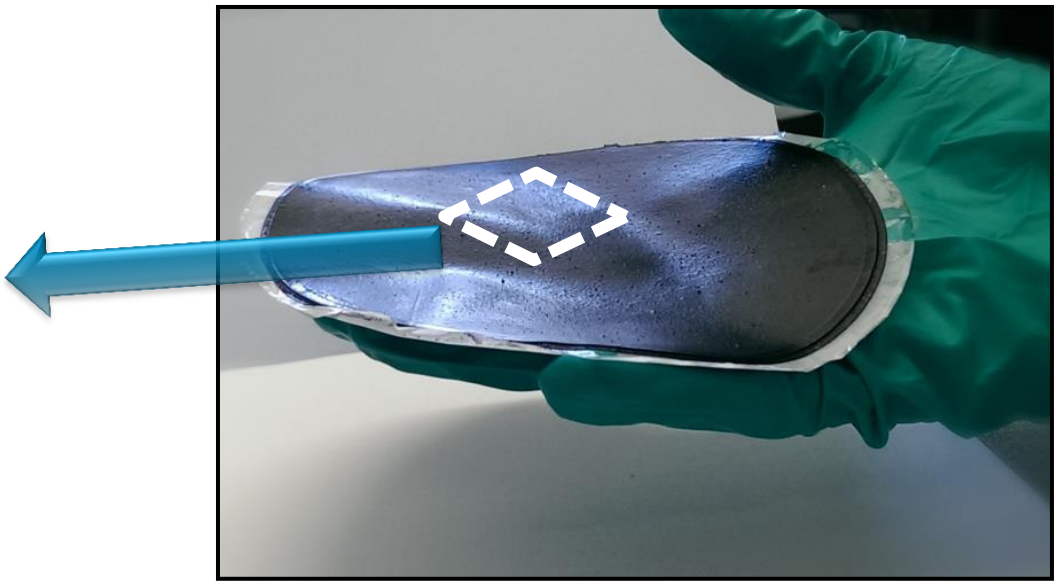
Wet film to electrodes



Wet film to electrodes

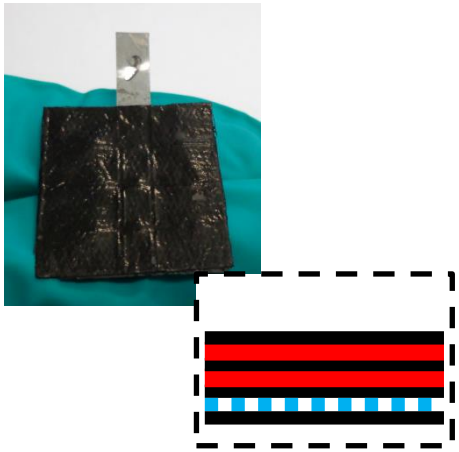




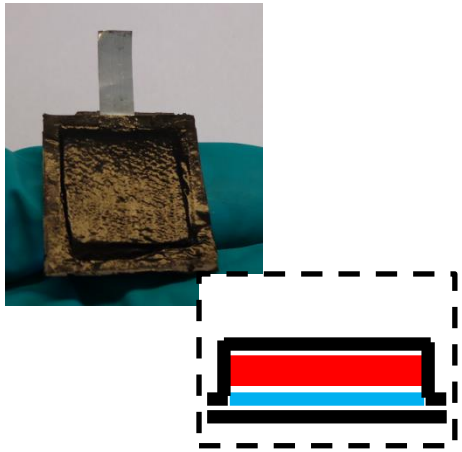


Different configurations

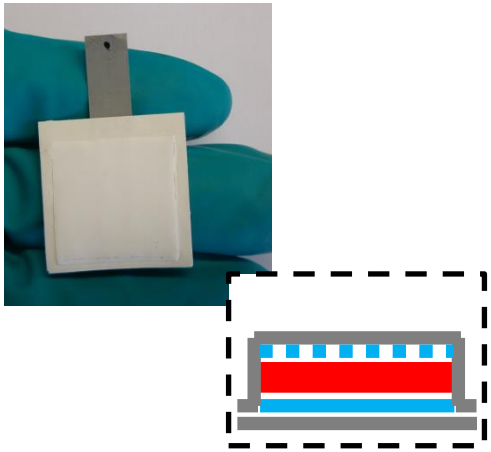
Layered structure



CNT enveloped



Polyamide enveloped



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Electrode manufacturing

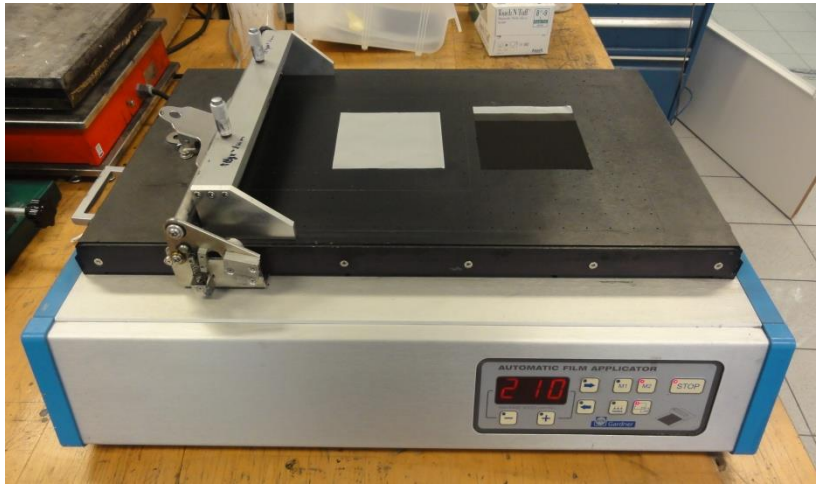
Fraunhofer
IPA

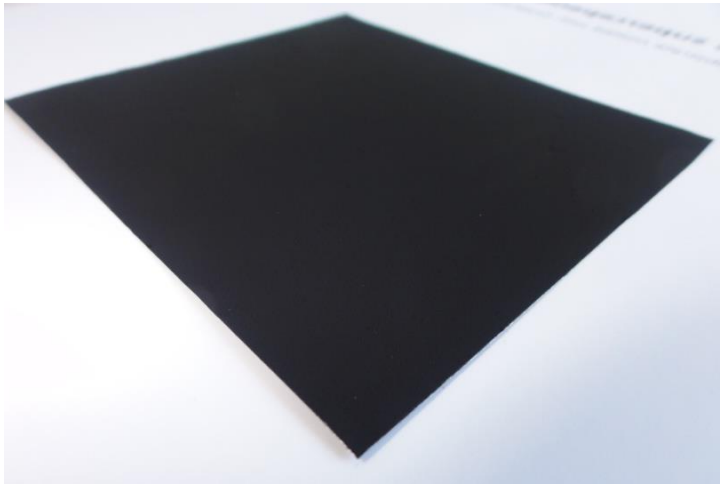
Process Engineering for components

Electrode layer fabrication via bar coating

1) Bar coating (commonly practiced in the industries)

- Controllable film thickness
- Fast and reproducible
- Up to DIN A4 – 30 x 21 cm





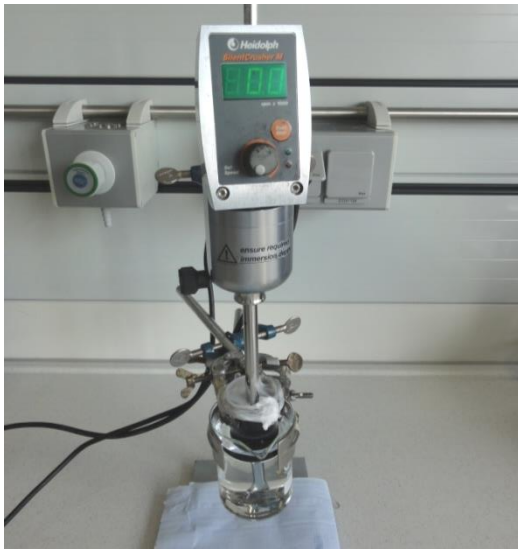
Process Engineering for components
Electrode ink preparation

Ink compositions

- Acetone/DI-H_2O
- High solid content (10 -15 w%)
- Different binders (10 w%)
  - PVDF-HFP
  - PTFE

Dispersion method

- Rotor/stator-homogeniser



Process Engineering for components

Dispersion preparation

Ultrasonication

GNP dispersion (water based)

0.1 w% GNP

CNT dispersion (water based)

0.1 w% MWCNT

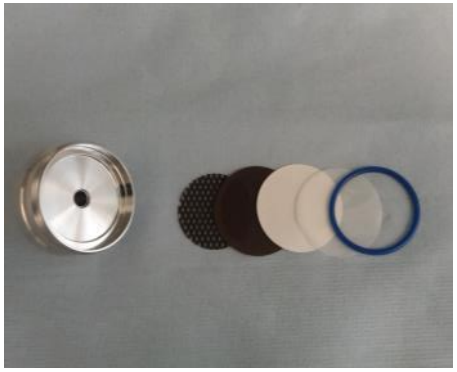
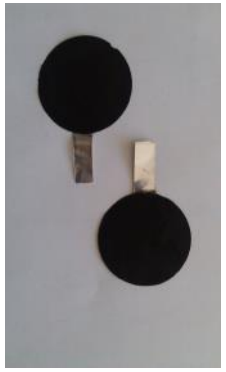
0.1 w% Polyvinyl-pyrrolidone (Dispersant)

Manual fabrication

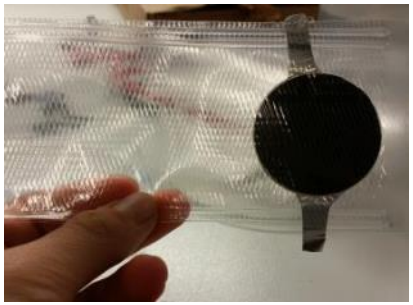
Lab scale

Electrode manufacturing
- via Filtration

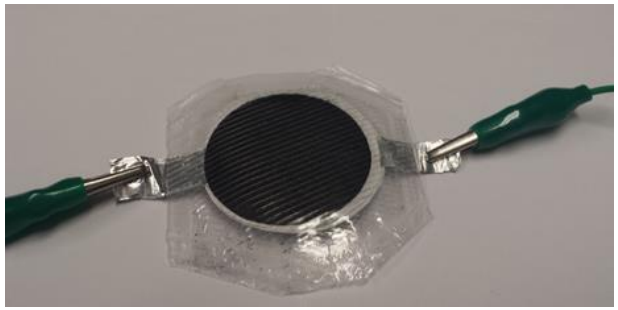


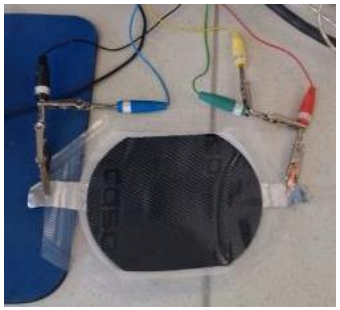



Cell manufacturing
- Wrapping
- Adding Electrolyte




Cell testing
- CV
- CC

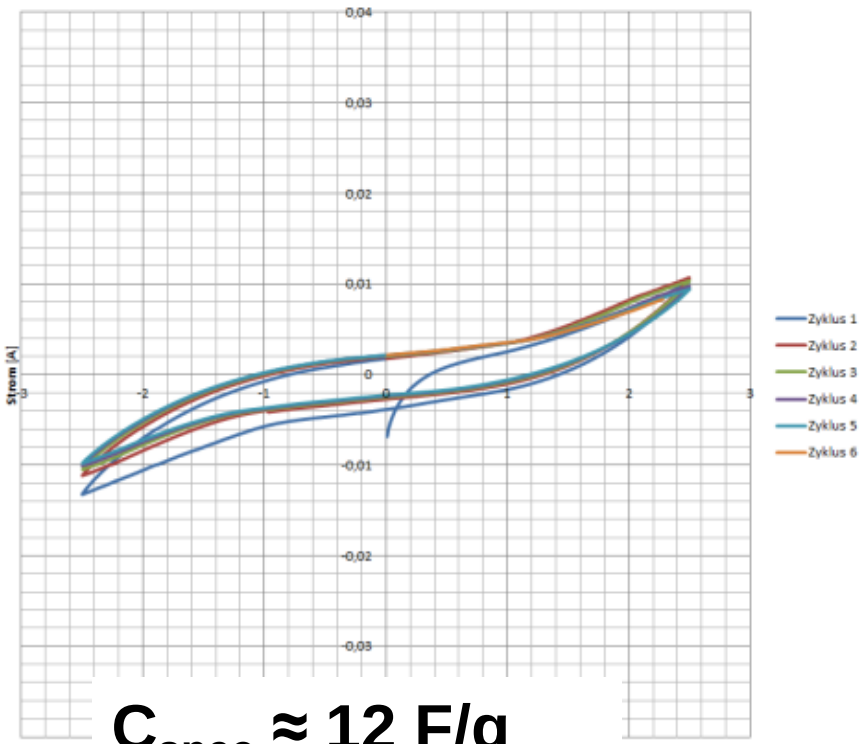




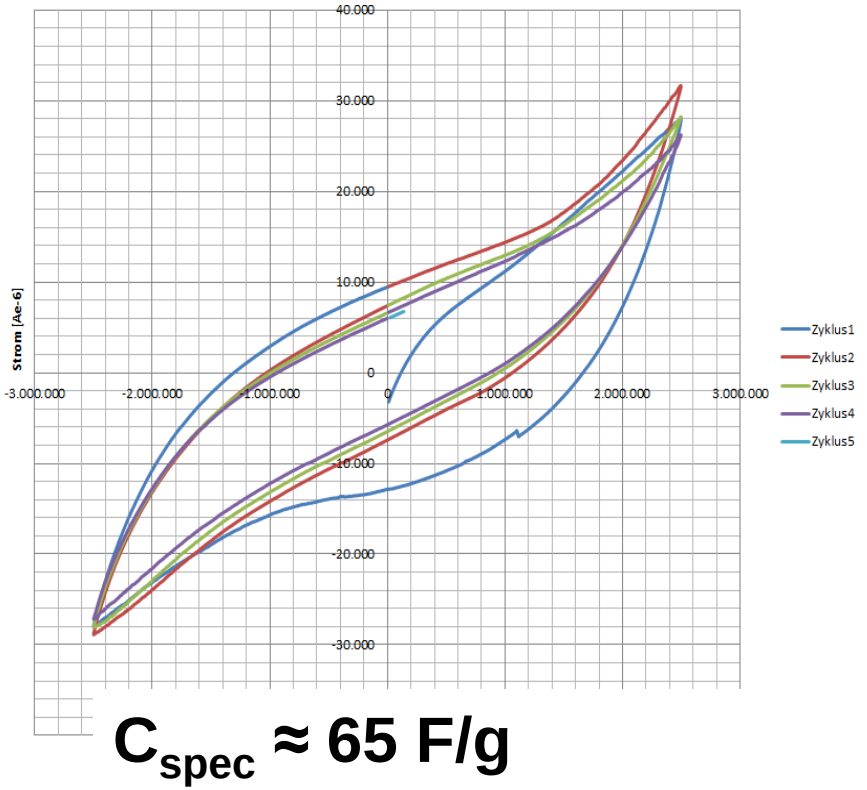
What are the results ?

Fraunhofer
IPA

Performance measuring
Cyclo-voltametry



$C_{spec} \approx 12$ F/g



$C_{spec} \approx 65$ F/g

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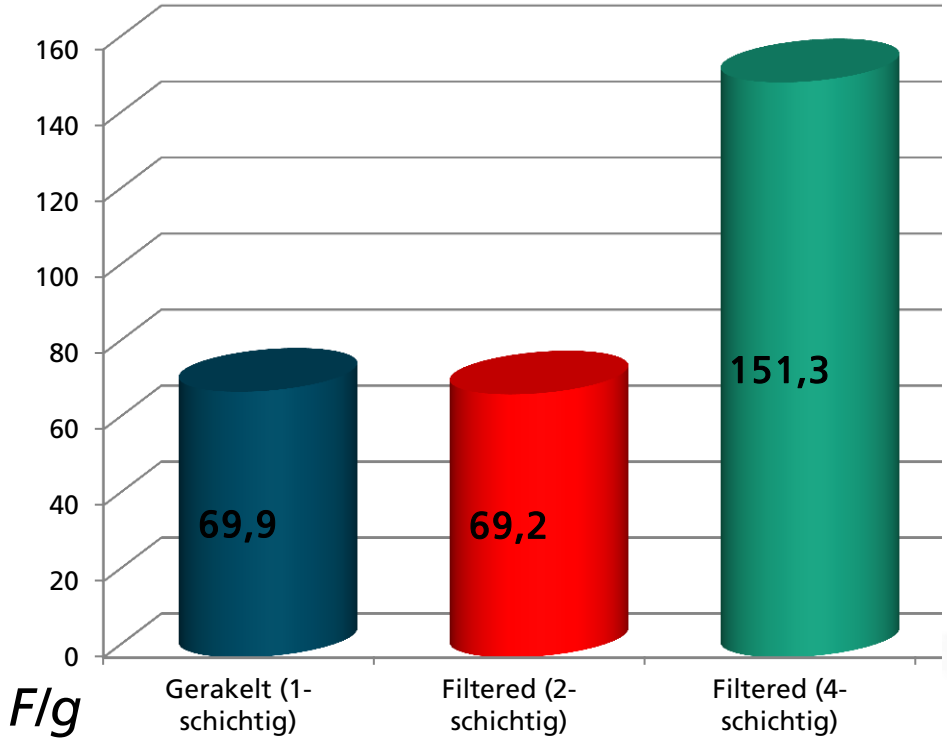
Fraunhofer IPA

Performance measuring

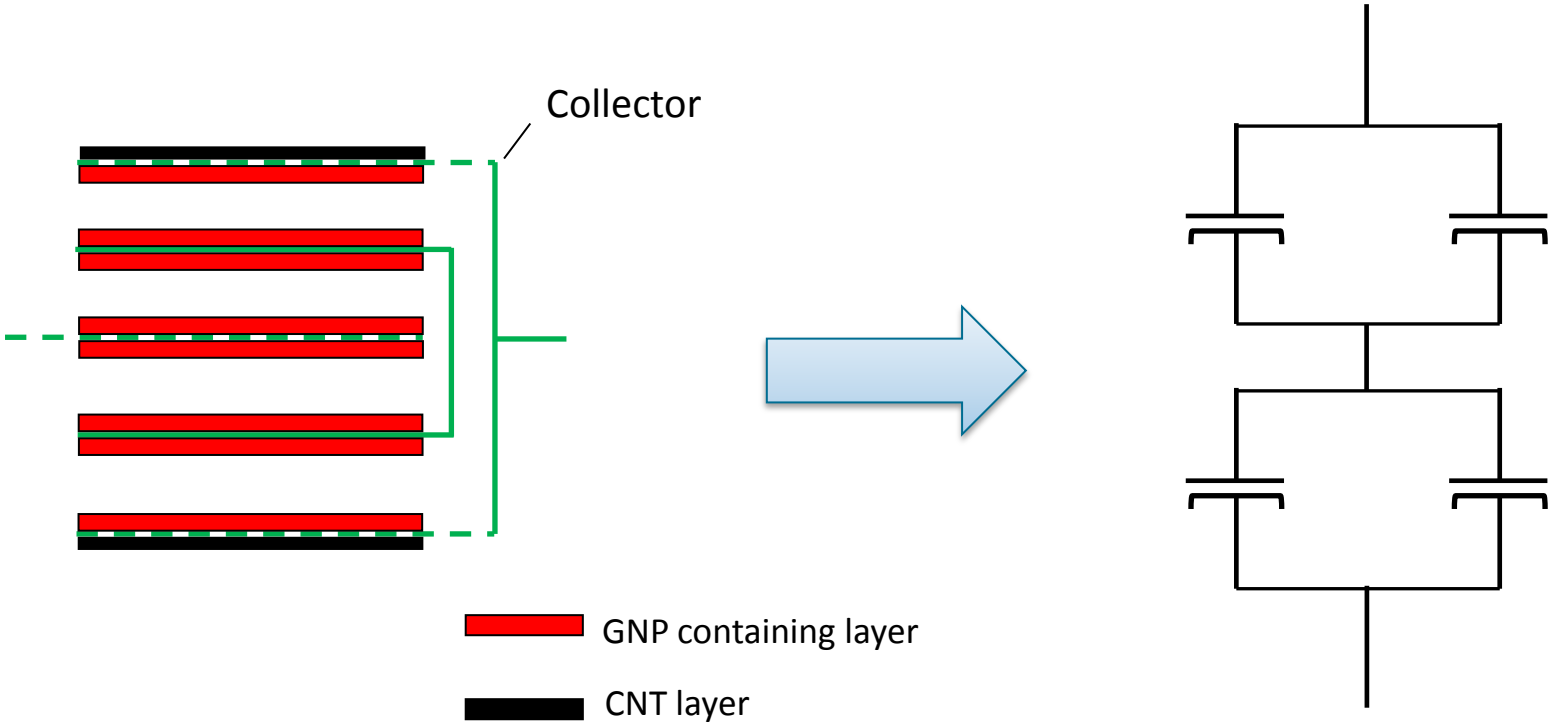
Results



Supercapacitor cell design

XG-Sciences GNPs with MnO_2

4 capacitors in a cell



Next Steps ?

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Upscaling

Summary

Graphene can reproducibly be used as active material in supercapacitor electrodes (price of GNPs is decreasing tremendously)

Hybrid electrodes can be reproducibly manufactured with spezific properties (Capacity of 150 F/g)

Energy density of supercapacitor cells & modules can be drastically increased by using a porous CNT-graphene nanostructure within the electrodes

THANK YOU !

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