Graphene-polypyrrole hydrid supercapacitor electrode by electron beam irradiation

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Introduction

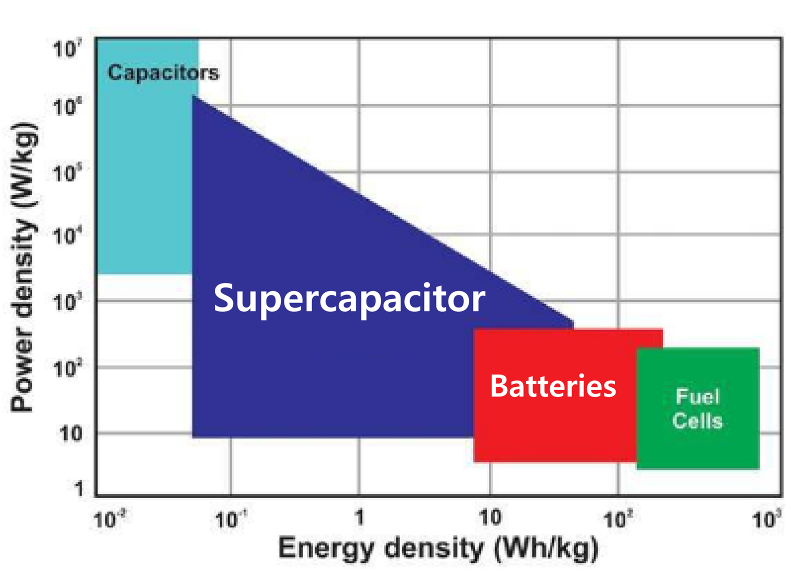
◆Definition of graphene

- Allotropes of carbon in the form of a 2-dimensional, hexagonal lattice
- Excellent electrical conductivity (~4,000cm²/Vs)
- High thermal conductivity (~5,000W/m•K)
- Superior light transmittance (~97.7%)
- Good Young's modulus (~1.0TPa)

◆ Supercapacitor

- Capacitor with highly large capacitance
- Rapid charging/discharging rate
- High power density
- Long life cycle
- Electrical Double Layer Capacitor(EDLC) or Pseudocapacitor

◆ Supercapacitor vs Battery

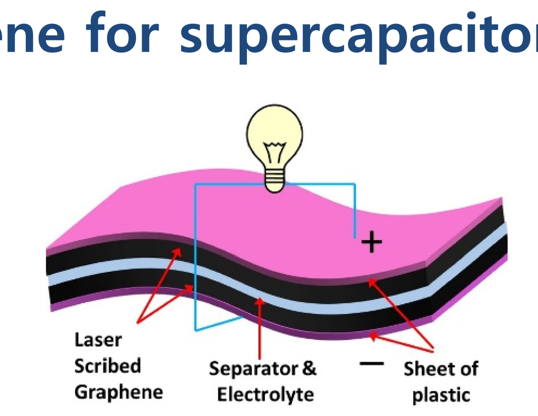


	Supercapacitor	Battery
Charge/discharge time	msec to sec	1 to10 hrs
Power density	High, >10,000 W/kg	Low, 100~3000 W/kg
Energy density	~10 Wh/kg	8-600 Wh/kg
Operation voltage	0.8V~2.75 V/cell	1.2V~4.2 V/cell
Life time	>100k cycles	150~1500 cycles

- Supercapacitor is more applicable for electric vehicle and energy storage requiring high power density, short charging/discharging time and long life cycle than batteries

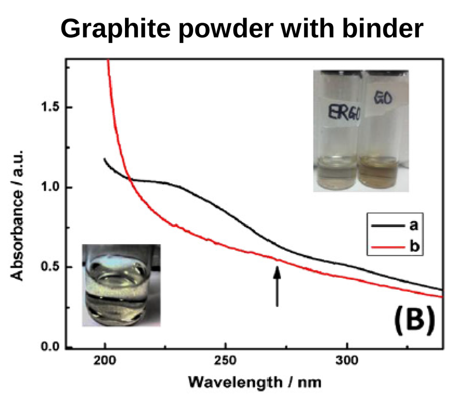
◆ Advantage & disadvantage of graphene for supercapacitor

- Large specific surface area (~2630²g⁻¹)
- Light weight
- Excellent electrical conductivity (~4,000cm2/Vs)



◆ Efforts to synthesis a graphene as a supercapacitor electrode

Graphite powder with binder



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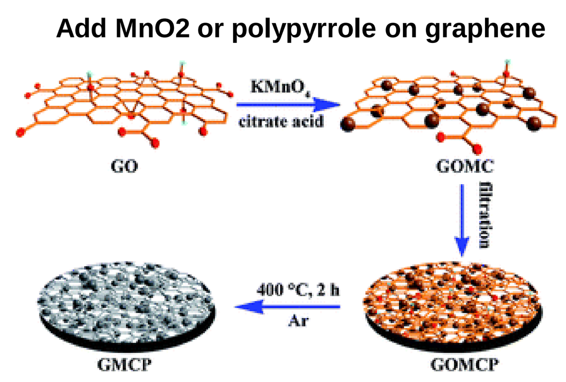
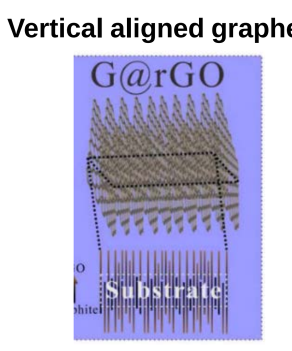
Add MnO2 or polypyrrole on graphene



Journal of Materials Chemistry 21.38 (2011): 14706-14711

Vertical aligned graphene



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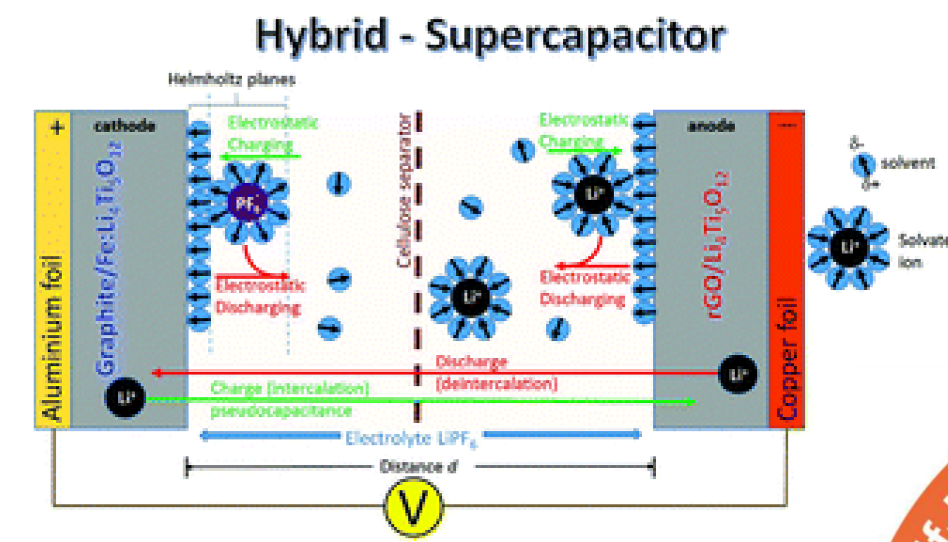
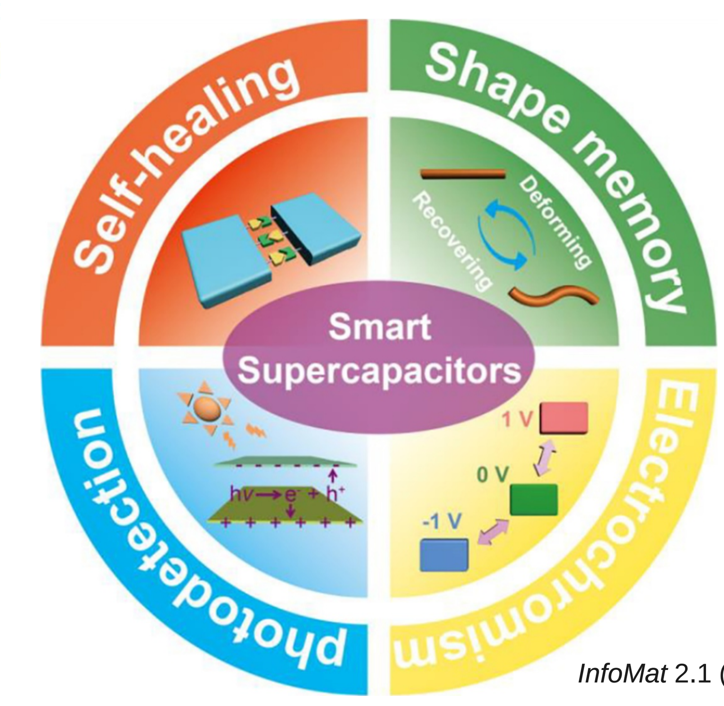
- Binder inhibits the electrical conductivity
- Add materials requires complicate process

Hybrid electrode



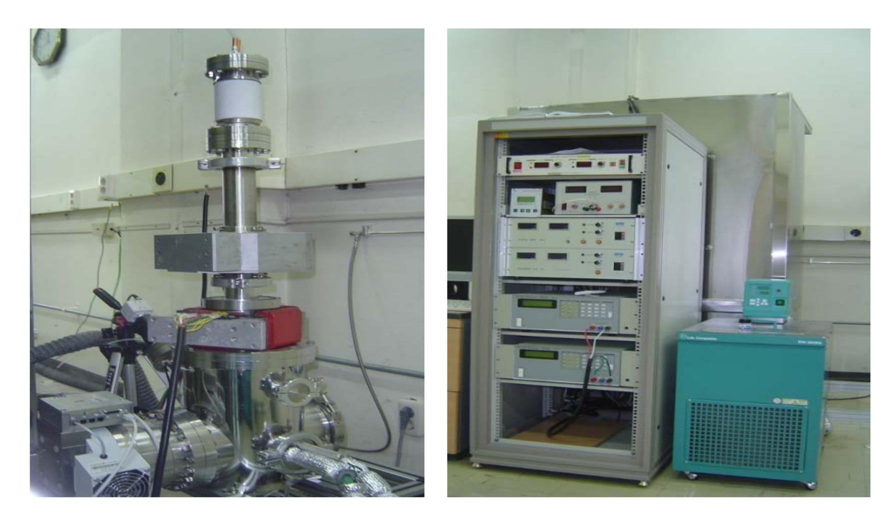
Pseudocapacitor + EDLC



InfoMat 2.1 (2020): 113-125.

Important factor: increase the bonding strength between two types of electrode materials and to increase the thermal stability

Electron beam device and Spectroscopy



Beam Energy	10 – 80 [keV]
Current Density	5 – 40 mA/cm²
Vacuum level	< 5 x 10⁻⁵ torr
Substrate Temperature	-35 ⁰C ~ 500 ⁰C
Beam Diameter	120 mm

50keV electron beam device and its condition

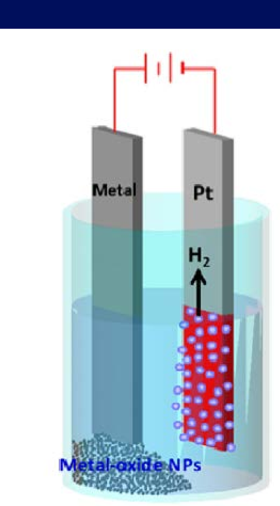
Scanning Electron Microscopy (SEM) & Raman spectroscopy

Methods

① Fabrication of graphene-PPy hybrid electrode

Graphene particles are prepared by electrochemical decomposition in 1M KCl aqueous solution. Graphene particles and polyvinylidene fluoride (PVDF) in a weight ratio of 9:1 are mixed. The mixture is molded in N-methyl-2-pyrrolidone and coated on Cu foil (t: 1mm) and dried in vacuum oven at 80 ºC for 1 hr [3].

Graphene-PPy hybride electrode is synthesized by electrochemical deposition using a cyclic voltammetry method at a potential window of -0.6 to 1.0 V with a scan rate of 20mVs⁻¹. Electrolyte is an mixed aqueous solution with 0.1M pyrrole monomer and 0.2M sodium-potassium hydrant tartrate (Fig. 1).



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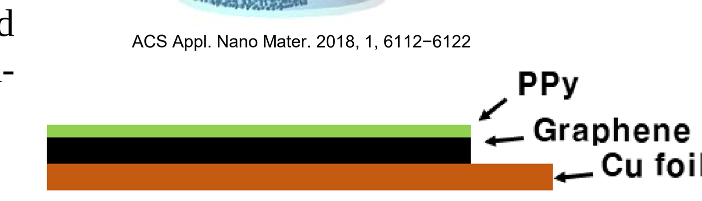

② Electron irradiation on hybrid electrode

50keV electron beam device produced in our lab is used. The hybrid electrode is fixedly placed in the electron beam irradiator, and then the inside of the irradiator is evacuated. At this time, the degree of vacuum is maintained at 10-6 Torr by using a rotary pump and a turbo pump. Then, electron beam is irradiated to the hybrid electrode by controlling the current and the electron beam irradiation time in each experimental condition.

Conclusion

- Hybrid supercapacitors have in attention as next-generation supercapacitors due to their large capacities and various advantages.
- This study designed a method for manufacturing hybrid supercapacitors using electron beam irradiation.
- Electronic beam irradiation is expected to dramatically improve the binding strength and capacitance of hybrid supercapacitors.
- It is expected that this research would expand the application of radiation to the energy fields.

Acknowledgements

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