Collaborative Research Progress on Supercapacitors

NECTEC ACE-2018

25 September 2018

บรรยายโดย

รศ.ดร.พิศิษฐ์ สิงห์ใจ

ภาควิชาฟิสิกส์และวัสดุศาสตร์

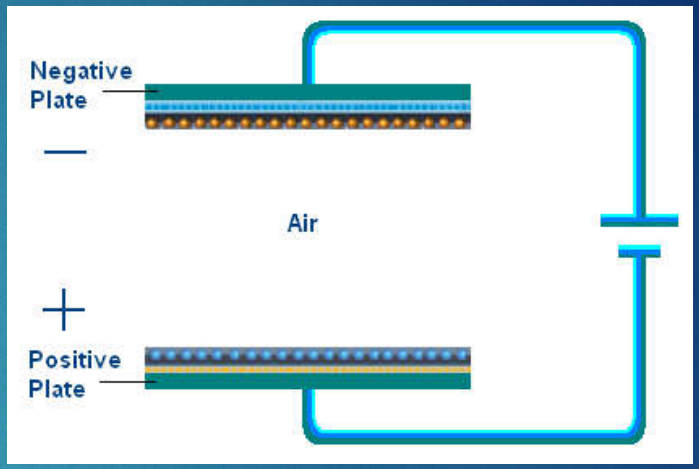
คณะวิทยาศาสตร์ มหาวิทยลัยเชียงใหม่

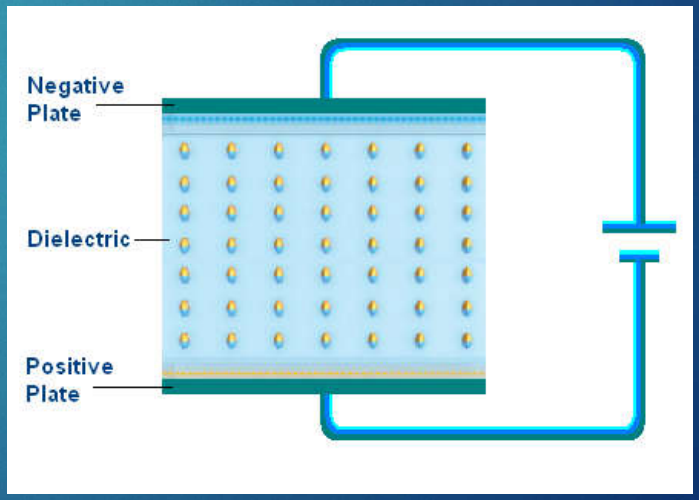
Capacitors

- Two parallel plates with dielectric in between
- Capacitance limited by flat surface area and dielectric properties

$$C = \epsilon_r \epsilon_0 \frac{A}{d}$$

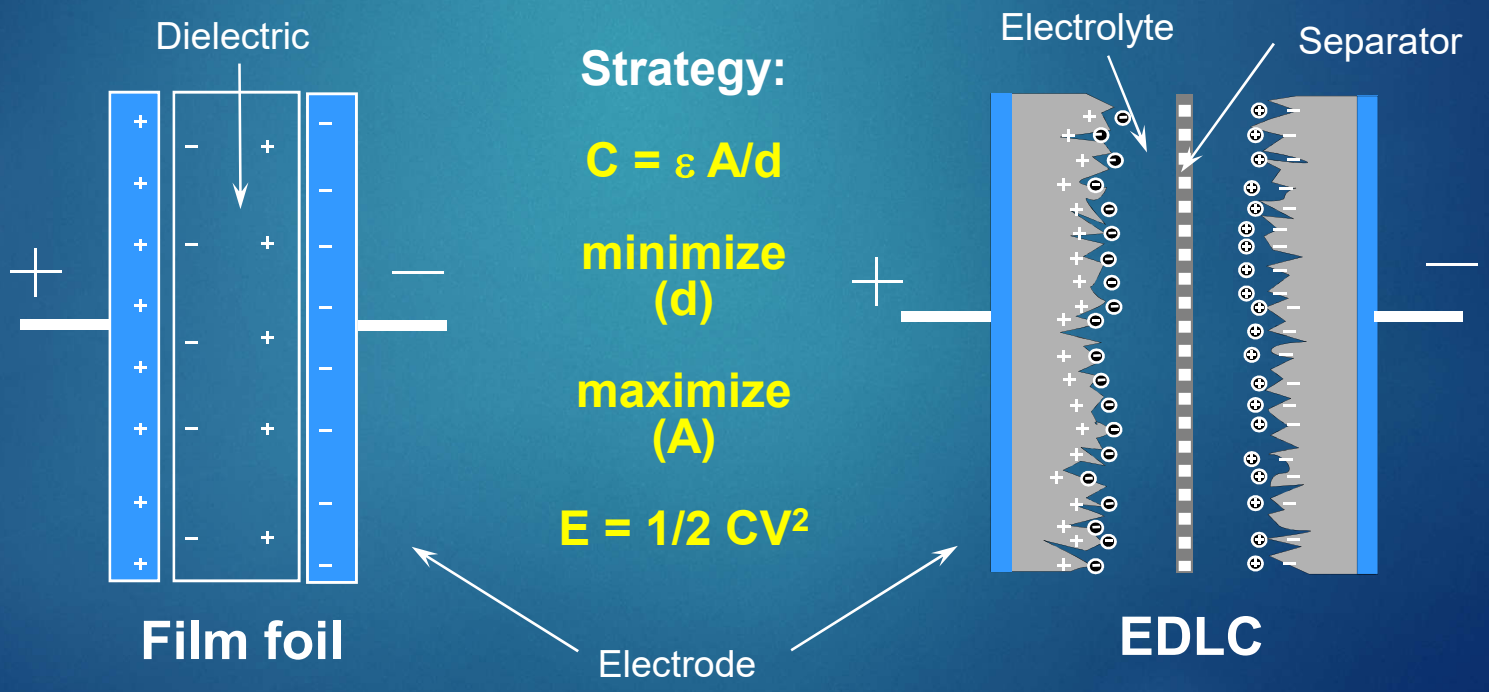
- *C* is the capacitance
- *A* is the area
- εr is the relative static permittivity (dielectric constant)
- εo is the permittivity of free space (8.854x10-12 F/m)
- *d* is distance





Supecapacitors คืออะไร?

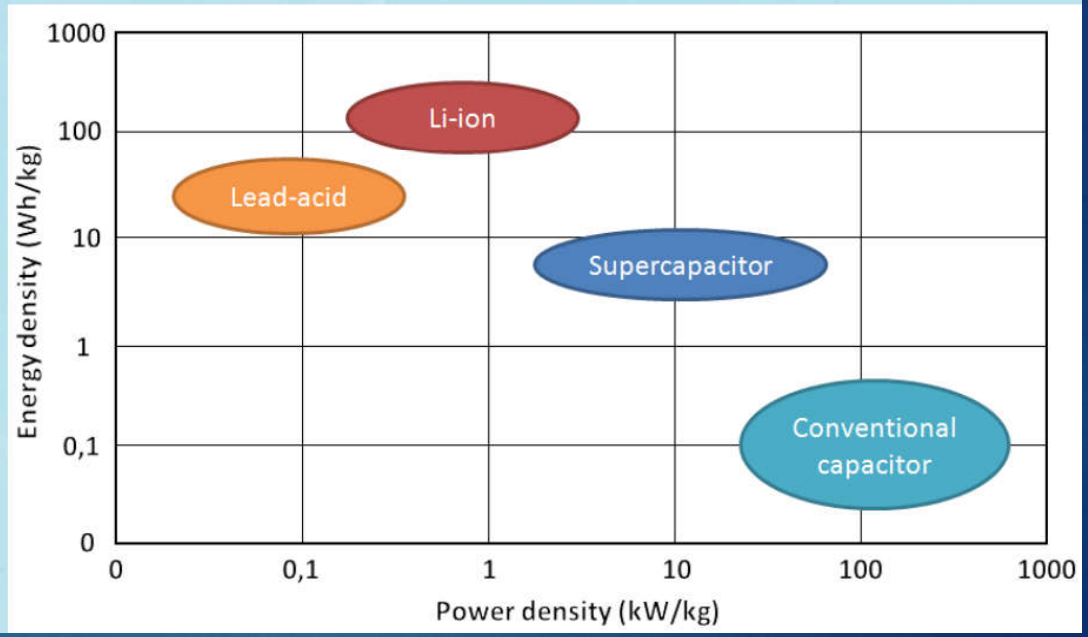
- Based on polarization of an electrolyte, high surface area electrodes and extremely small charge separation
- Electric Double Layer Capacitors (EDLCs)
- Based on a carbon technology which creates a very large double-layer surface area



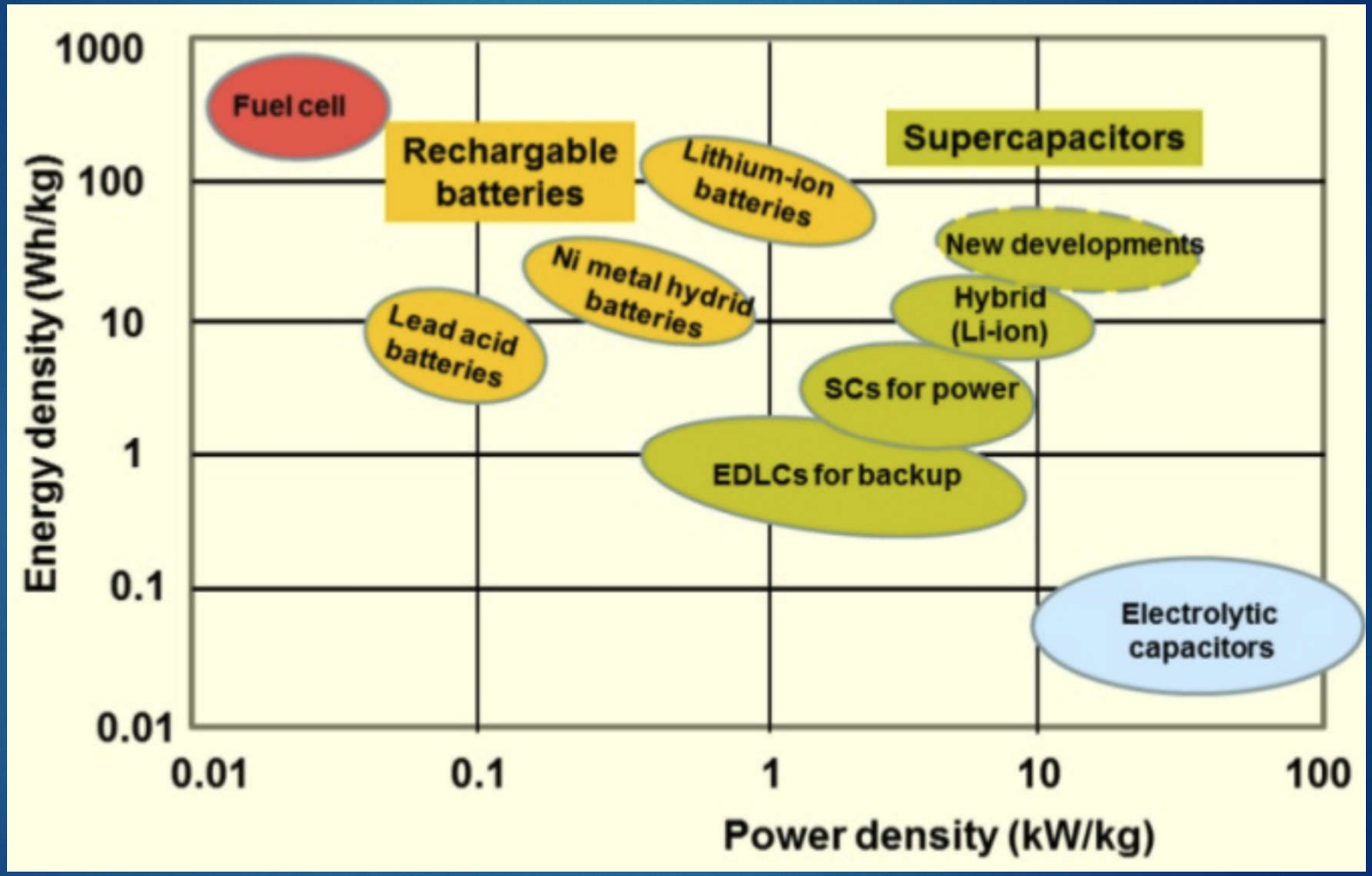
Batteries Vs. Supercapacitors

	Power Density (W/kg)	Energy density (Wh/kg)
Lead-acid battery	50 - 500	30 - 50
Li-ion battery	300 - 3.000	100 - 180
Supercapacitor	6.000 - 60.000	4 - 10
Conventional capacitor	>200.000	0,01 - 0,02

Figures are rough numbers as there are many types of Lead-acid batteries as well as conventional capacitor and Li-ion batteries.



เทคโนโลยีปัจจุบัน



Batteries Vs. Supercapacitors

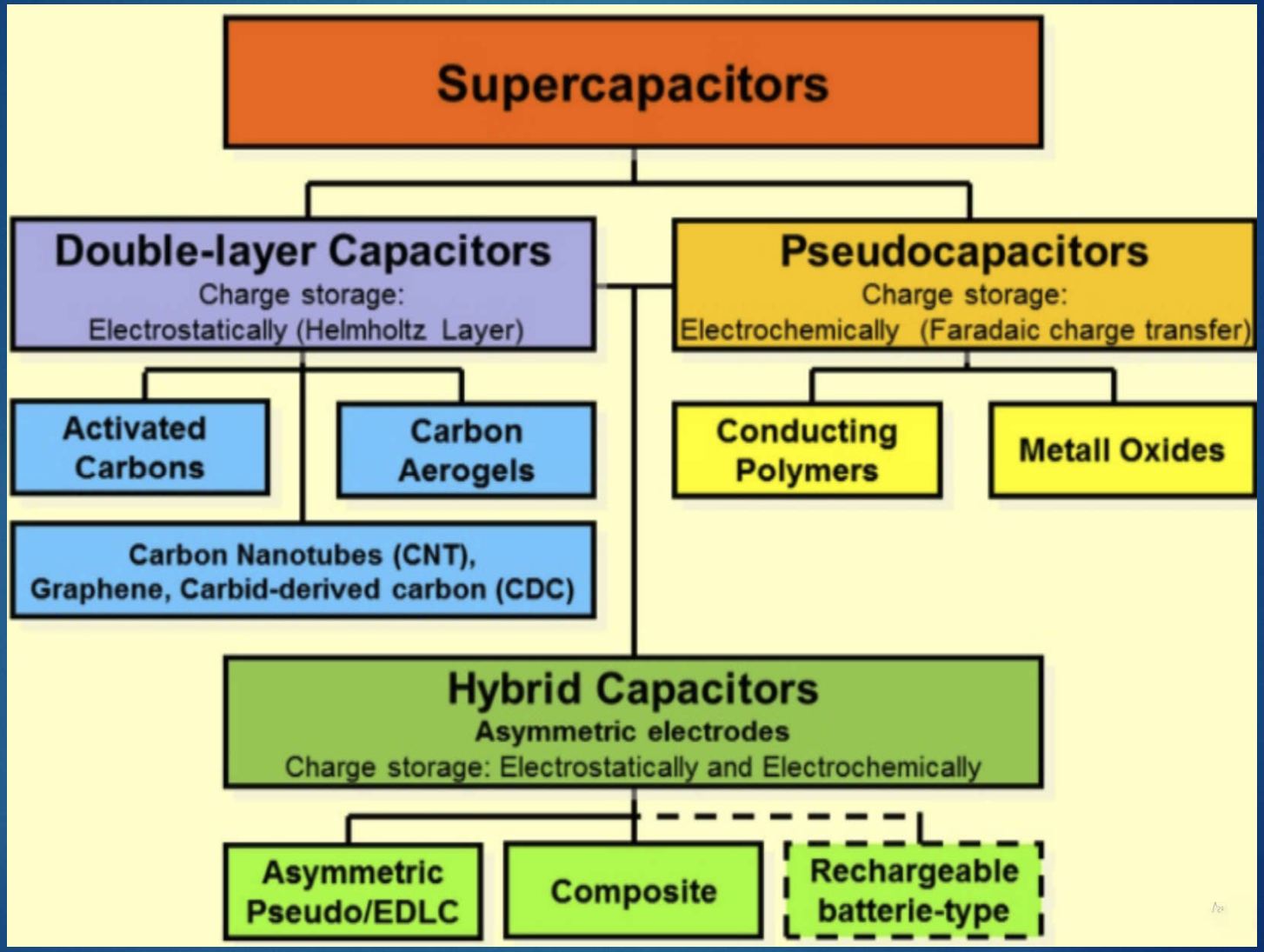
Batteries:

- Higher energy density
- Much slower charge and discharge rate
- Typically 200–1000 charge-discharge cycles
- Contain highly reactive and hazardous chemicals
- Negatively effected by low temperatures

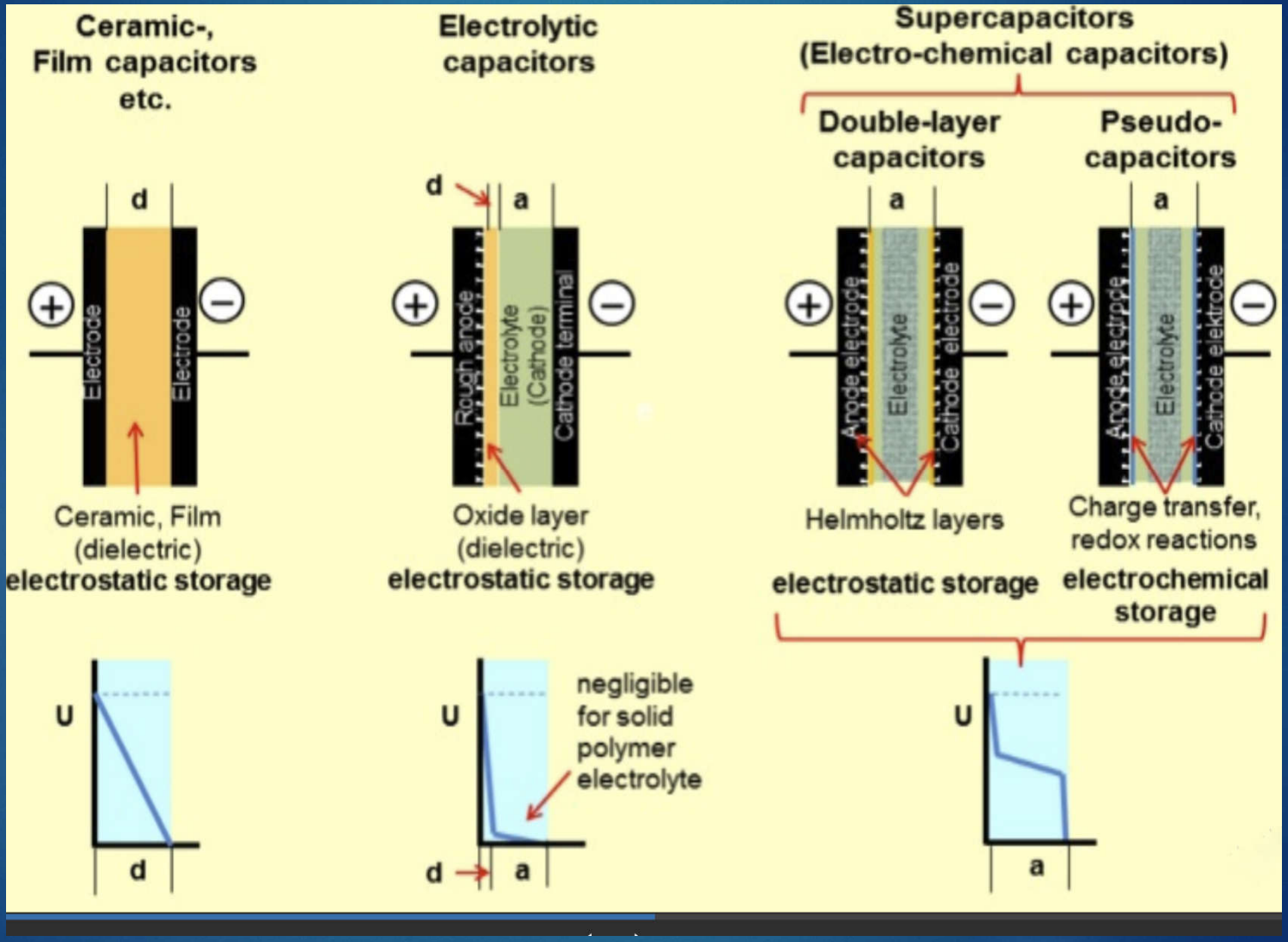
Supercapacitors:

- Higher power density
- Much faster charge and discharge rate
- Over a million charge-discharge cycles
- Environmentally friendly
- No-negatively effected by low temperatures, -40 to 60 deg.C

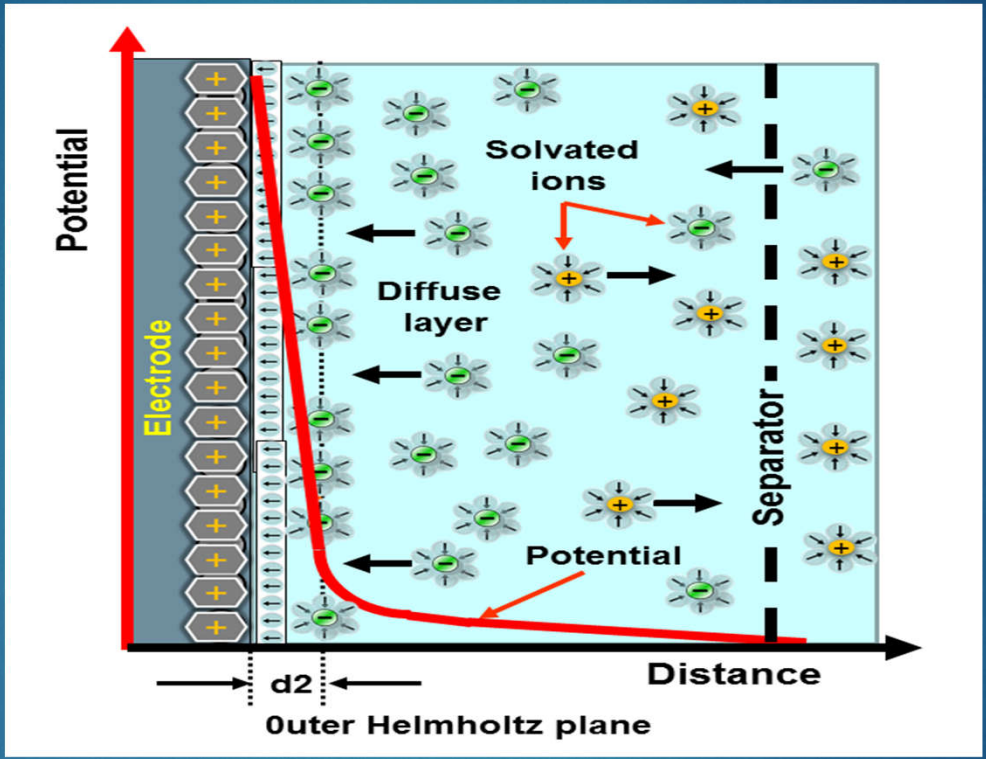
Supercapacitors แบบต่าง ๆ



ศักย์ไฟฟ้าระหว่างขั้วแผ่นขนาน



ประจุบริเวณรอยต่อ electrode–electrolyte



d = 0.1 to 10 nm, E = Thousands kV/mm, store up 10000 times more charge per unit mass than electrolytic capacitors.

$1/C_{รวม} = 1/C_1 + 1/C_2$

Materials for Supercapacitors

- Carbon nano tubes, carbon aerogels are used for supercapacitors plates or electrodes.
- Sodium perchlorate ($NaClO_4$) or lithium perchlorate ($LiClO_4$) are used as electrolytes.
- Polyacrylonitrile$(C_3H_3N)_n$ is used as a separator(thickness 0.3-0.8 nm).
- Aluminium as a packing component.

Carbon Aerogel

- Aerogel is a low-density solid derived from gel that has had the liquid component replaced with a gas.

- Composed of nanometer sized particles covalently bonded together
- High porosity (>50% under 100 nm)
- Large surface area (400–1000 m^2/g)

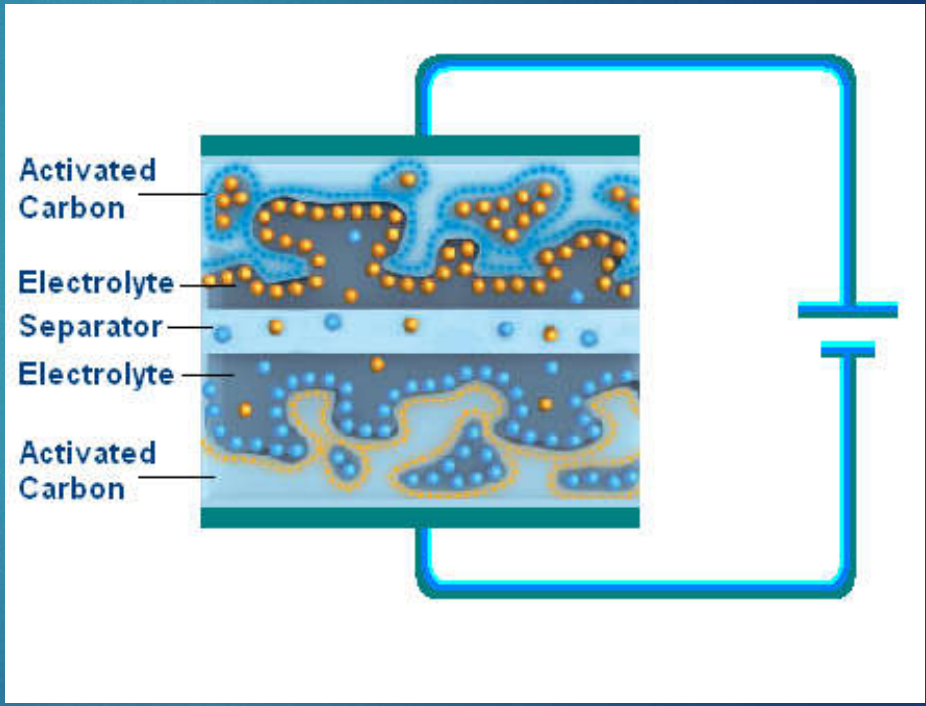
Activated Carbon:

- Extremely porous with a very large surface area.
- Surface resembles a sponge.
- Area allows more electrons to be stored than other conductors.

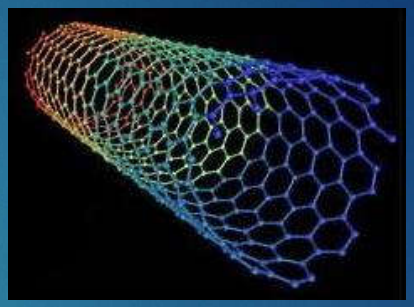
Activated Carbon
(Activated Charcoal)

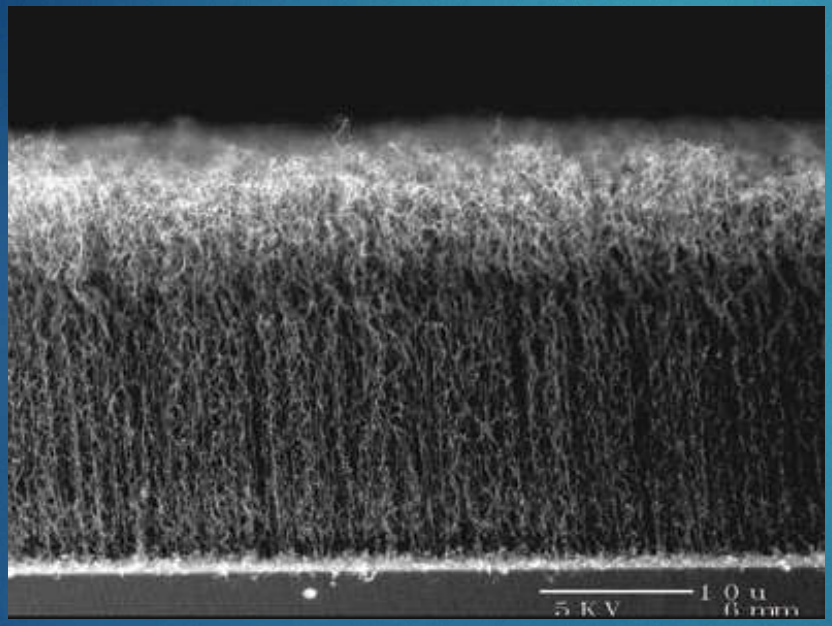
Double Layer Electrolytic Capacitors Using Activated Carbon

- Two layers consisting of nanoporous electrodes
- Separator is impregnated with an organic electrolyte
- Thin separator can only withstand low voltages



Carbon Nanotubes

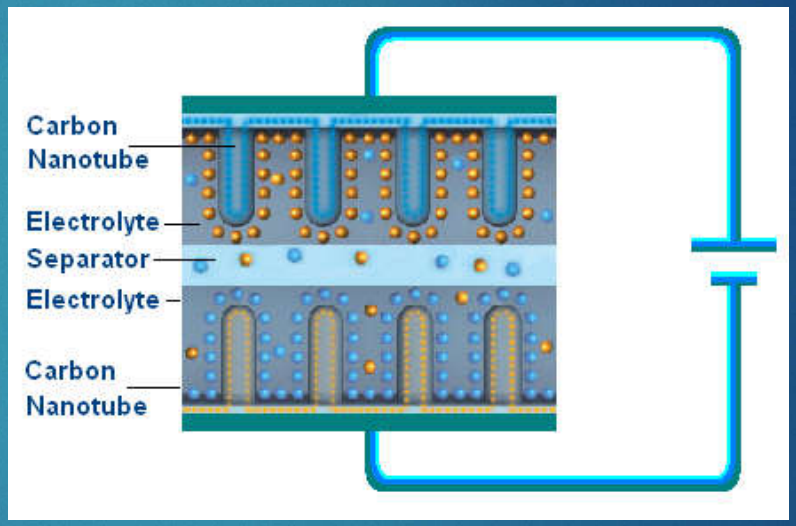




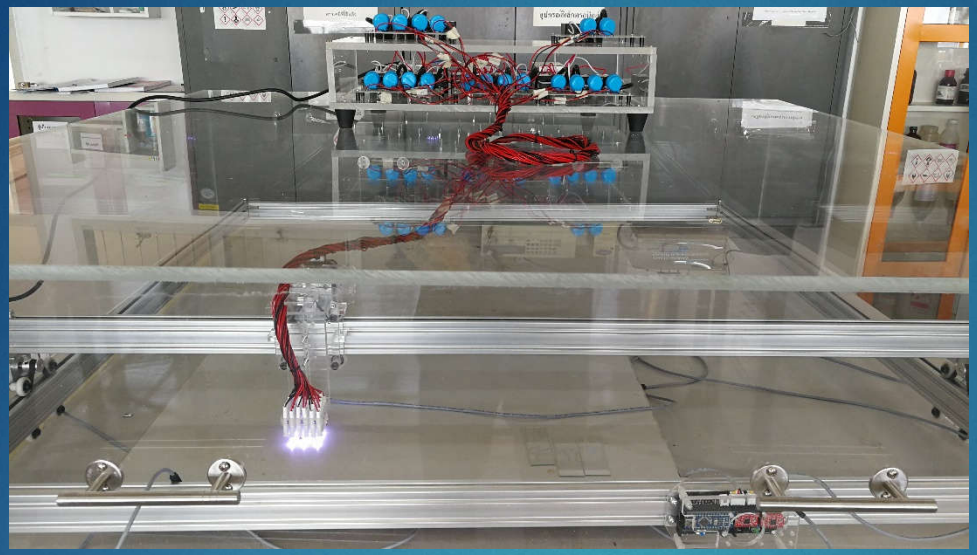
- Approximately 1/50,000th the width of a human hair
- Strongest and stiffest materials
- Low density

Double Layer Electrolytic Capacitors Using Carbon Nanotubes

- Under development at MIT
- Replaces activated charcoal with carbon nanotubes
- Aligned in a regular pattern that exposes greater surface area
- Dramatically increases effective area of electrodes
- Greatly increases power density



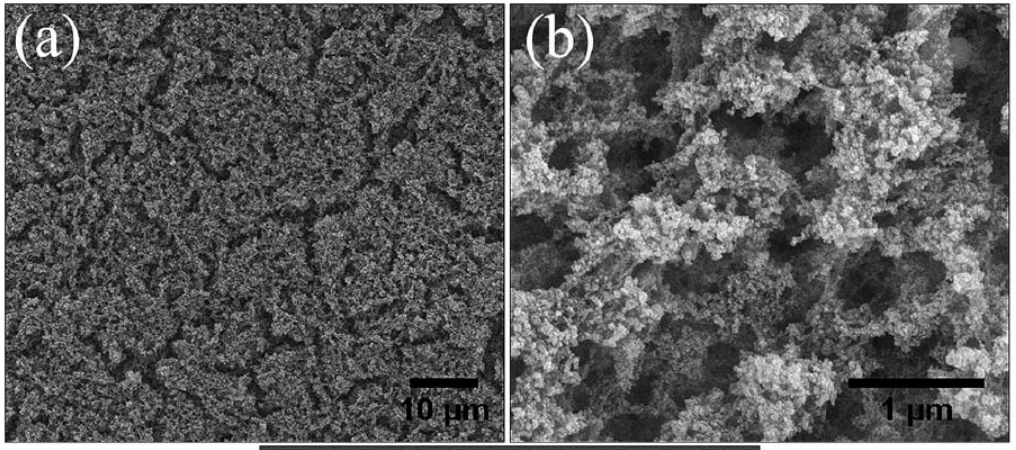
NECTEC-CMU Collabolation

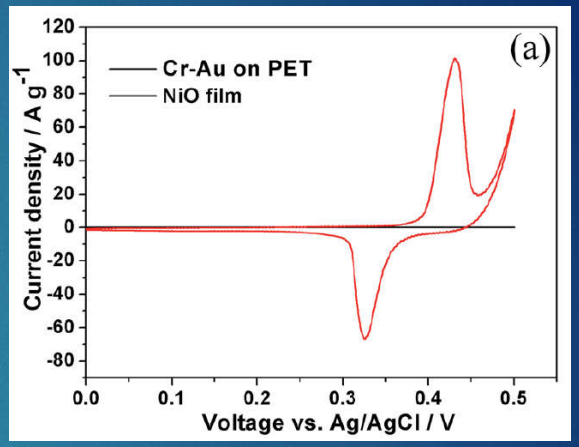


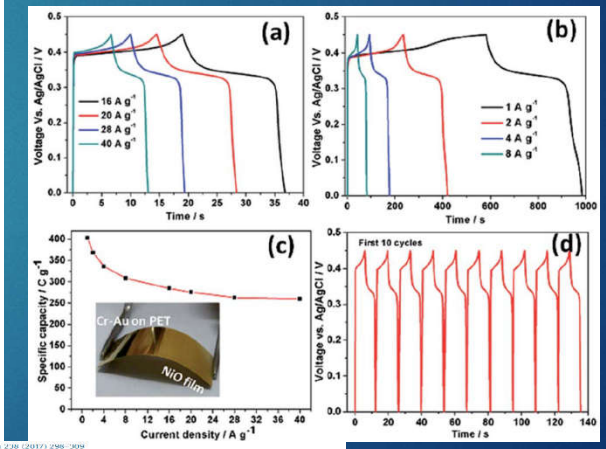
- Spark-Coating Machine has been developed at CMU since 2006

- Electrochemical Measurement , CV, GCD and Impedance spectroscopy (Nyquist plots)

NiO Films by Spark-Coating for Pseudo-Capacitors, SEM, CV, GCD







RSC Advances

PAPER

CrossMark

Cite this: *RSC Adv.*, 2015, 5, 67795

Electrochemical energy-storage performances of nickel oxide films prepared by a sparking method

Yaowamarn Chuminjak,[a] Suphaporn Daothong,[b] Preeyaporn Reanpang,[c] Johannes Philipp Mensing,[d] Ditsayut Phokharatkul,[d] Jaroon Jakmunee,[c] Anurat Wisitsoraat,[d] Adisorn Tuantranont[d] and Pisith Singjai*[a]

Electrochimica Acta 238 (2017) 298–309

Contents lists available at ScienceDirect

Electrochimica Acta

journal homepage: www.elsevier.com/locate/electacta

High-performance Electrochemical Energy Storage Electrodes Based on Nickel Oxide-coated Nickel Foam Prepared by Sparking Method

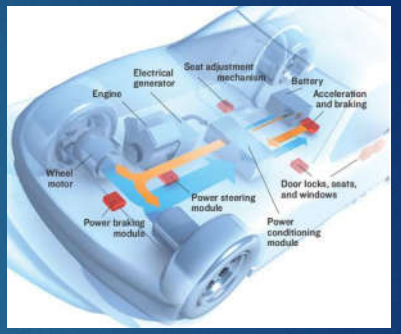
Yaowamarn Chuminjak[a,b], Suphaporn Daothong[c], Aekapong Kuntarug[a], Ditsayut Phokharatkul[d], Mati Horprathum[d], Anurat Wisitsoraat[d], Adisorn Tuantranont[d], Jaroon Jakmunee[c], Pisith Singjai[a,d,*]

สิ่งที่งานวิจัยต้องพัฒนาต่อ

- Increase energy and power densities
- Increase single cell voltage, maximum at 2.7 V
- Reduce self-discharge
- Increase life time
- Range improvements of operating temperature

ตัอย่างการประยุกต์ใช้งานSupercapacitors

- Back up for uninterruptable power supplies (UPS)
- Light weight power supplies for small aircraft
- Provide short duration power for various vehicle systems such as breaking or steering
- Used to absorb power during short periods of generation such as Regenerative breaking/energy capture – trucks, busses, trains
- Extend range and battery life in Hybrid Electric Vehicles (HEV)
- Robotics, fork lifts, cranes, electric carts – providing power boosts and backup
- Modules are used to start large commercial diesel powered generator
- Engine starting – auto, truck, train, initiates startup and minimizes starting surge



More Applications!

- Wind Turbine
  Energy Storage Application
- Military – similar needs to those found in other markets, plus any military equipment that is motorized
- Medical – Non-life critical applications, such as support for motor driven diagnostic and patient mobility equipment
- Smart Grid – Power smoothing, backup, energy storage
- Commercial Cooking Equipment

52 F, 129 WVDC, -40 to +60C,
Charge/Discharge current 674 A
Weight: 110 lb.

THANK YOU… Q&A