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| Author(s): | Yen, Hung-Ju |
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| Issued: | 2016-11-14 |

# *Organic Synthetic Advanced Materials for Optoelectronic and Energy Applications (at Center for Condensed Matter Sciences)*

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**Chemistry Division, Los Alamos National Laboratory (LANL), New Mexico, USA**

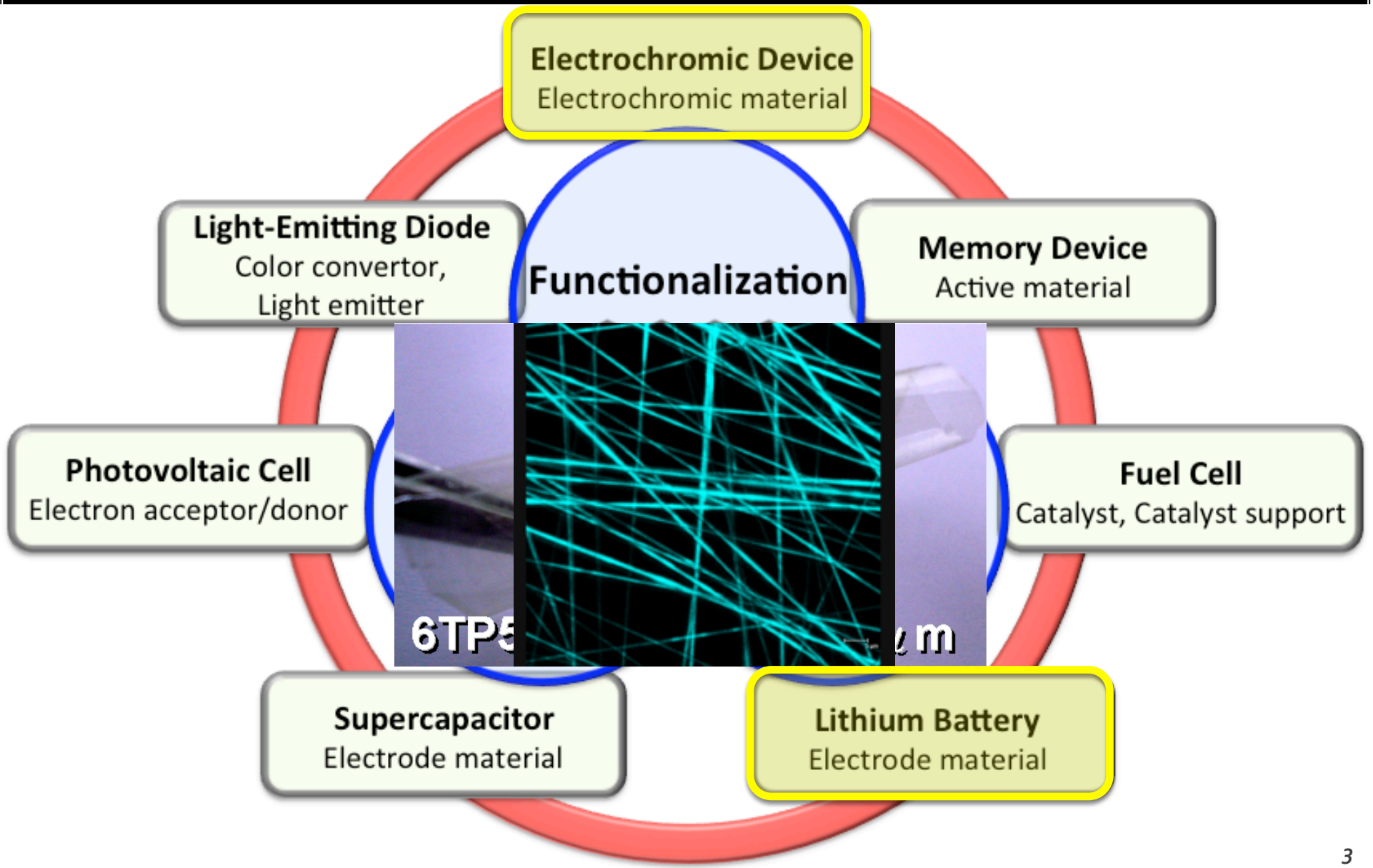
**Dec. 23, 2016**

國立臺灣大學 凝態科學研究中心

# Professional Experience And Education

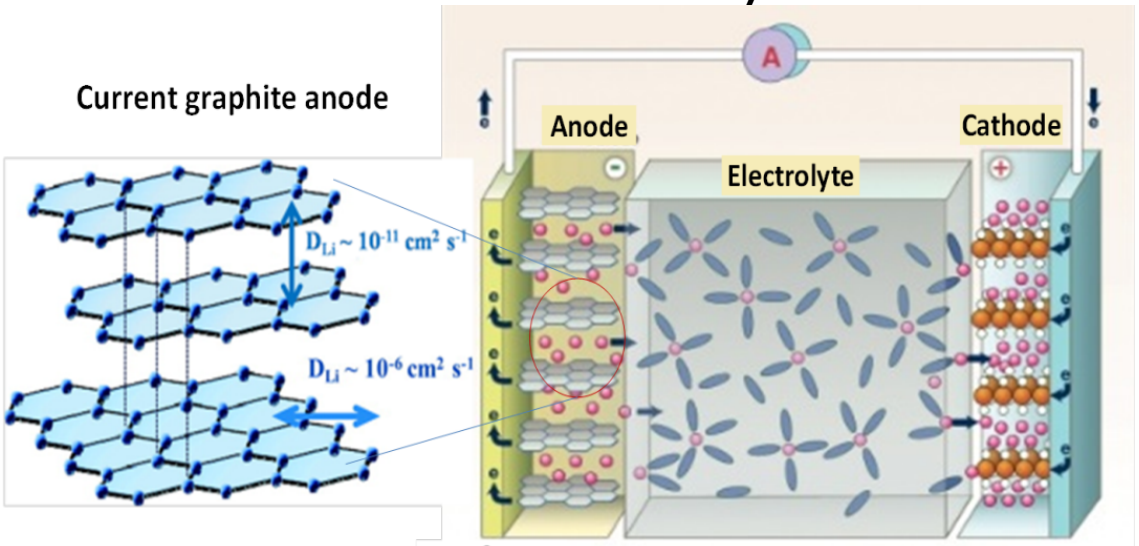
- Jan. 2014-*present*,
  *J. Robert Oppenheimer Distinguished Postdoctoral Fellow*, LANL
- May 2013-Jan. 2014,
  *Director's Postdoc Fellow*, LANL
- Feb.-Aug. 2011 & July 2012-May 2013,
  *Postdoctoral Researcher*, National Taiwan University (NTU)
- July-Sep. 2009,
  *Visiting Doctoral Researcher*, Tokyo Institute of Technology

- Jan. 2011, *Ph.D. with 1st prize*, (4.0/4)
  Institute of Polymer Science and Engineering, NTU
- June 2007, *M.S. with Honors*, (3.8/4)
  Department of Applied Chemistry, National Chi Nan University
- June 2006, *B.S.*, (3.2/4)
  Department of Applied Chemistry, National Chi Nan University


Electrochromic Device
Electrochromic material
Light-Emitting Diode
Color convertor,
Light emitter
Functionalization
Memory Device
Active material
Photovoltaic Cell
Electron acceptor/donor
Fuel Cell
Catalyst, Catalyst support
Supercapacitor
Electrode material
Lithium Battery
Electrode material

# Current Challenges for LIBs

**Lithium-Ion Battery**




**Challenges:**

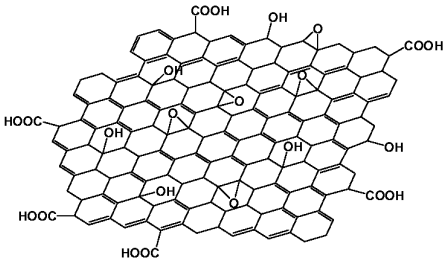
- Insufficient capacity – Li adsorption sites
- Slow charging rate – Li diffusivity
- Cycling stability – Structural instability
- Energy density (Wh/Kg) – Light weight required

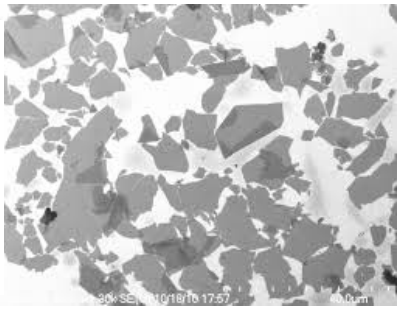
**Solution:** Advanced Nanomaterials


***Development of advanced nanomaterials is required to overcome these challenges***

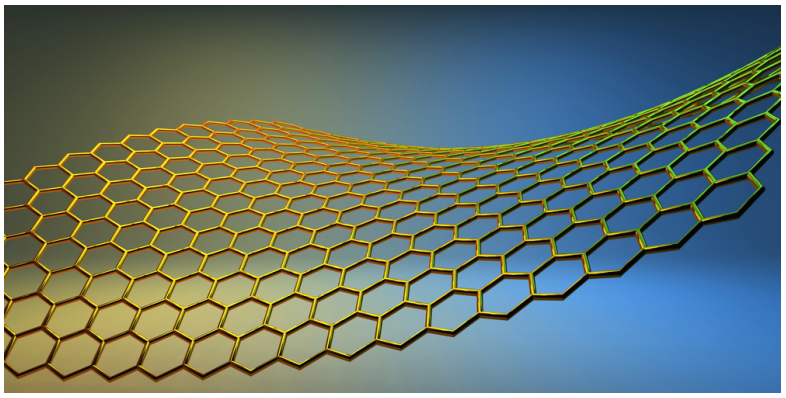
# Graphene, Graphene Oxide and Nanographene

## Graphene Oxide



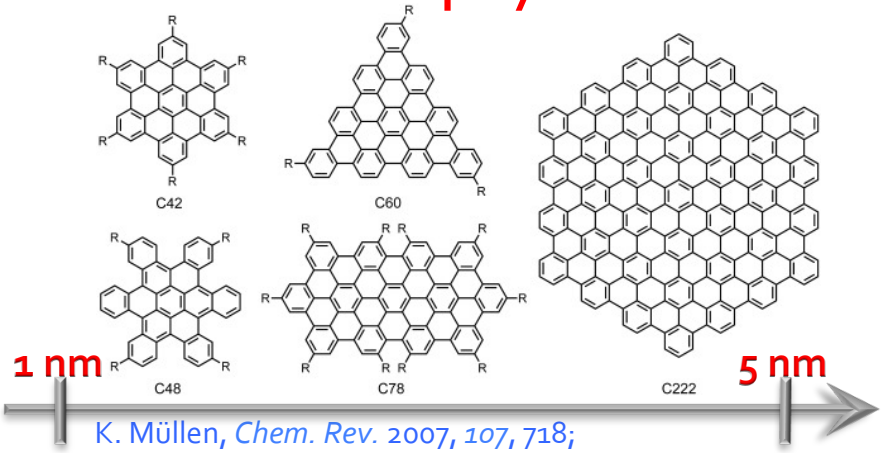



## Graphene

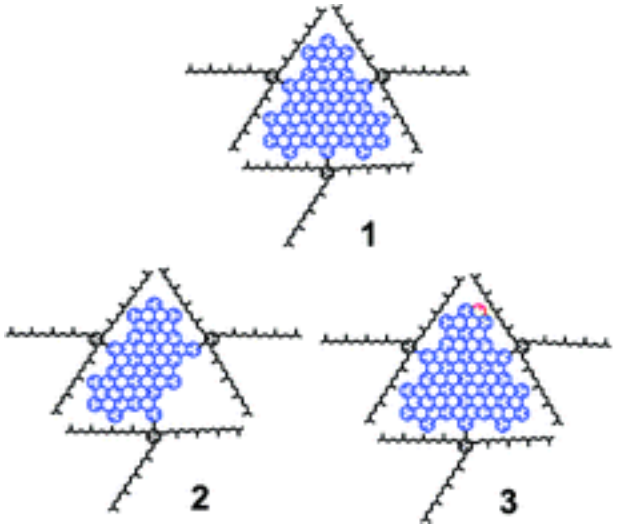


**Exfoliation of Graphite**
**Chemical Vapor Deposition**

## Precise Bottom-Up Synthesis

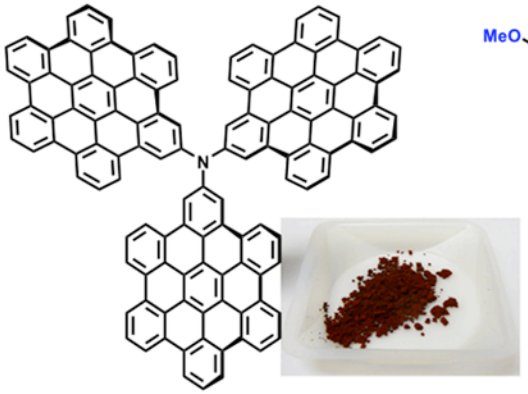



K. Müllen, *Chem. Rev.* 2007, *107*, 718;

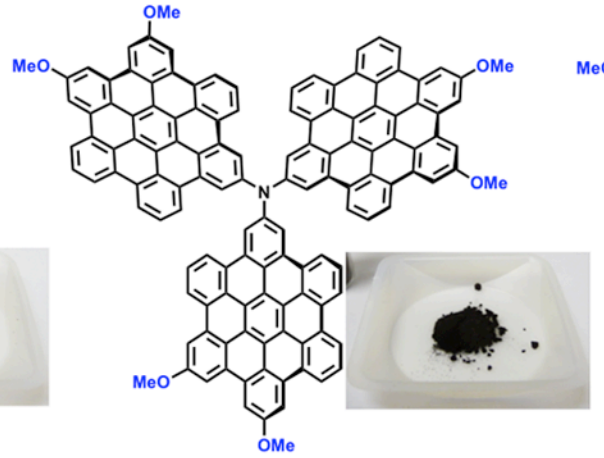



Li et al., *J. Am. Chem. Soc.*, 2010, *132*, 5944.

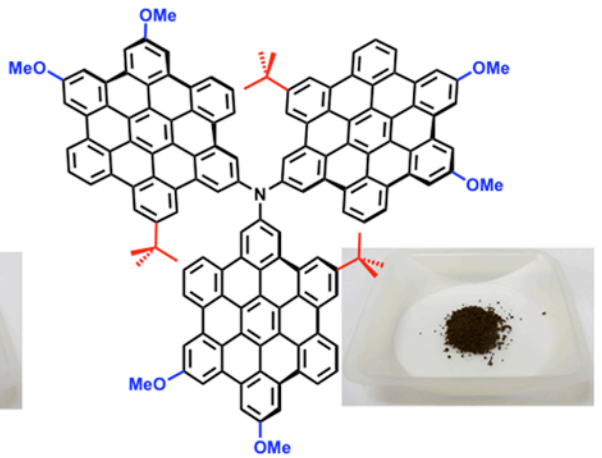
# Nanographenes with Various Functional Groups



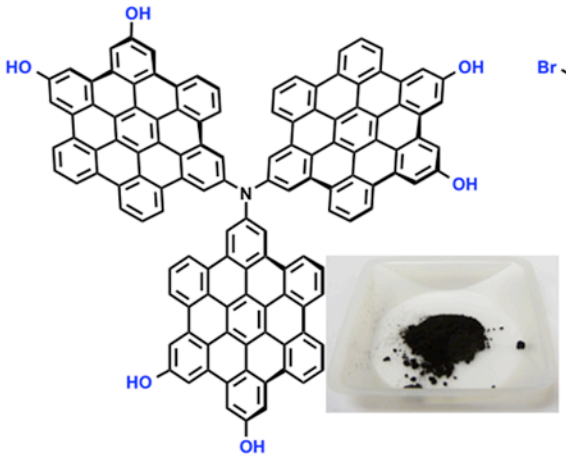
HBC-H



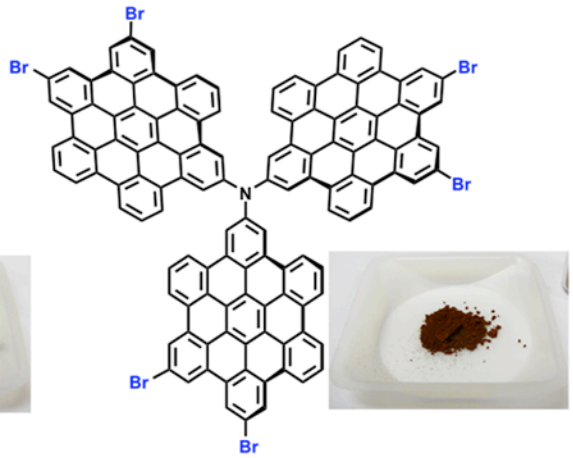

HBC-OMe



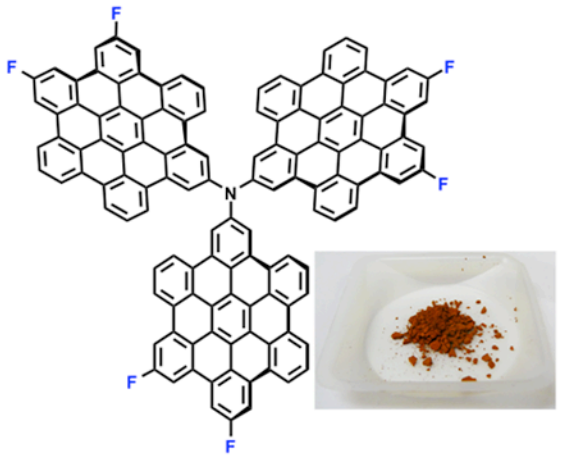

HBC-*t*BuOMe




HBC-OH



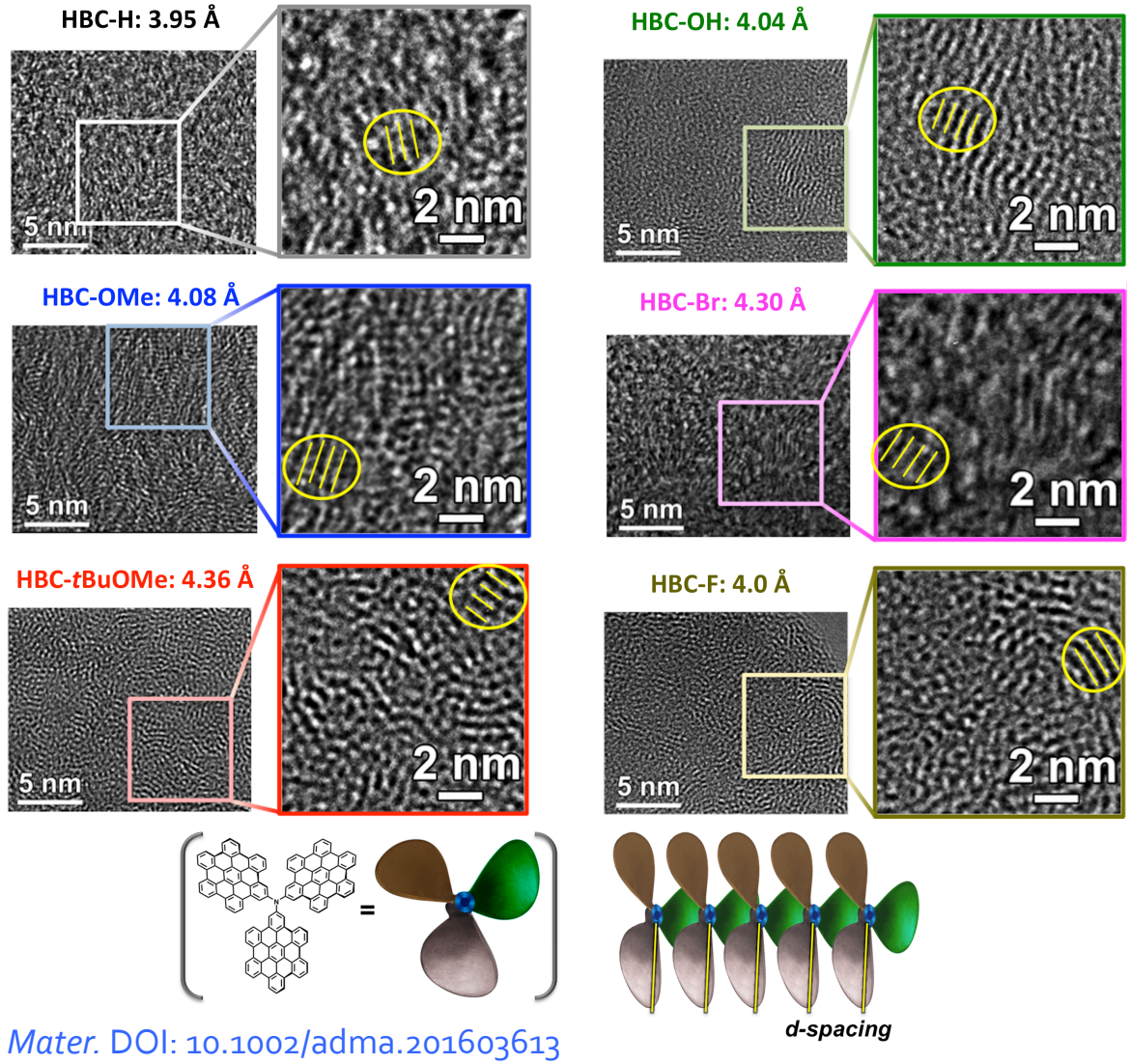

HBC-Br

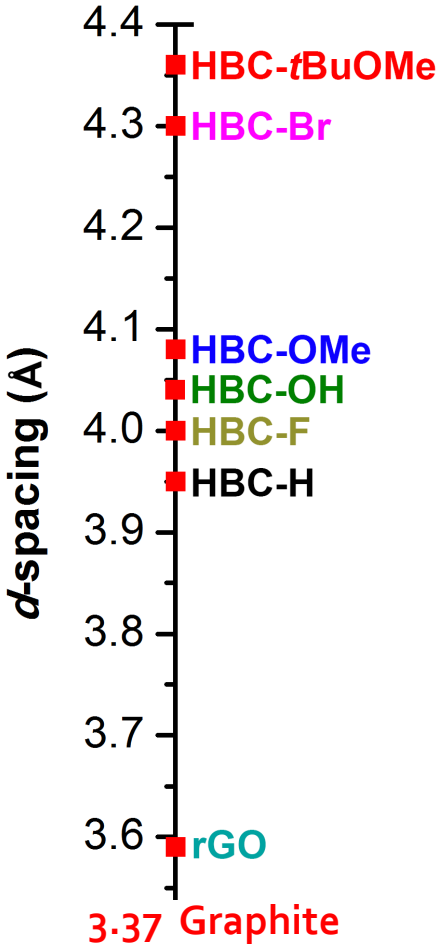



HBC-F

*Adv. Mater.* DOI: 10.1002/adma.201603613

# Fine Tune *d*-Spacing through Organic Synthesis: Varying Functional Group

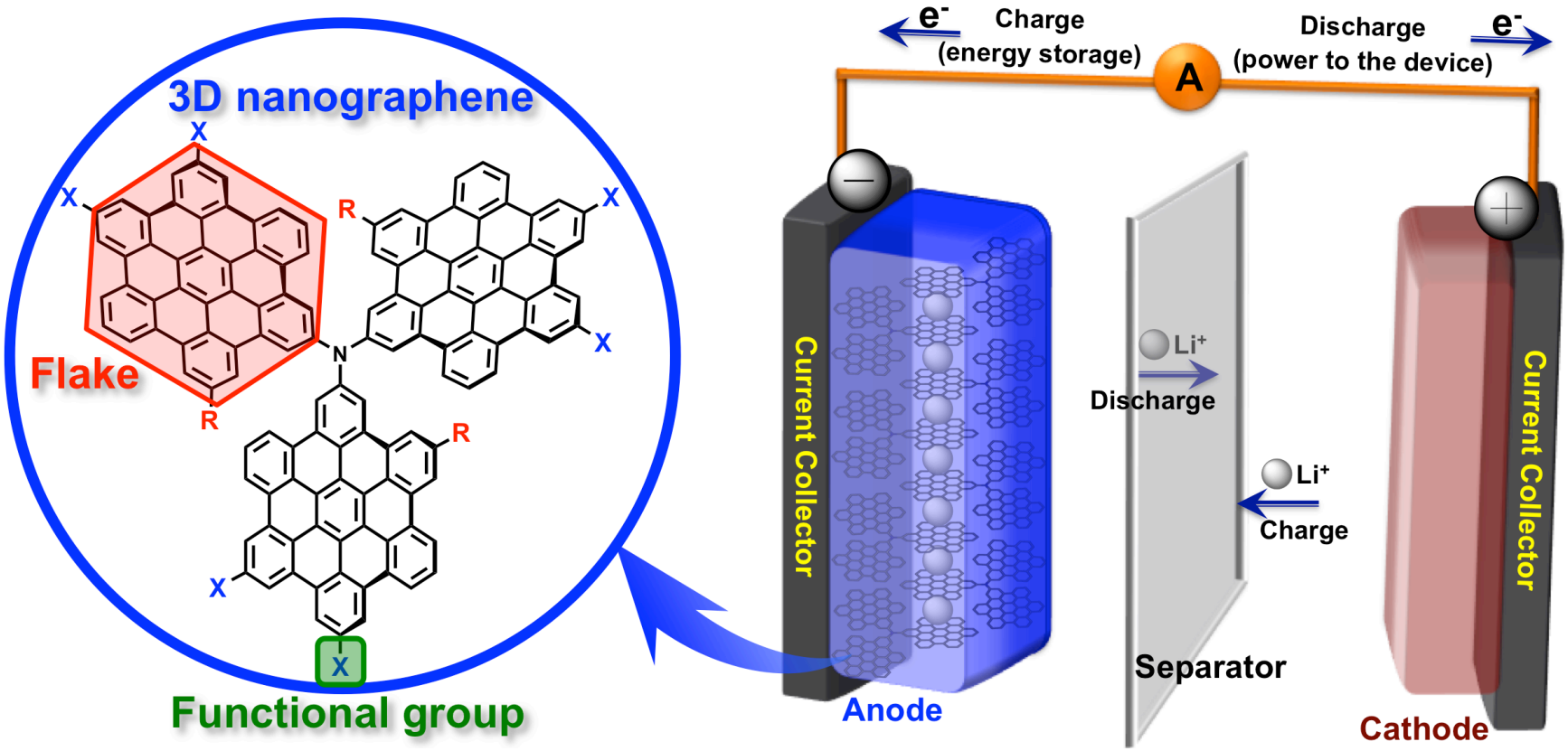



*Adv. Mater.* DOI: 10.1002/adma.201603613

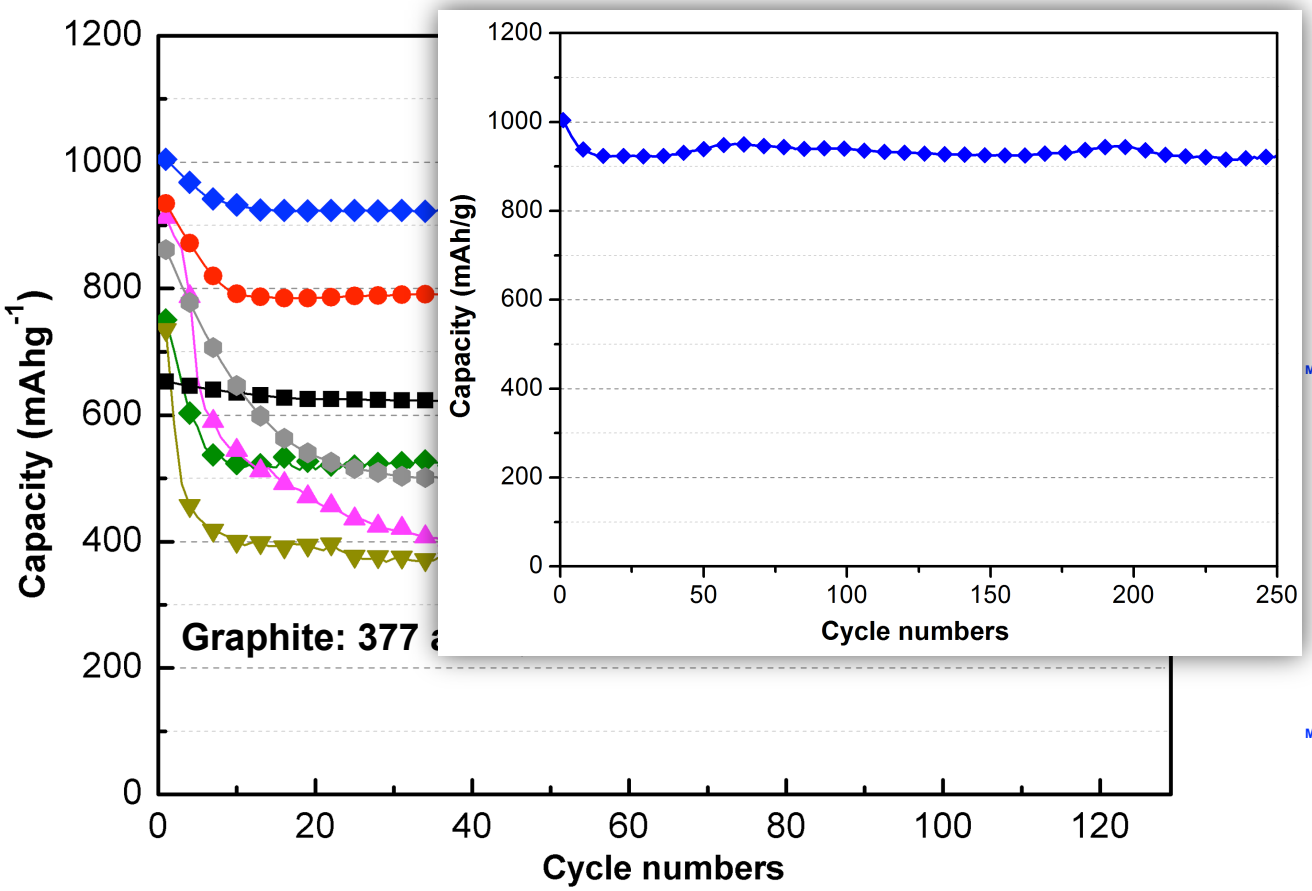
*TEM courtesy of Aiping Chen*

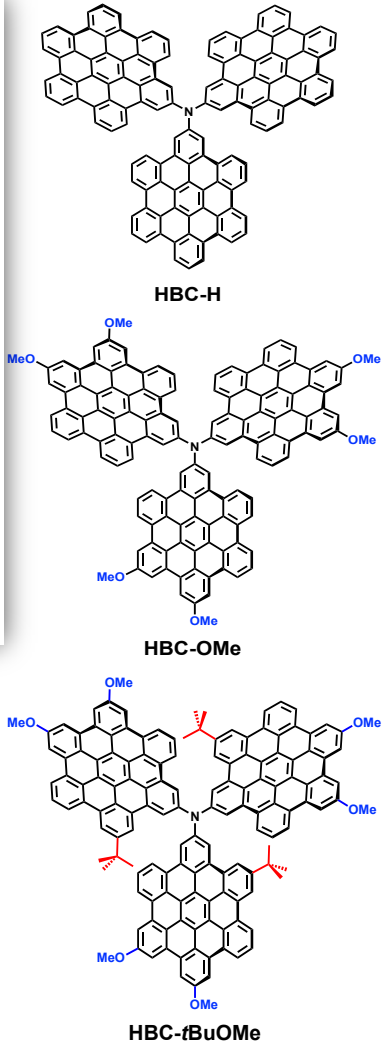
# Schematic View of LIBs




*Adv. Mater.* DOI: 10.1002/adma.201603613

# Nanographenes as LIB Anode

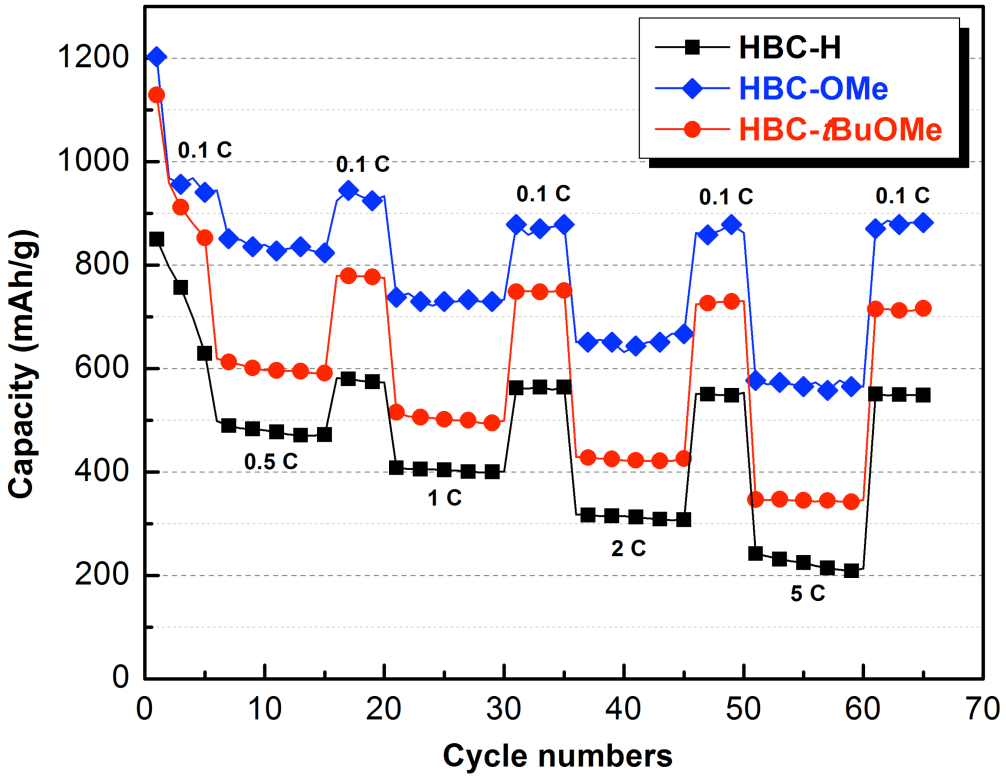


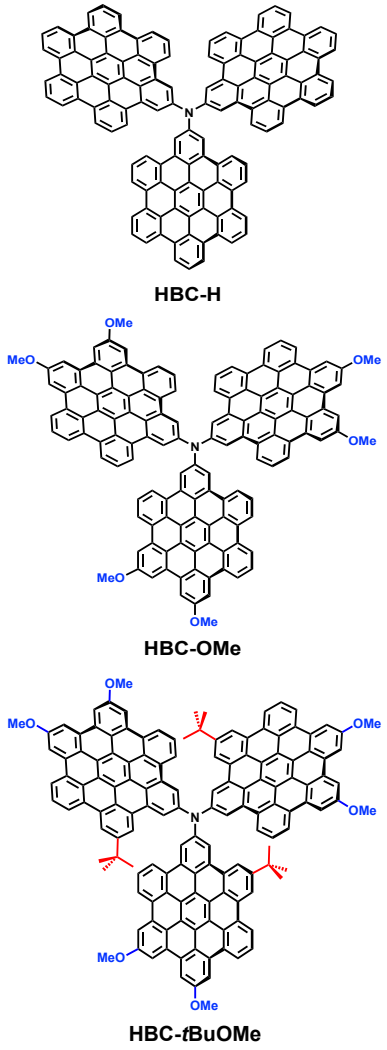




- **These NG anode LIBs exhibiting stable cycle stability.**
- **Capacity: OMe > *t*BuOMe > H > OH > Br > F**

*Adv. Mater.* DOI: 10.1002/adma.201603613

# Rate Performance (Charging-Discharging)




Excellent rate performance achieved on the NG **HBC-OMe** anode, evidenced by the high capacity at high charging-discharging current.

Comparative study between **HBC-OMe**, **HBC-*t*BuOMe** and **HBC-H** reveals electron donating group enhance the rate performance.

*Adv. Mater.* DOI: 10.1002/adma.201603613

# Electrochromism

**Electrochromic theory**
**J. R. Platt**
*J. Chem. Phys.* **1961**, *34*, 862

**Electrochromic devices**
**S. K. Deb**
*Appl. Optics, supp.* **1969**, *3*, 192

# Electrochromic Technology

- ***Electrochromic Display (NTera®)***


U. Bach et al. *Adv. Mater.* **2002**, *14*, 845

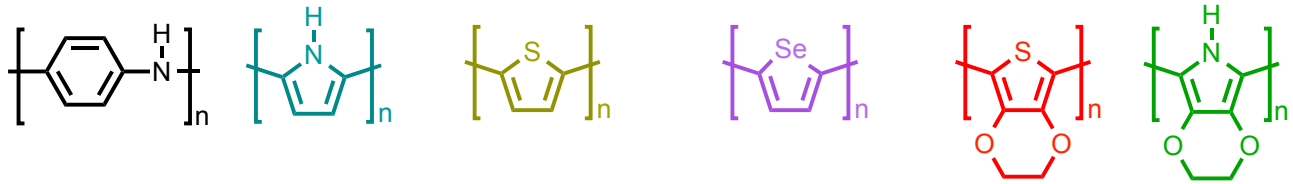
***Anti-Glare Back Mirror***

***Smart Window***

***Smart Sunglasses***

# Electrochromic Materials

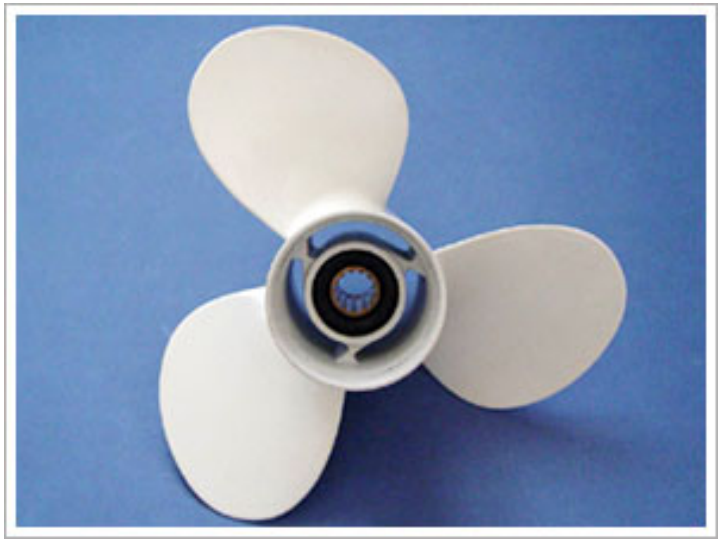
- **Metal oxides (*$WO_3$*, *$IrO_2$*, *$MoO_3$*, *etc.*)**
- **Mixed-valence metal oxides complex (*Prussian Blue; $Fe^{III}[Fe^{II}(CN)_6]^-K^+$*)**
- **Small organic molecules (Viologens and phthalocyanines)**
- **Electroactive polymers (PPy, PT, PEDOT, etc.)**




***Polyaniline*** ***Polypyrrole*** ***Polythiophene*** ***Polyselenophene*** ***PEDOT*** ***PEDOP***

# Advantages of Triphenylamine

- Hole Transporting Material
- High Electron Mobility
- Low Ionization Potential
- Electrochemical Stability
  - Reversible Redox Couple
- Processability
  - Good Solubility
- Thermal Stability
  - High Glass Transition Temperature ($T_g$)
  - High Thermal Stability ($T_d$)



# Requirement of Electrochromic Materials for Practical Applications

(1) Low driving voltage (< 1.5 or 3.5 V)

(2) Rapid response time [second (mirror)~ minute (window)]

(3) High color contrast (transmittance attenuation=ΔT> 30% )

(4) Long cycle life (>10 yr for window, >3yr for mirror)

(5) Environmental stability (electrochemical, thermal, & UV)

(6) Low cost, easy processing

(7) Multiple colors with the same material

*Polym. Chem.* **2012**, *3*, 255-264

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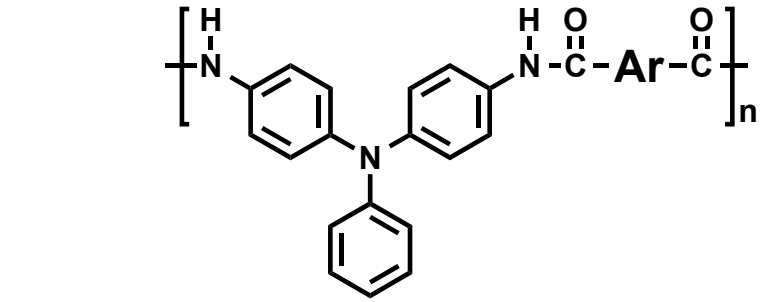
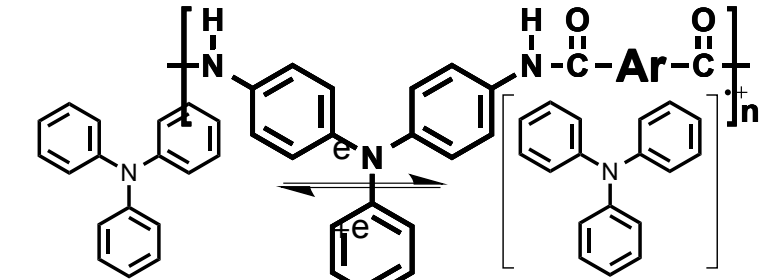
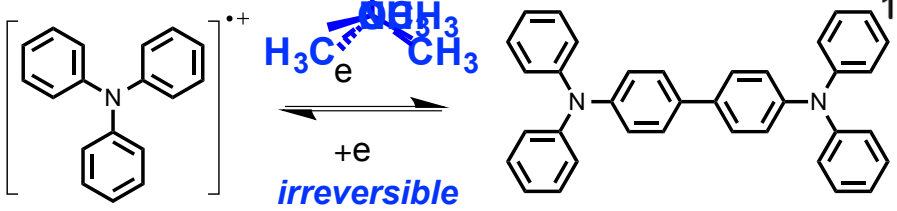
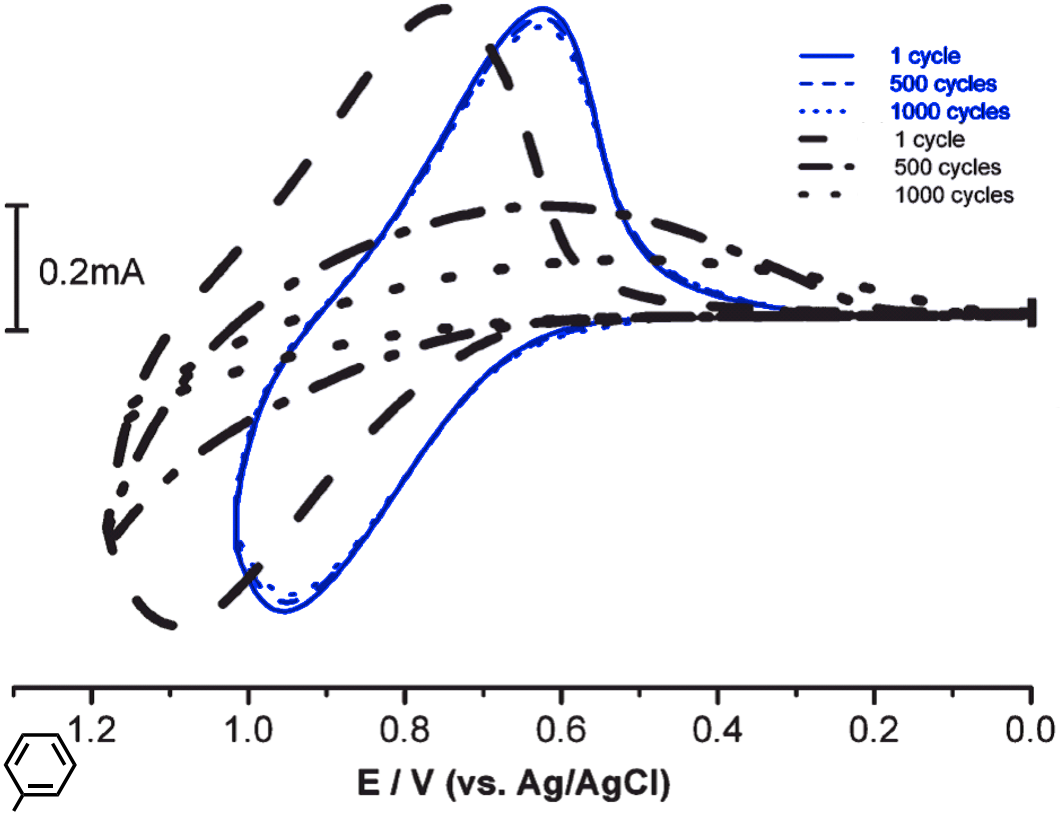
*Polym. Chem.* **2012**, *3*, 255-264

# Low driving voltage & Long cycle life








*Polym. Chem.* **2012**, *3*, 255-264
*J. Mater. Chem.* **2008**, *17*, 1007-1015
*Macromolecules* **2008**, *41*, 2800-2808

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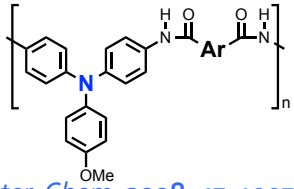
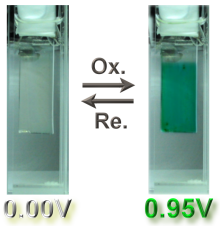
(7) **Multiple colors with the same material**

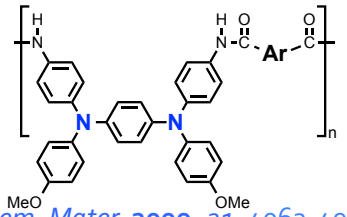
*Polym. Chem.* **2012**, *3*, 255-264

# Increasing the electroactive sites by multi-step synthetic procedures.

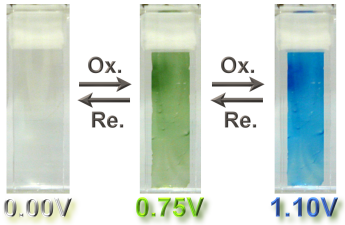


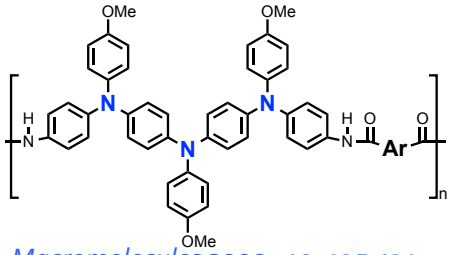

*J. Mater. Chem.* **2008**, *17*, 1007-1015



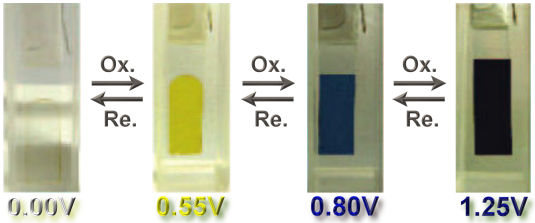



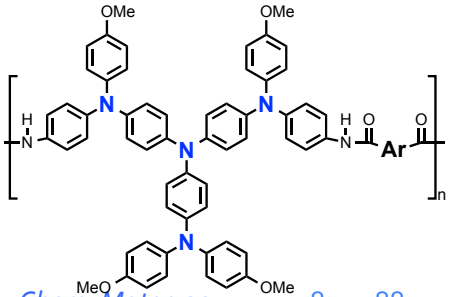

*Chem. Mater.* **2009**, *21*, 4062-4070



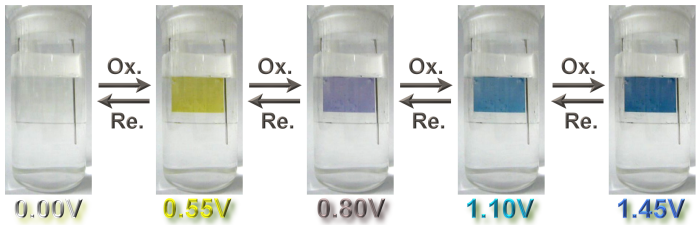




*Macromolecules* **2009**, *42*, 125-134



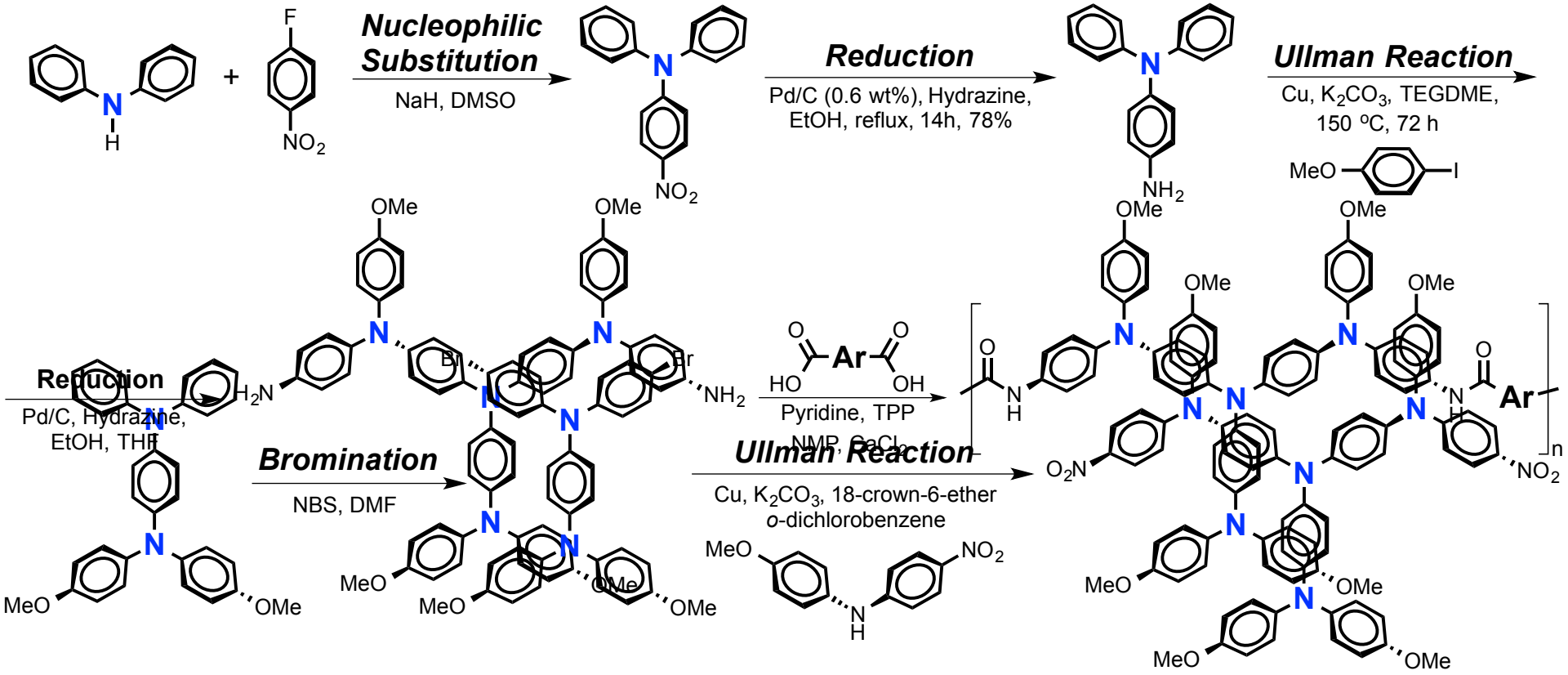




*Chem. Mater.* **2011**, *23*, 1874-1882

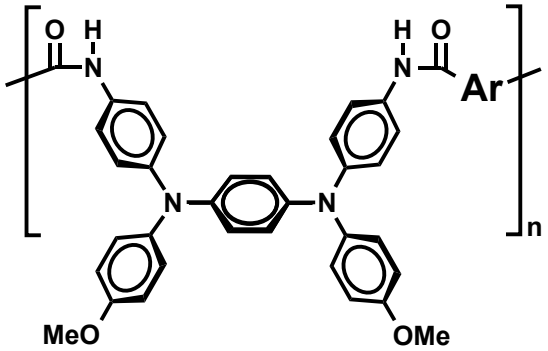


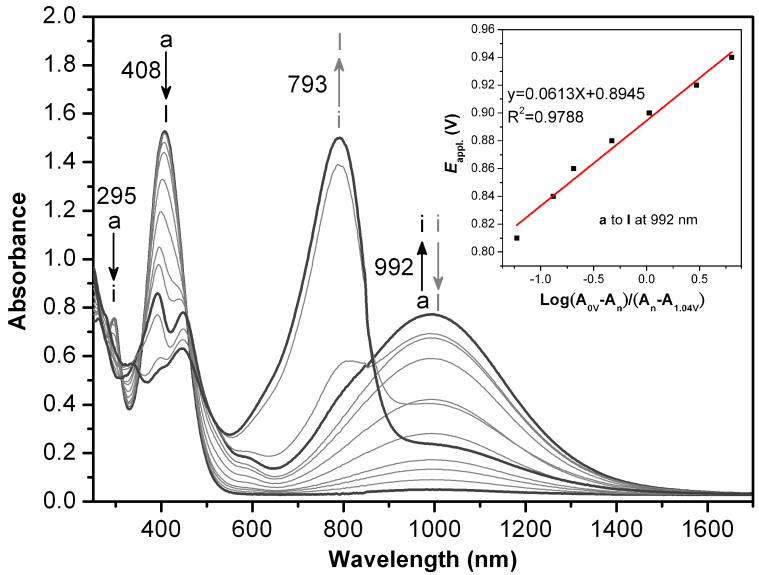

*Polym. Chem.* **2012**, *3*, 255-264

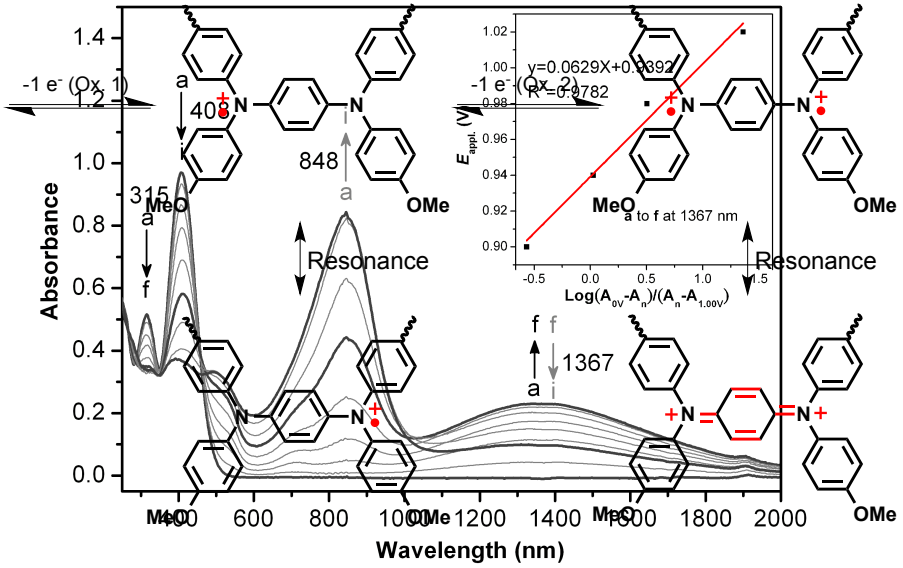
# Synthetic route to Starburst Triarylamine-based Polyamide



# Electrochromism ranging from visible to NIR region

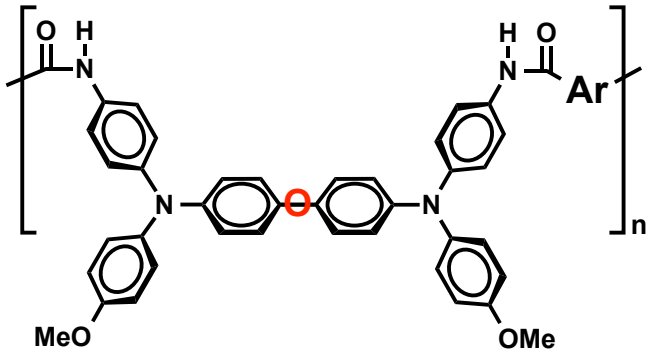


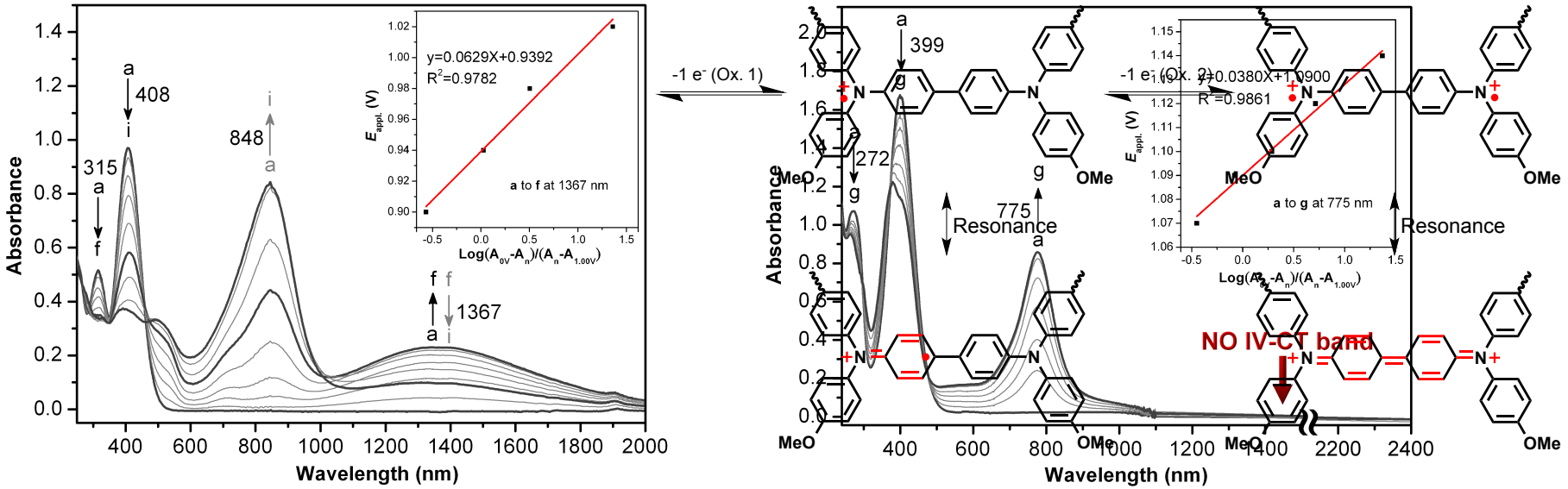




*Chem. Mater.* **2009,** *21,* 4062-4070
*J. Mater. Chem.* **2011,** *21,* 6230-6237

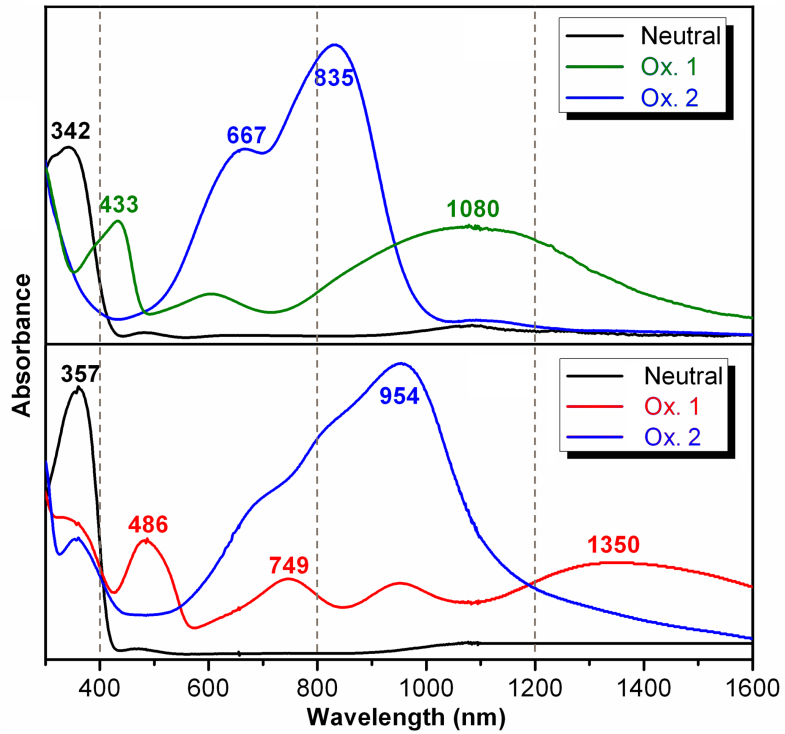
# Electrochromism ranging from visible to NIR region

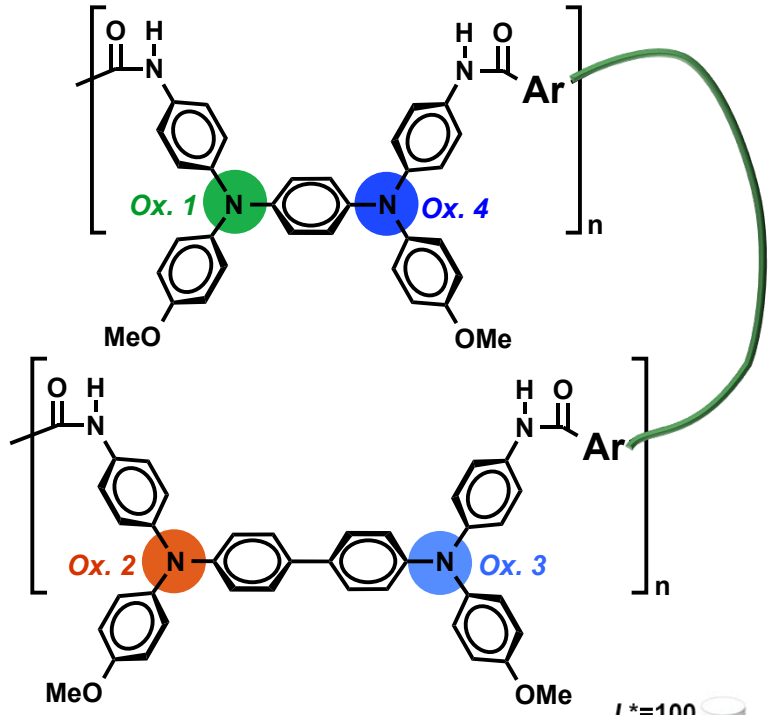


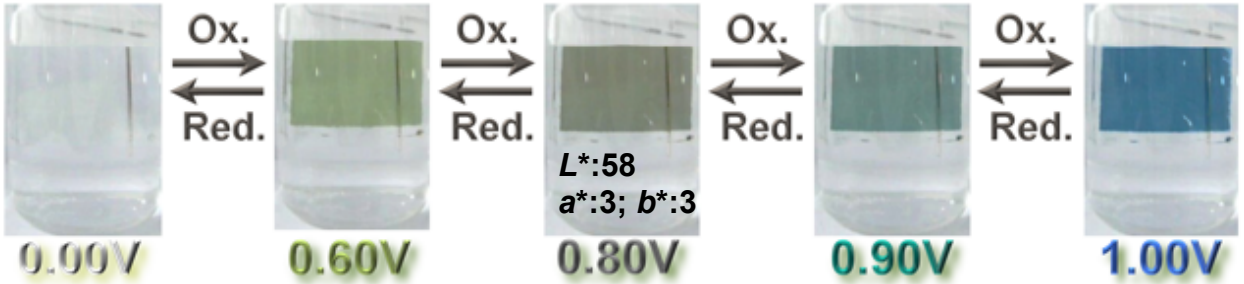



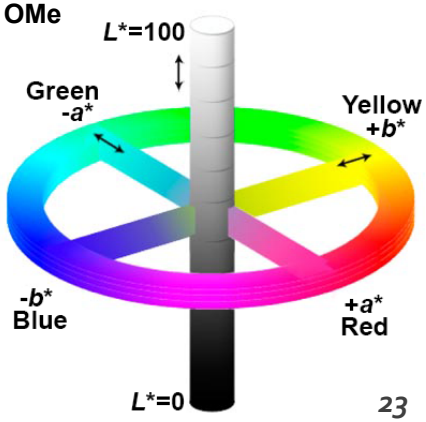

*JPS-A.* **2011**, *49*, 3805-3816
*J. Mater. Chem.* **2011**, *21*, 6230-6237

# Transmissive to Black Electrochromism



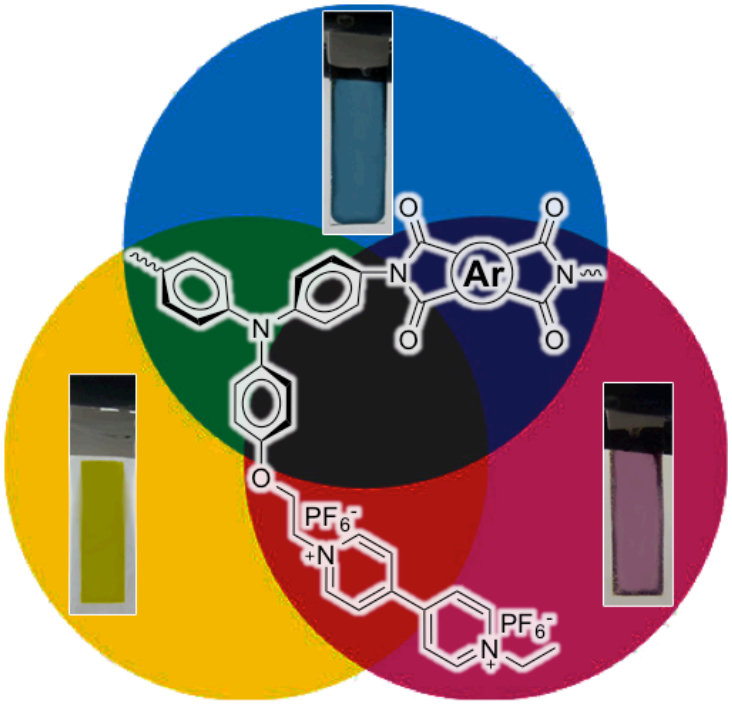



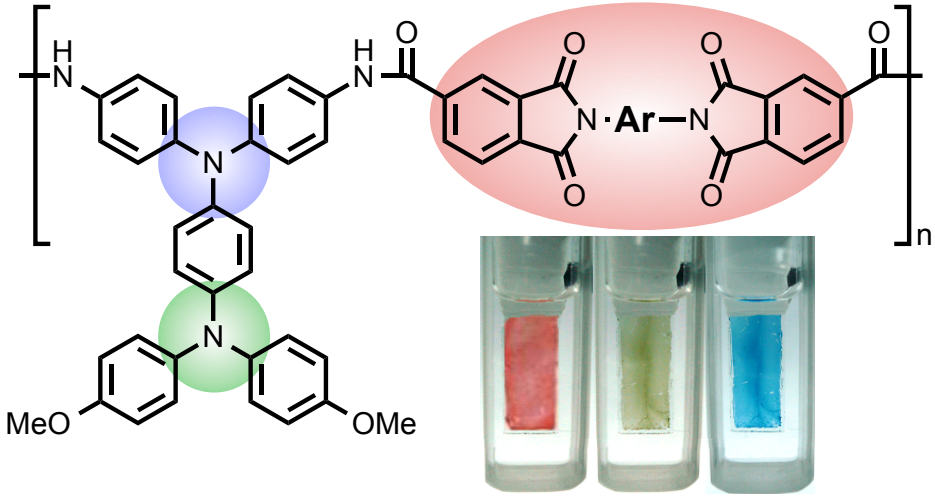




*Chem. Mater.* **2009,** *21,* 4062-4070
*J. Mater. Chem.* **2011,** *21,* 6230-6237

# RGB & CMY Electrochromism



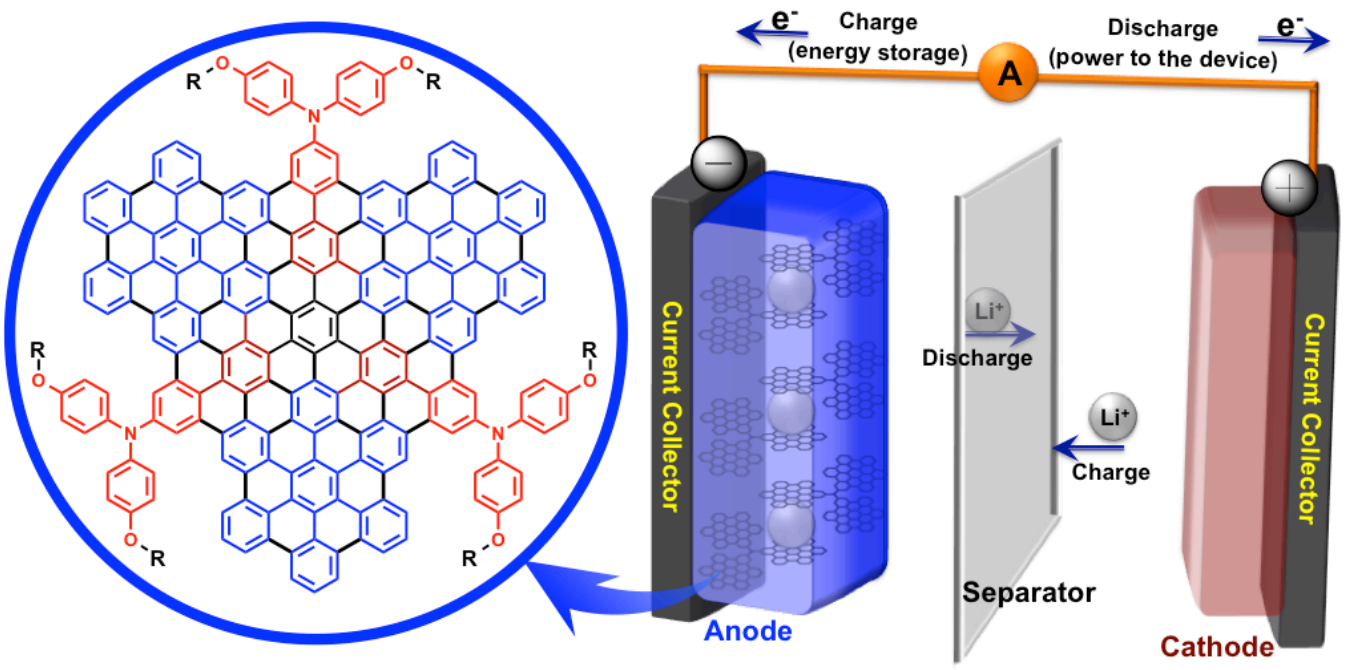

*JPS-A* **2010**, *48*, 4747-4757

*Nanoscale* (Under revision)

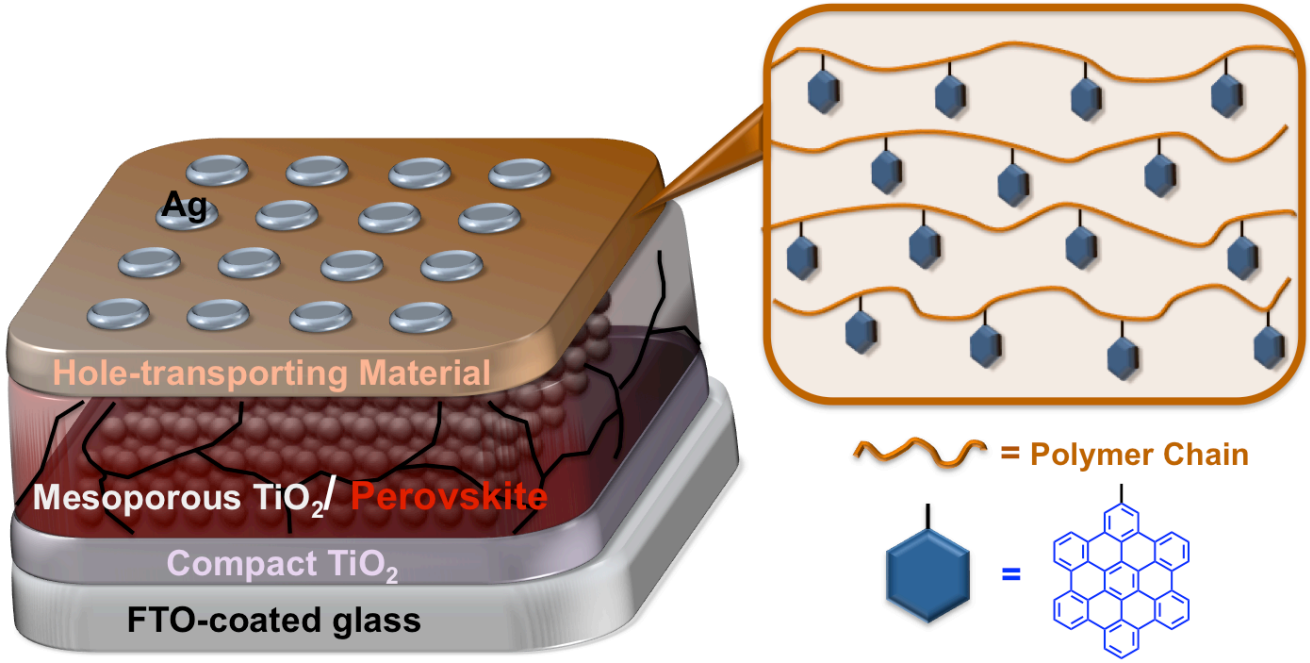
# Summary

- This talk covered my recent work in the synthesis and structural design of functional materials, which were further used for optoelectronic and energy applications, such as **lithium ion battery**, **solar cell**, **LED**, **electrochromic**, and **fuel cells**.

# 未來規劃1


e⁻
Charge
(energy storage)
A
Discharge
(power to the device)
e⁻
Current Collector
Li⁺
Discharge
Li⁺
Charge
Separator
Current Collector
Anode
Cathode

# 未來規劃2


Ag
Hole-transporting Material
Mesoporous TiO2/ Perovskite
Compact TiO2
FTO-coated glass
= Polymer Chain
=