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Nanocarbons as electrode materials for electrochemical capacitor

Yasushi SONEDA, PhD.

National Institute of Advanced Industrial Science and Technology (AIST) Energy Technology Research Institute Energy Storage Materials Group



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- Research centers are limited-term (typically 7 years) organizations with clear goals. Research resources of AIST, such as budget and personnel, are strategically distributed, and research centers have priority to the resources.
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- Research initiatives are rather small units of limited terms. The purposes of research initiatives are to promote specific research projects, especially those of cross-fields. Some research initiatives also aim to meet immediate governmental needs.



Energy Technology Research Institute

Distributed Energy Network Technology

Energy Materials and Devices





Energy Storage Materials Group



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AIST

Energy Storage Materials Group



Energy Storage Materials Group conducts research and development on carbon materials for energy storage, which contributes to energy system in commercial and residential use. Our group, having great potentials for synthesis and characterization of carbon materials, aims at development of innovative nanocarbons used for electric double layer capacitors, hydrogen storage and fuel cell applications.



Application of Electric Double Layer Capacitor (EDLC)





Energy storage devices





Charge-Discharge Mechanism of EDLC









Design of Carbon Nanostructure



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Electrolyte

Aqueous (0.8-1.2V)

High conductivity

 (high power density)
 Stable
 Wide temperature range
 Impedance

Disadvantage · Low energy density

·Low cost, safety

High energy densityVariety of components

Non-aqueous (2-3V)

Long-term stability
High cost (material and moisture control)
Flammability

Application

• Small device for power usage

·Large device for energy storage



Pseudo capacitance in electrochemical capacitor

 $RuO_2 + H^+ + 2e^-$ RuOOH

Charge-discharge response is similar to EDLC Activated carbon: ca.200F/g, RuO₂: ca.800F/g

Candidates: transition metal oxides (compounds) conducting polymers intercalation reactions carbon surface functional groups hetero atom substitution in carbon structure



Nanocarbons







Carbon Aerogels

Surface area ~ 2000 m²/g Mesoporosity





Diameter ~ 100nm Various nanotexture



<u>Mesoscopic Carbons</u>

Thickness ~ 2 nm Unique structure



Dependence of Capacitance on micropore size



Electric Double-layer Capacitance of Activated Carbon Aerogels depends on the micropore size.



Carbon Aerogels



Electrochemical properties of carbon xerogels coated with poly(p-fluorophenylthiophene)



Carbon xerogel

PFPT-coated carbon xerogel





Conductive polymer/Carbon Nano-Composite

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Rate performance of PFPT coated on carbon xerogels

Optimum thickness 200 nm (PFPT content in electrodes >90%)





<u>Electrochemical reactions of N-hetero cyclic</u> compounds

Reduction of pyridinic N

in aqueous solvent



Reduction of quaternary N

in aprotic solvent





Template Carbons from Melamine Precursor





Pseudocapacitance on nitrogen-enriched carbon surface



Kodama M et al., *Mat Sci Eng B-Solid* 2004;108 (1-2):156-161.



Melamine/MgO template method





Specific capacitance (at 40 mA/g) vs. melamine/MgO mixing ratio



40% H₂SO₄ RE:Ag/AgCl



Rate characteristics (high rate discharge)



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Summary

~Nanocarbons for capacitor~

- Controlled pore structure
 - Carbon aerogels, carbon nanofibers & nanotubes, mesoscopic carbons, exfoliated carbon fibers
- Nitrogen substitution in carbon network

 Nitrogen functionality, change in electronic structure
- Combining with pseudocapacitance materiasls
 - Polymer nano-coating on carbon aerogels, carbon coated W and Mo carbides,



Acknowledgement

 This work was supported by Research and Development of Nanodevices for Practical Utilization of Nanotechnology Program in 2008 from the New Energy and Industrial Technology Development Organization (NEDO) of Japan.