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Title: Organic Synthetic Advanced Materials for Optoelectronic and Energy Applications (at National Sun Yat-sen University)

Author(s): Yen, Hung-Ju

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***Organic Synthetic Advanced Materials for
Optoelectronic and Energy Applications
(at National Sun Yat-sen University)***

顏宏儒 (Hung-Ju Yen)

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

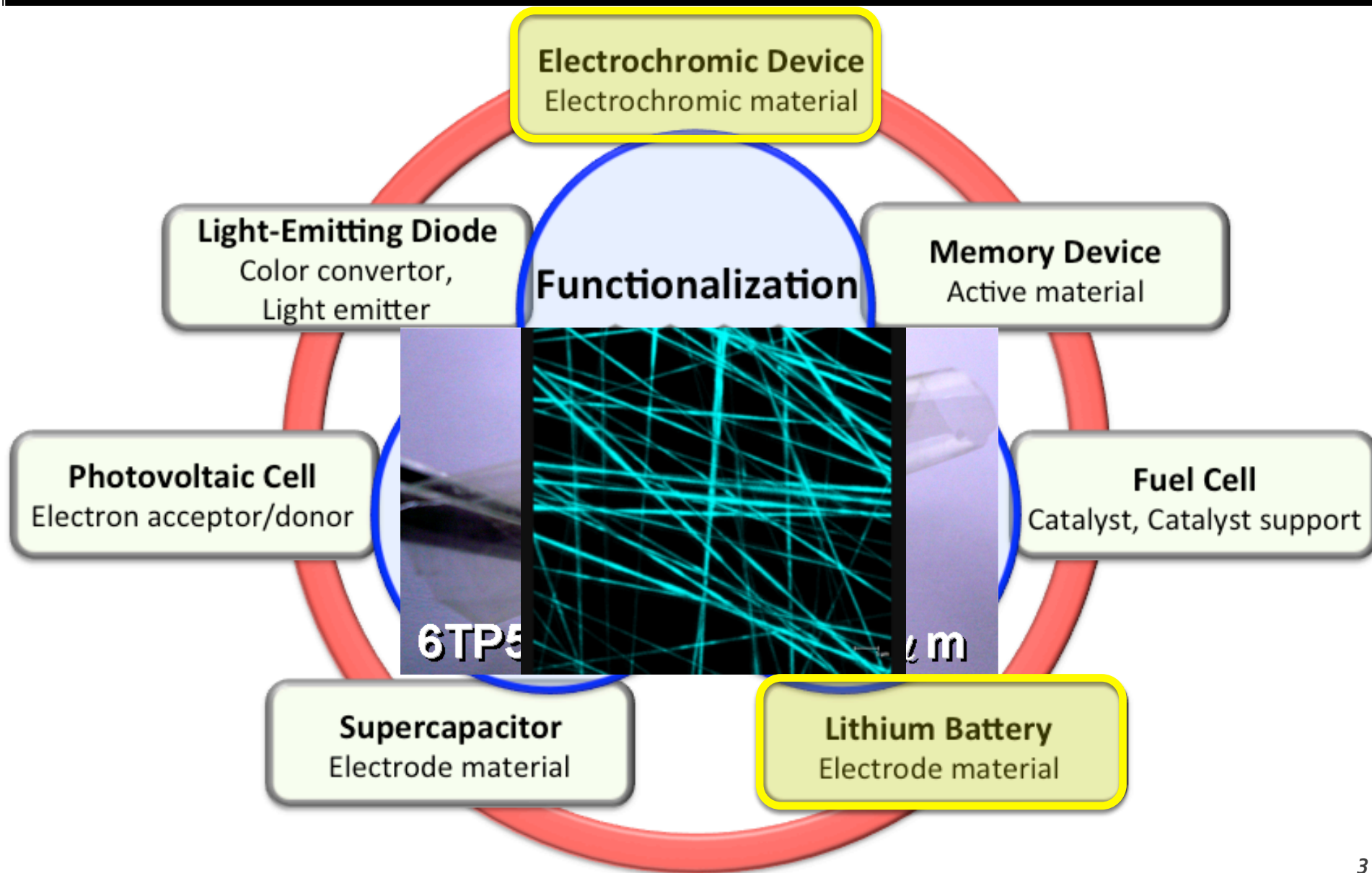
Dec. 13, 2016

國立中山大學 材料與光電科學學系

Professional Experience And Education

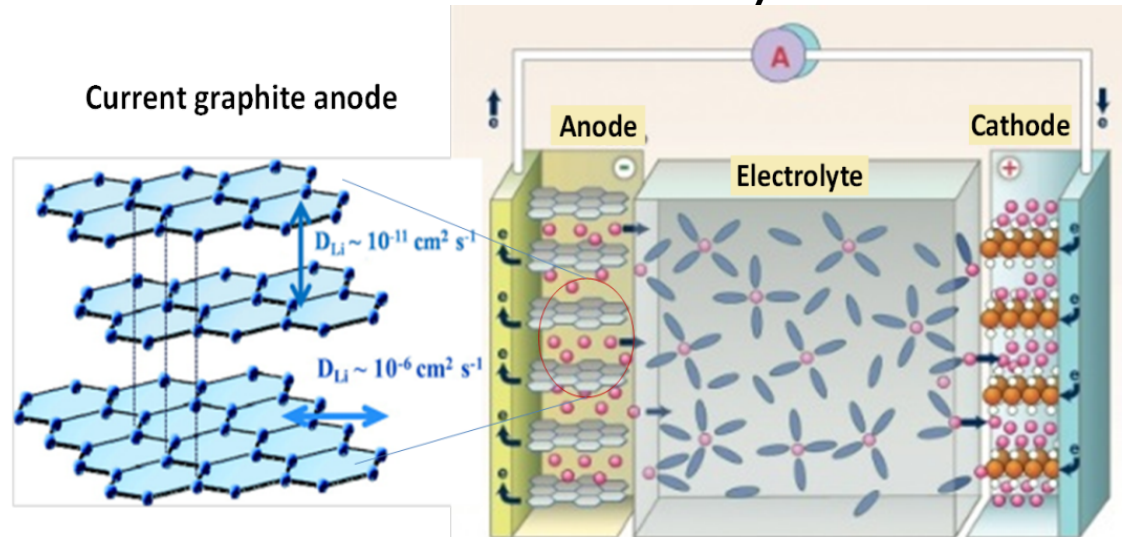
- Jan. 2014-present,
J. Robert Oppenheimer Distinguished Postdoctoral Fellow, LANL
- May 2013-Jan. 2014,
Director's Postdoc Fellow, LANL
- Feb.-Aug. 2011 & July 2012-May 2013,
Postdoctoral Researcher, National Taiwan University (NTU)
- July-Sep. 2009,
Visiting Doctoral Researcher, Tokyo Institute of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



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

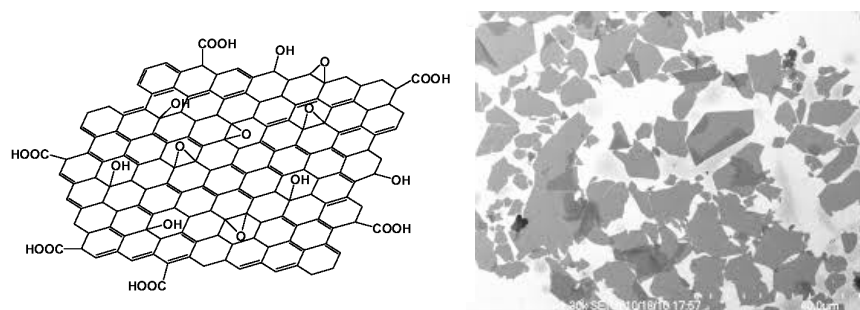
Solution: Advanced Nanomaterials



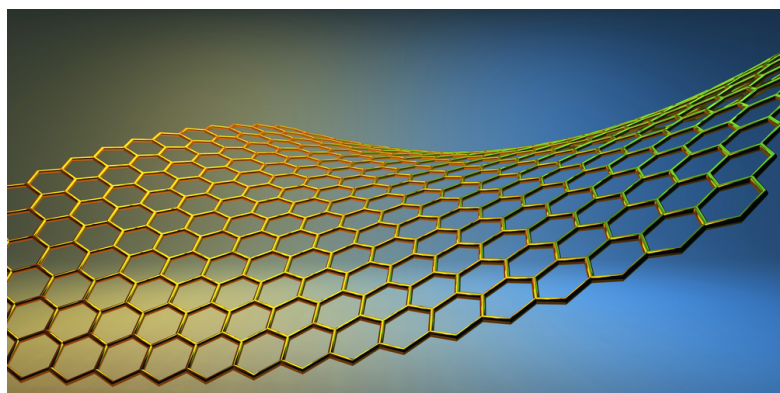
Development of advanced nanomaterials is required to overcome these challenges

Graphene, Graphene Oxide and Nanographene

Graphene Oxide

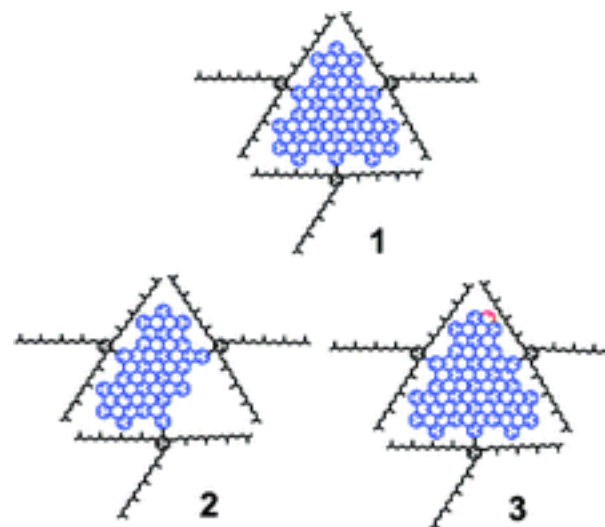
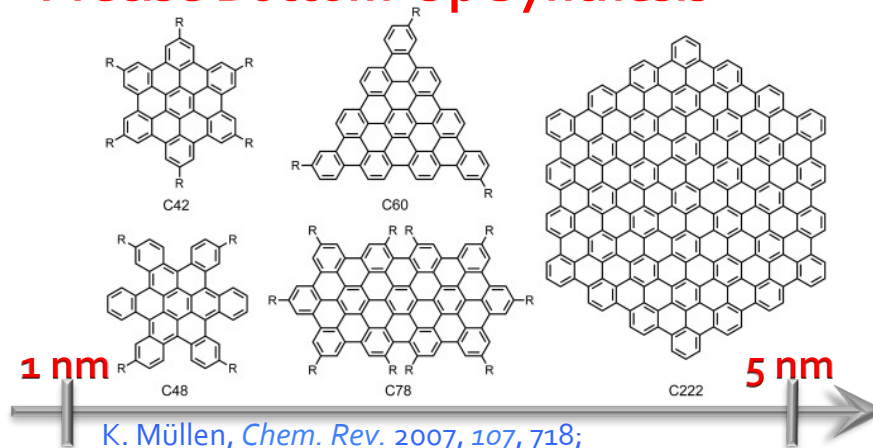


Graphene



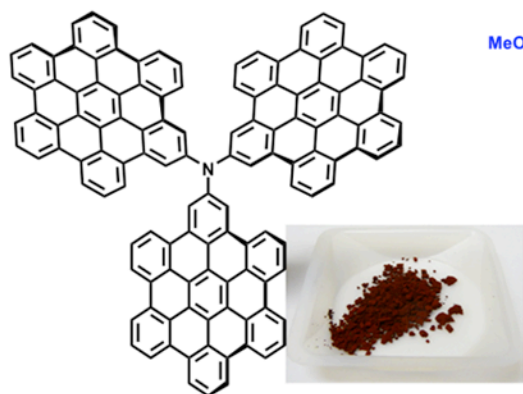
Exfoliation of Graphite
Chemical Vapor Deposition

Precise Bottom-Up Synthesis

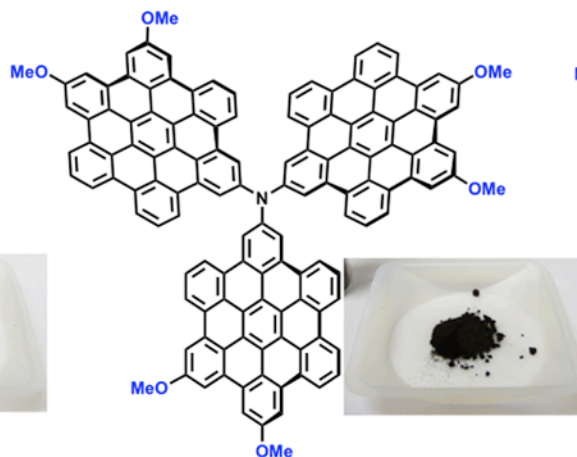


Li et al., *J. Am. Chem. Soc.*, 2010, 132, 5944.

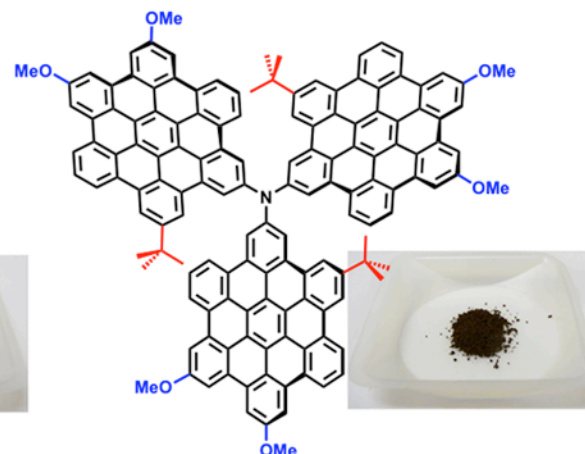
Nanographenes with Various Functional Groups



HBC-H



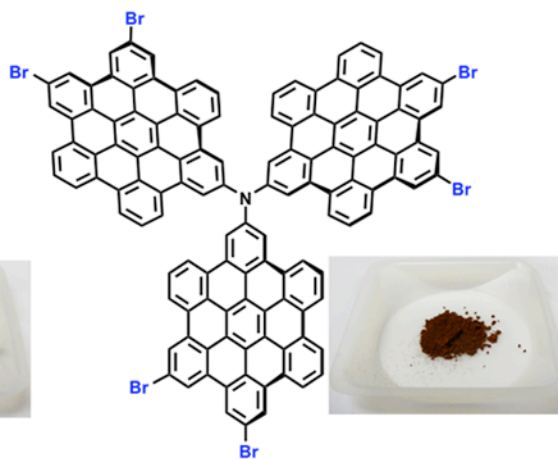
HBC-OMe



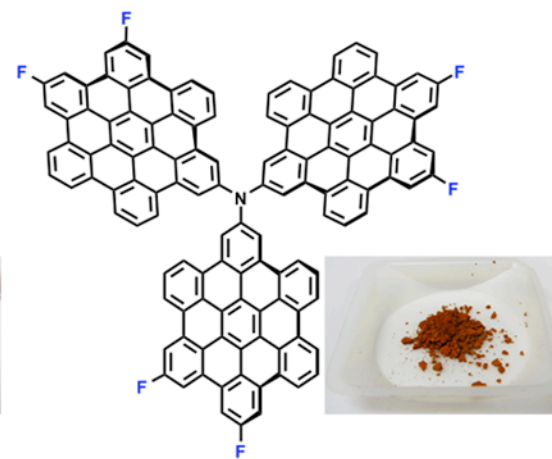
HBC-*t*BuOMe



HBC-OH

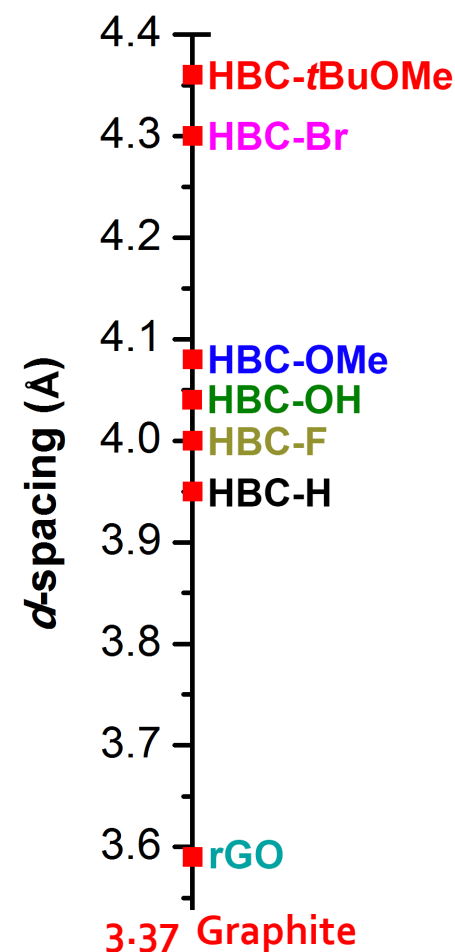
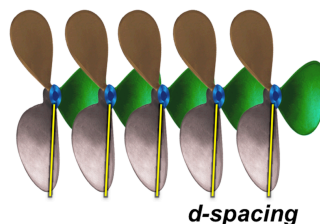
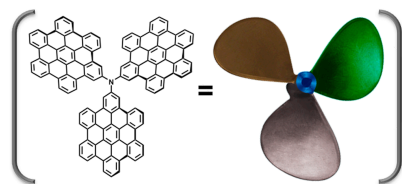
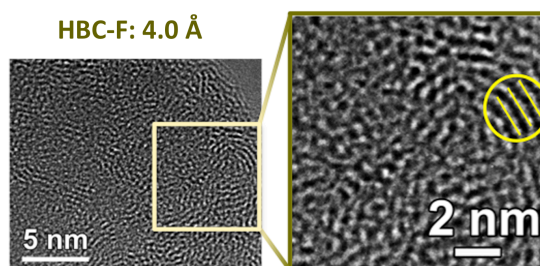
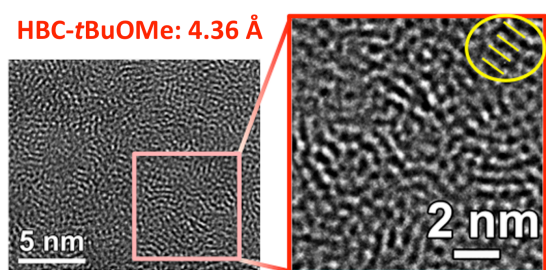
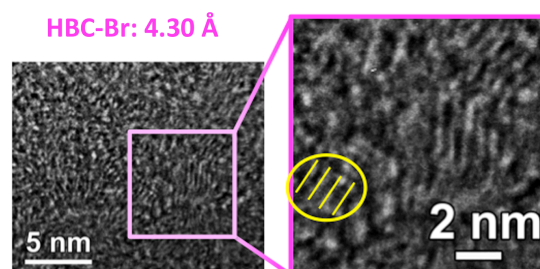
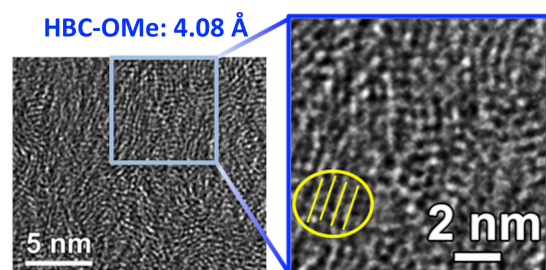
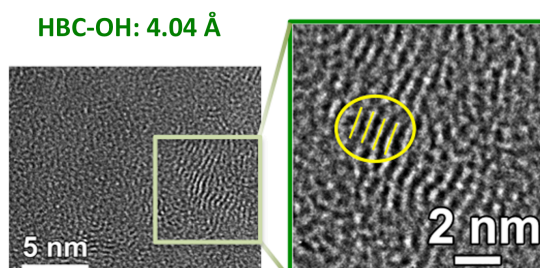
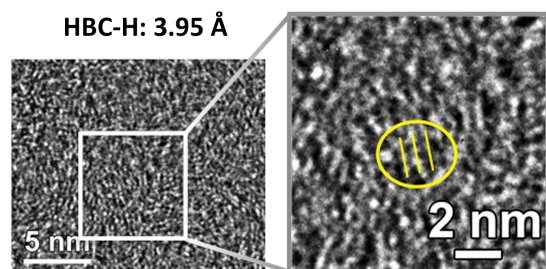


HBC-Br

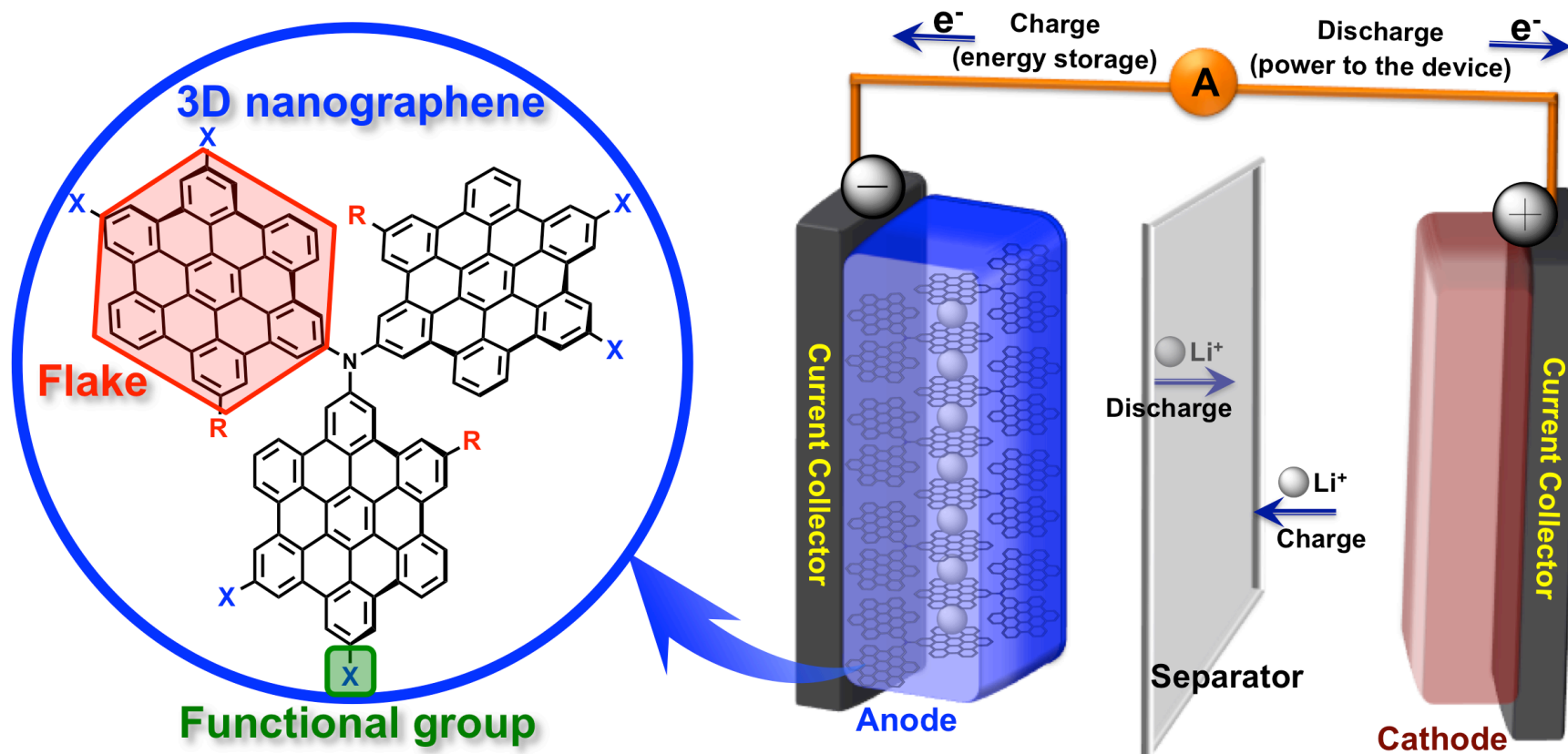


HBC-F

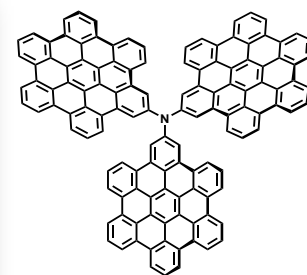
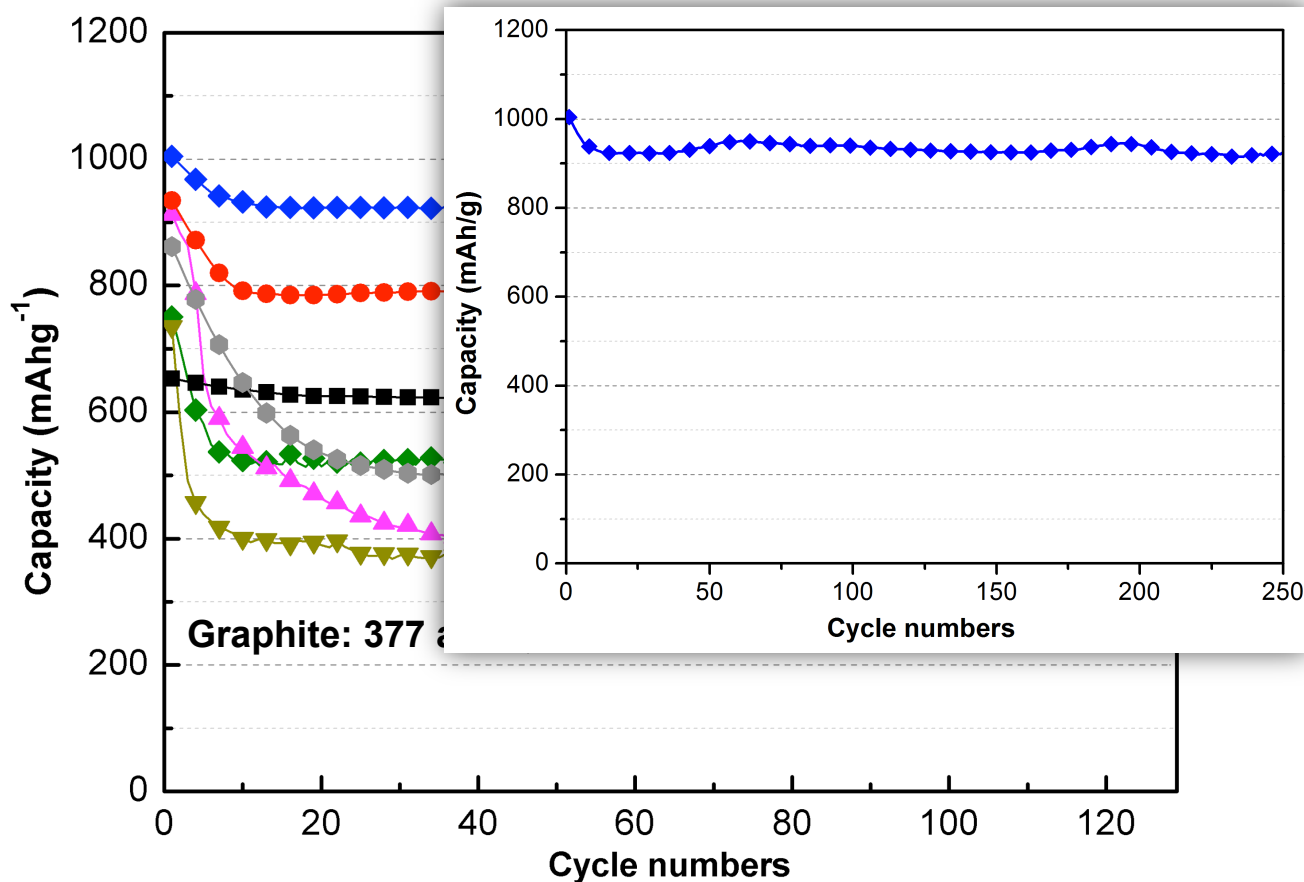
Fine Tune d -Spacing through Organic Synthesis: Varying Functional Group



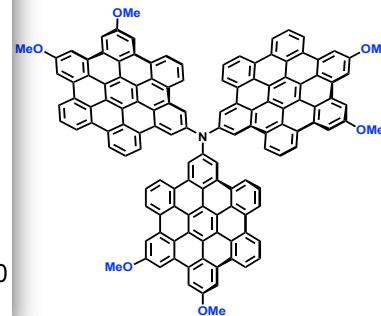
Schematic View of LIBs



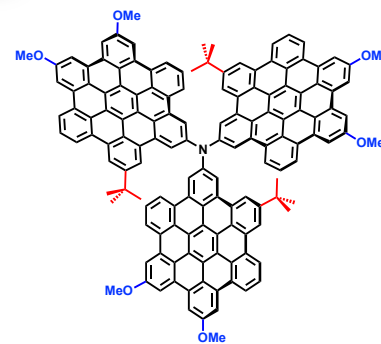
Nanographenes as LIB Anode



HBC-H



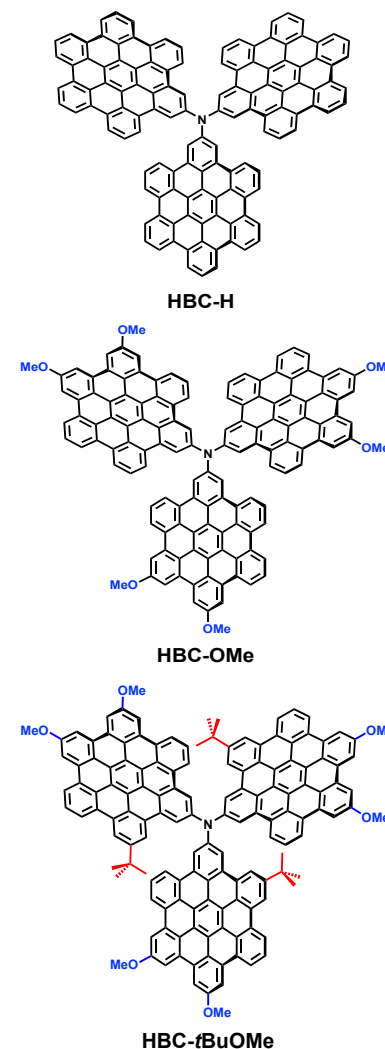
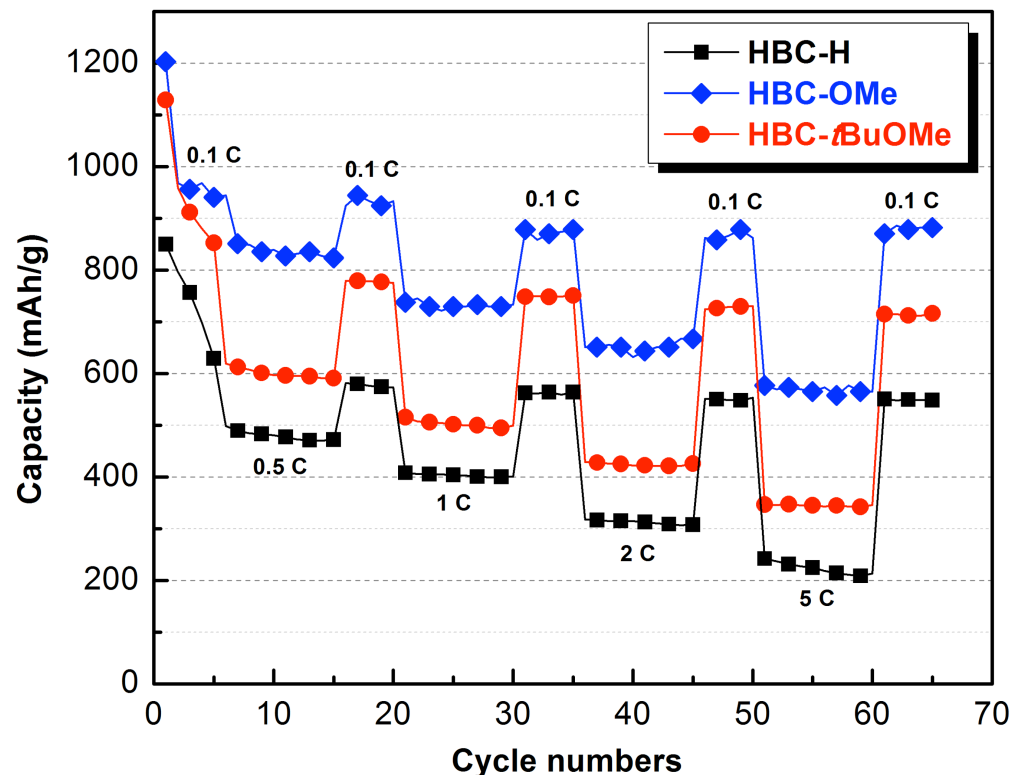
HBC-OMe



HBC-tBuOMe

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

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.

Electrochromism



Electrochromic theory
J. R. Platt

J. Chem. Phys. **1961**, 34, 862

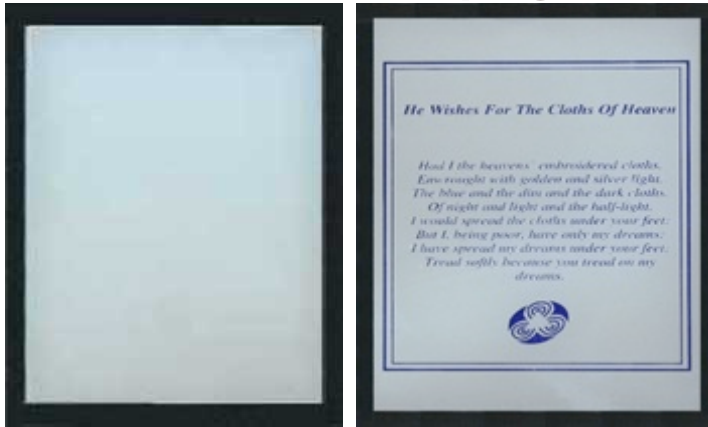


Electrochromic devices
S. K. Deb

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

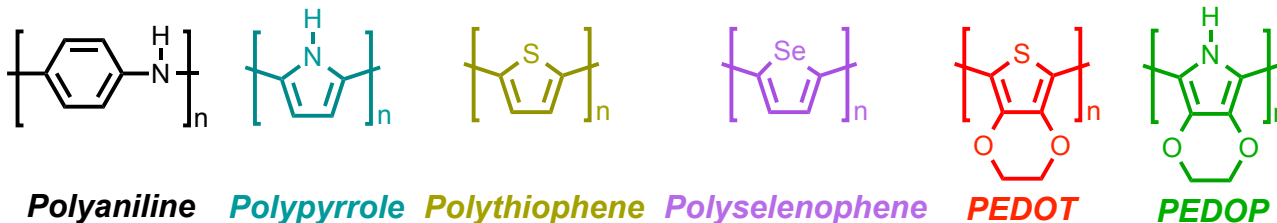


Smart Sunglasses



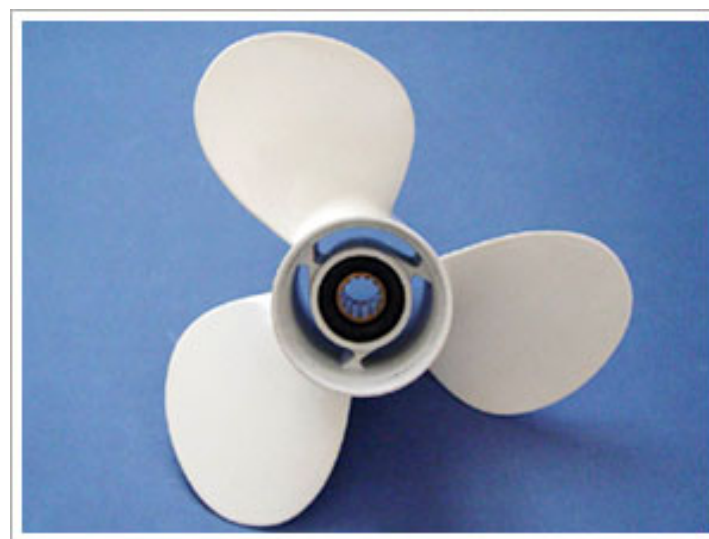
Electrochromic Materials

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



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)



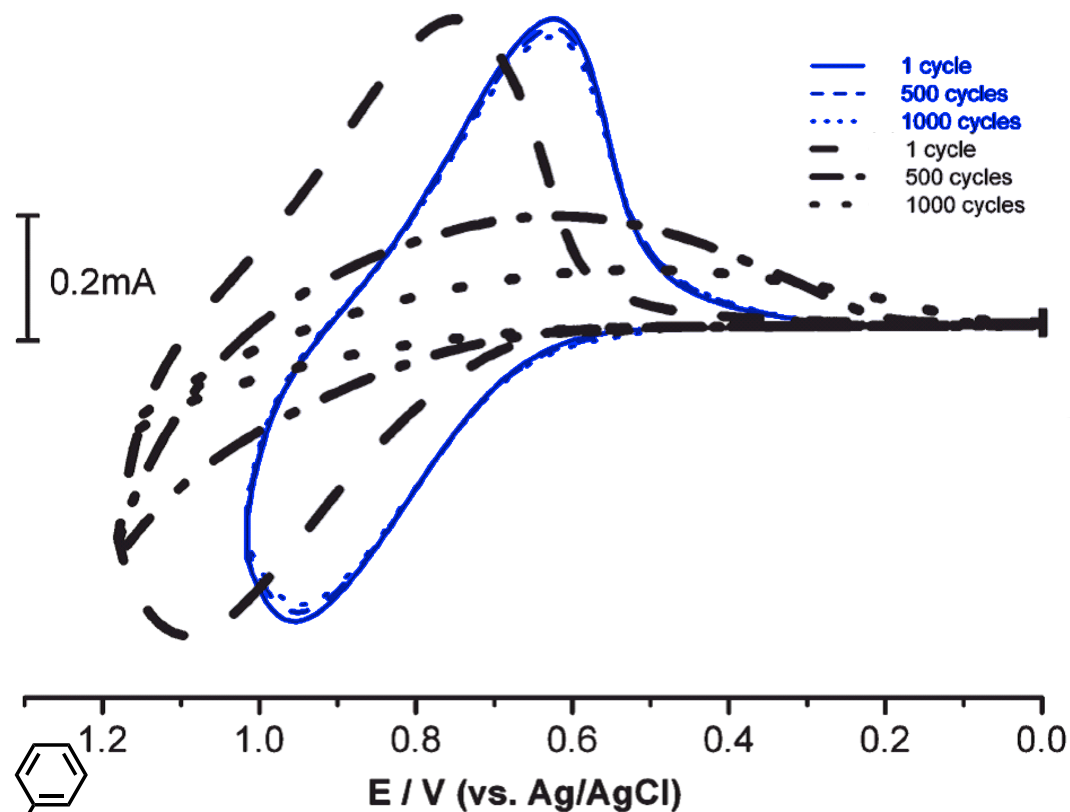
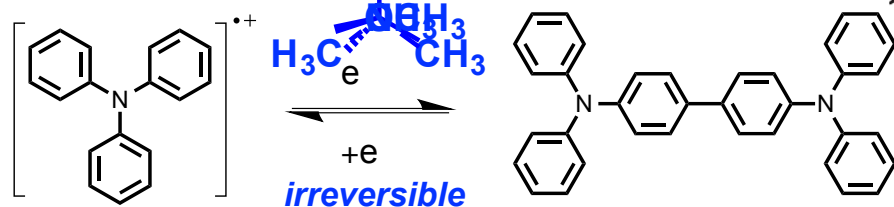
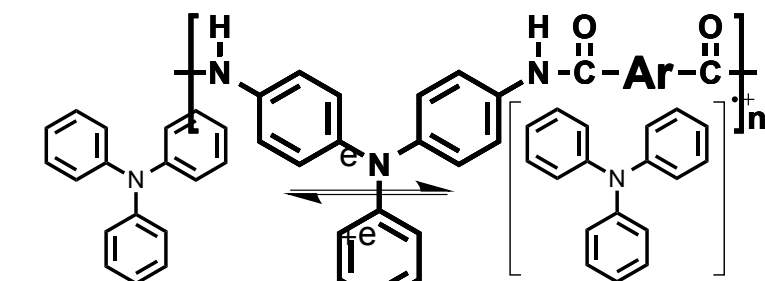
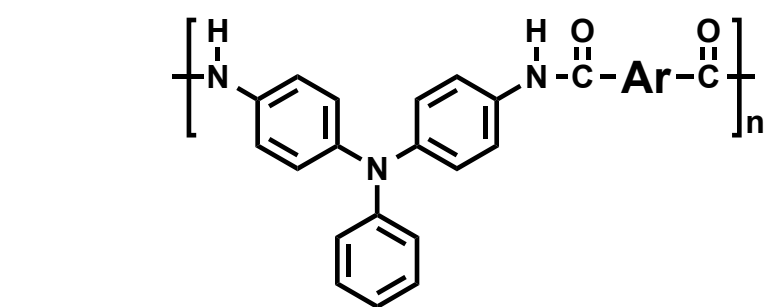
Requirement of Electrochromic Materials for Practical Applications

- (1) Low driving voltage (< 1.5 or 3.5 V)
- (2) Rapid response time [second (mirror)~ minute (window)]
- (3) High color contrast (transmittance attenuation= $\Delta T > 30\%$)
- (4) Long cycle life (>10 yr for window, >3 yr for mirror)
- (5) Environmental stability (electrochemical, thermal, & UV)
- (6) Low cost, easy processing
- (7) Multiple colors with the same material

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Low driving voltage & Long cycle life

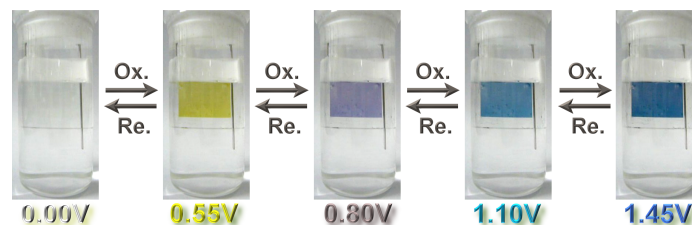
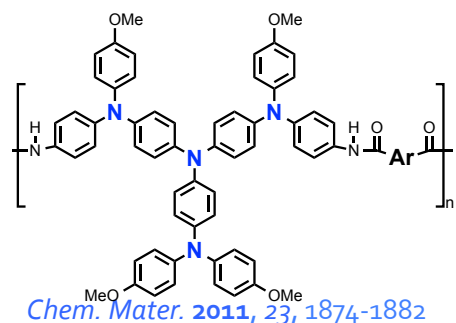
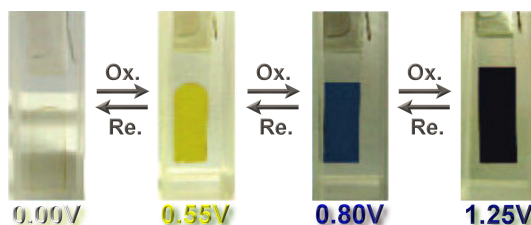
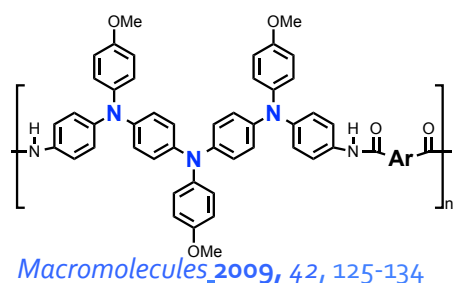
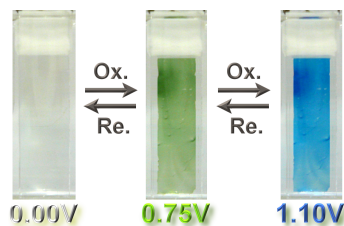
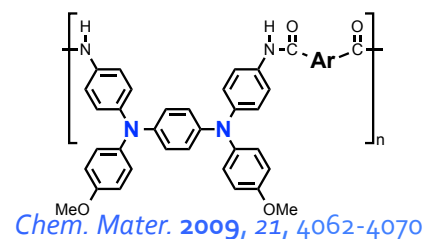
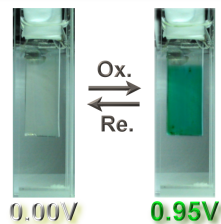
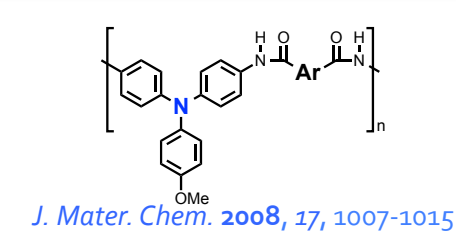


Polym. Chem. 2012, 3, 255-264
 J. Mater. Chem. 2008, 17, 1007-1015
 Macromolecules 2008, 41, 2800-2808

Requirement of Electrochromic Materials for Practical Applications

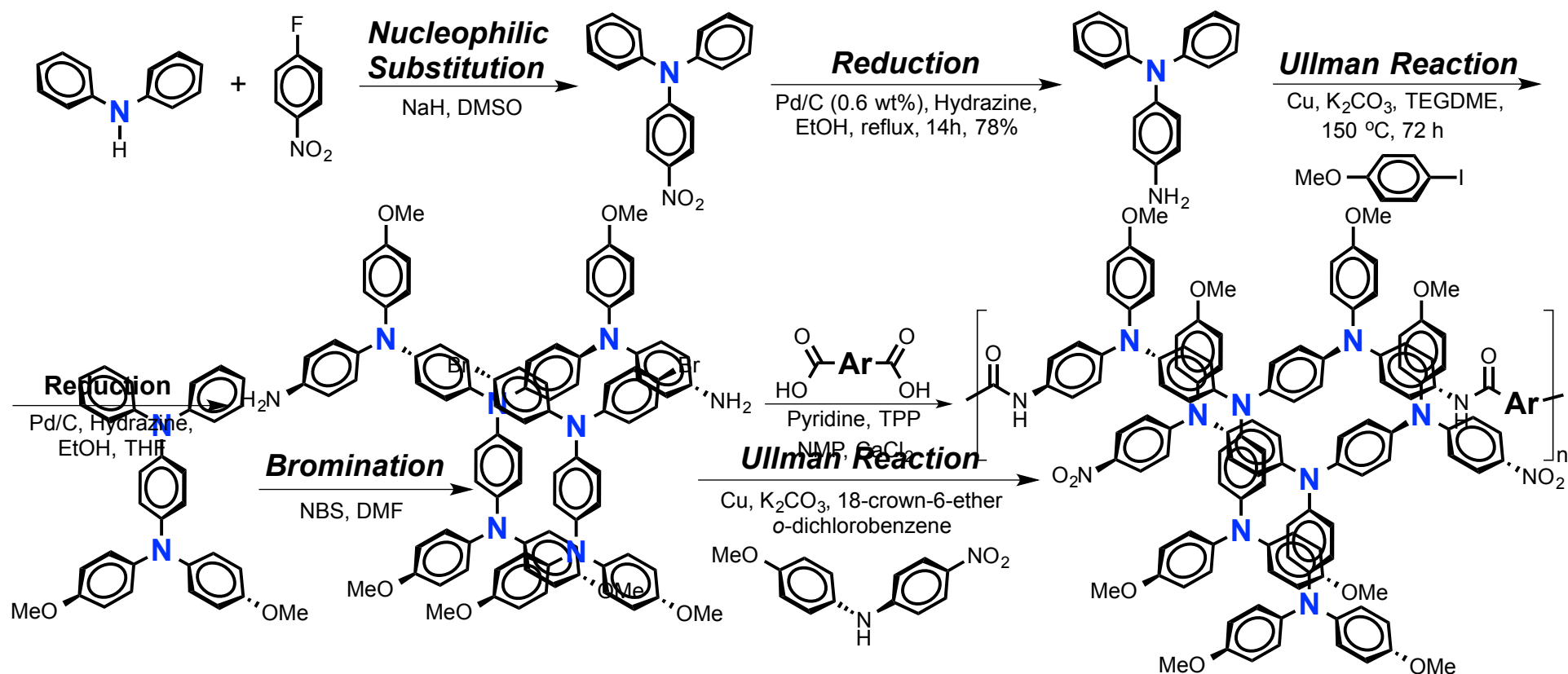
- (1) Low driving voltage (< 1.5 or 3.5 V)
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- (5) Environmental stability (electrochemical, thermal, & UV)
- (6) Low cost, easy processing
- (7) **Multiple colors with the same material**

Increasing the electroactive sites by multi-step synthetic procedures.

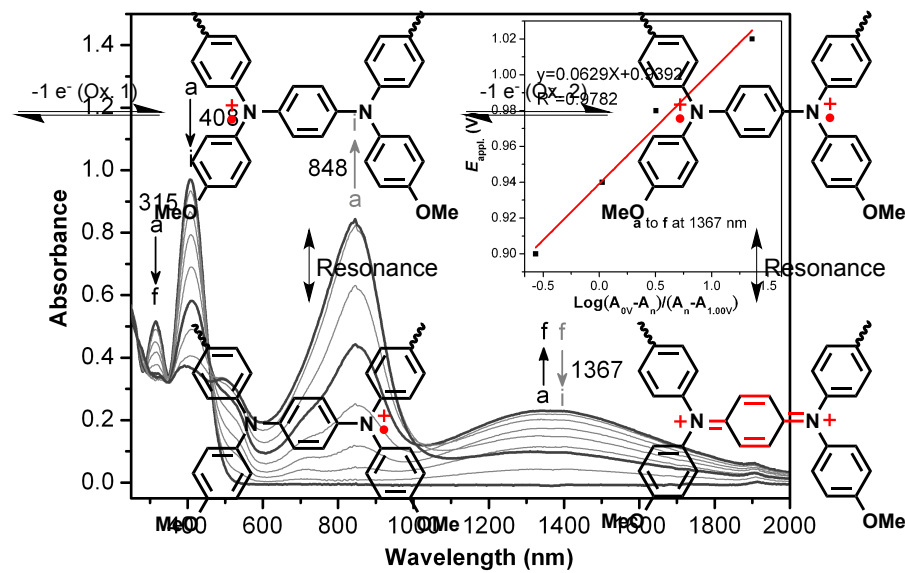
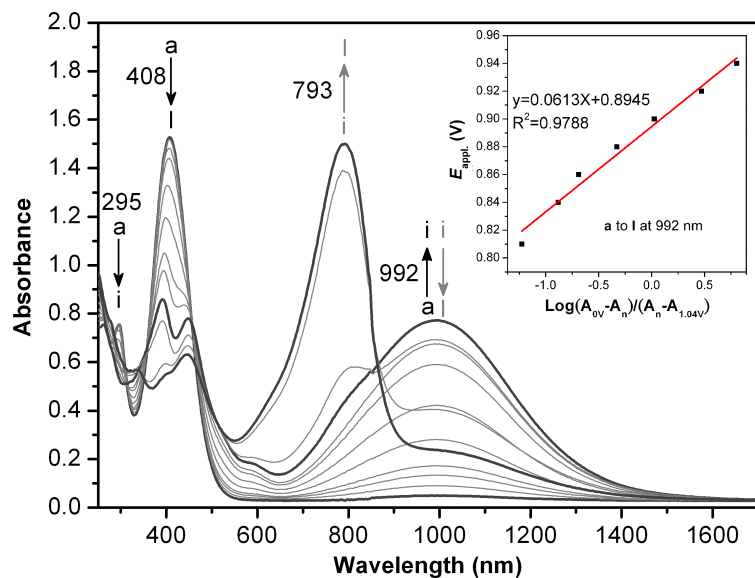
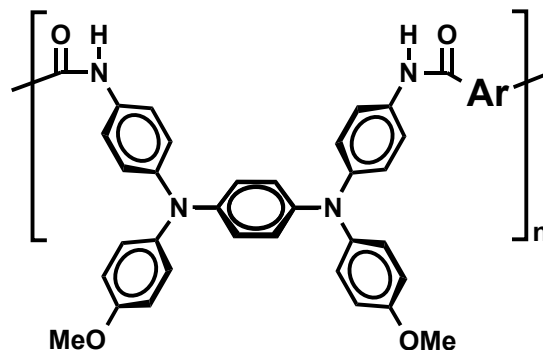


Polym. Chem. **2012**, *3*, 255-264 ¹⁹

Synthetic route to Starburst Triarylamine-based Polyamide

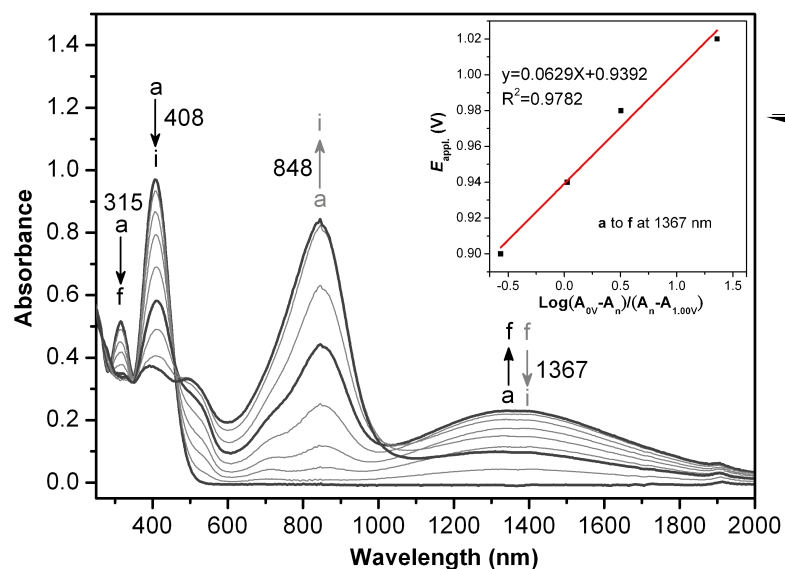
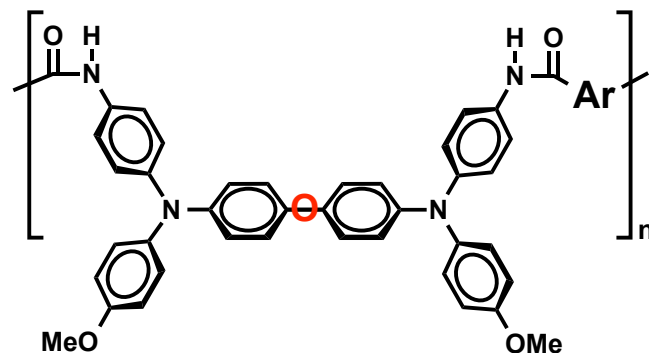


Electrochromism ranging from visible to NIR region

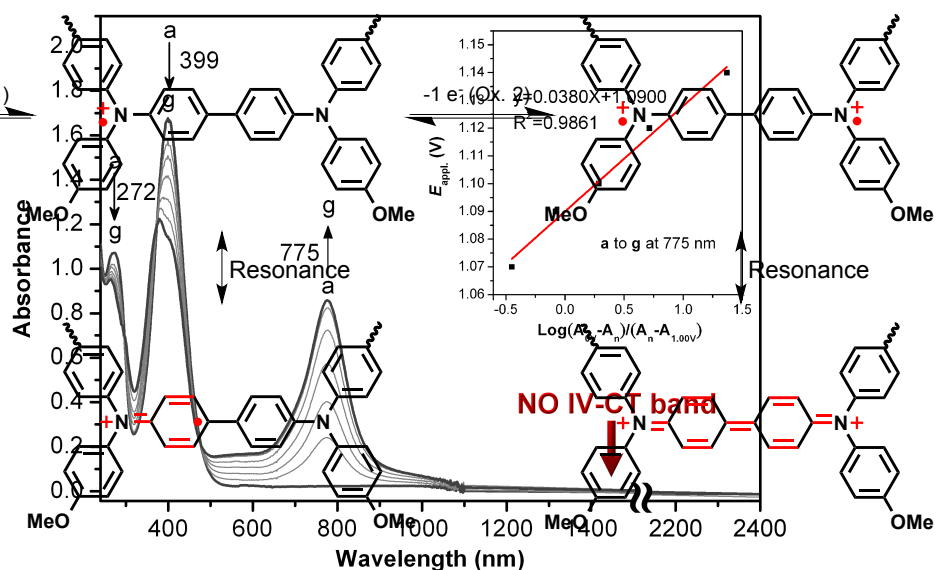


Chem. Mater. 2009, 21, 4062-4070
J. Mater. Chem. 2011, 21, 6230-6237

Electrochromism ranging from visible to NIR region



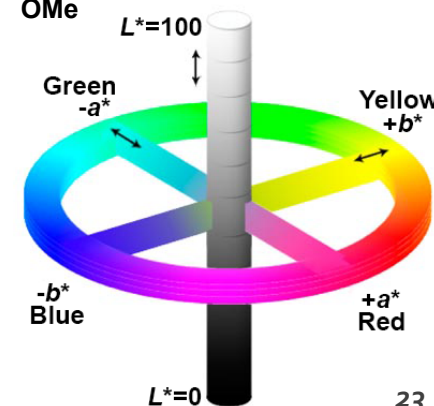
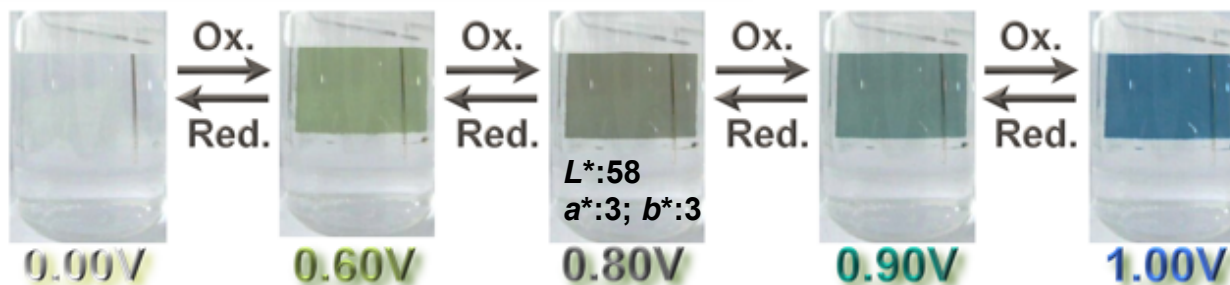
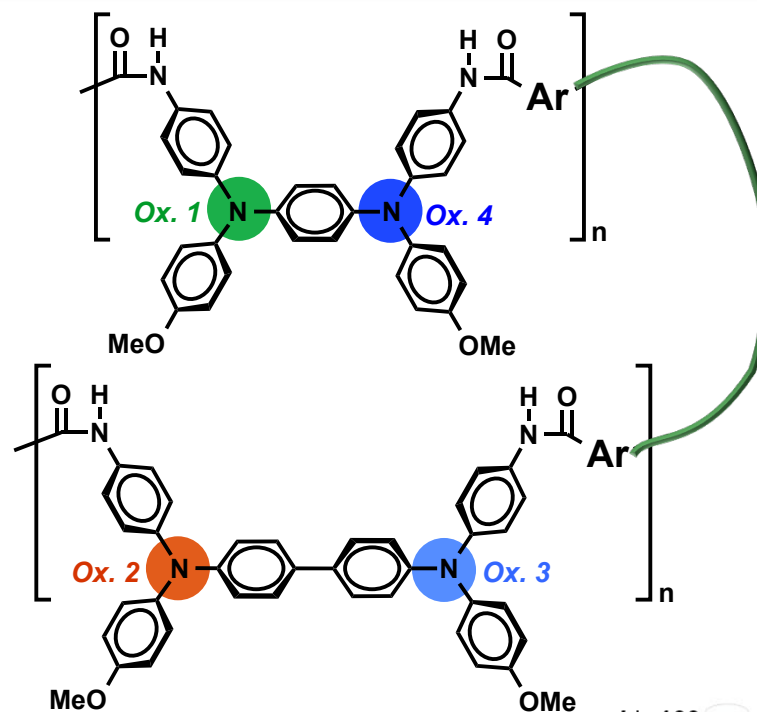
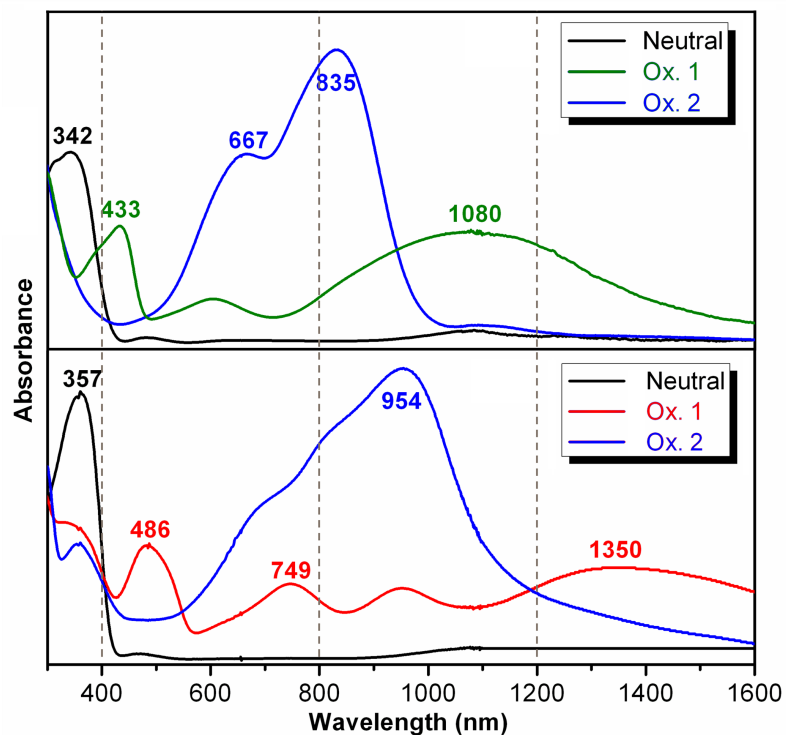
$-1 e^-$ (Ox. 1)



JPS-A. **2011**, *49*, 3805-3816

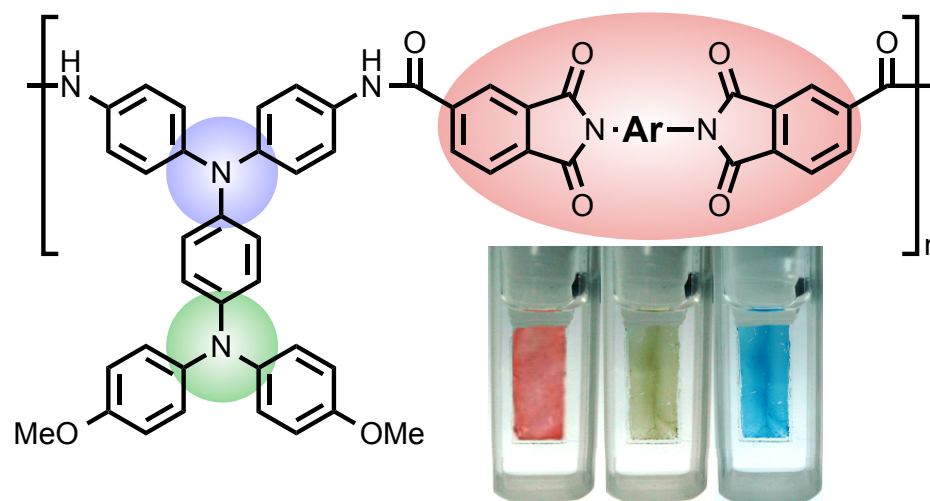
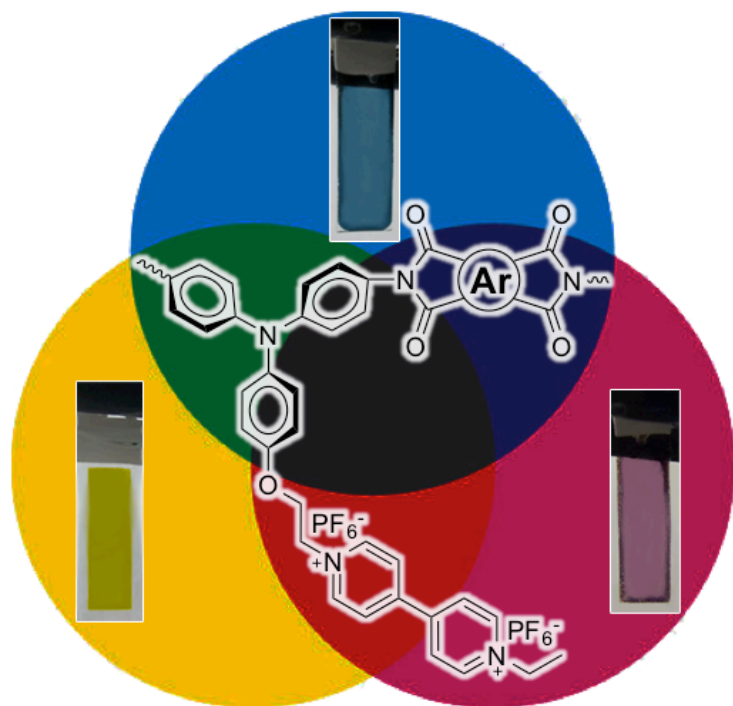
J. Mater. Chem. **2011**, *21*, 6230-6237

Transmissive to Black Electrochromism



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

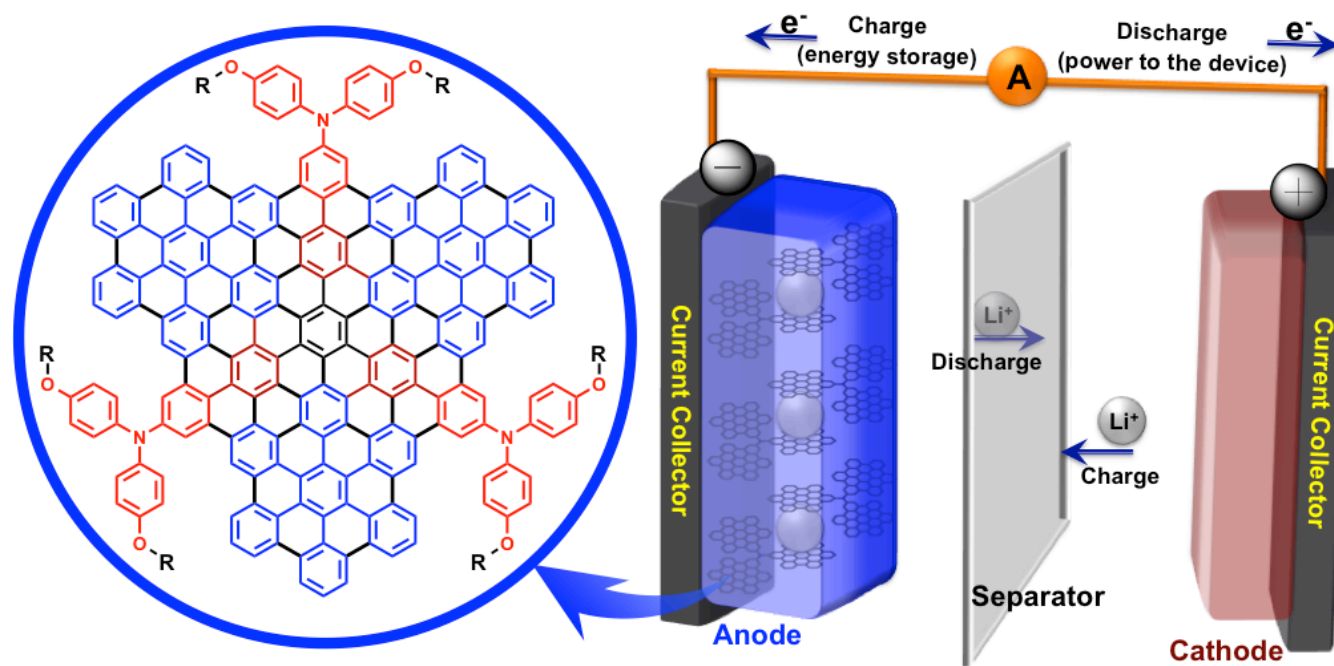
RGB & CMY Electrochromism



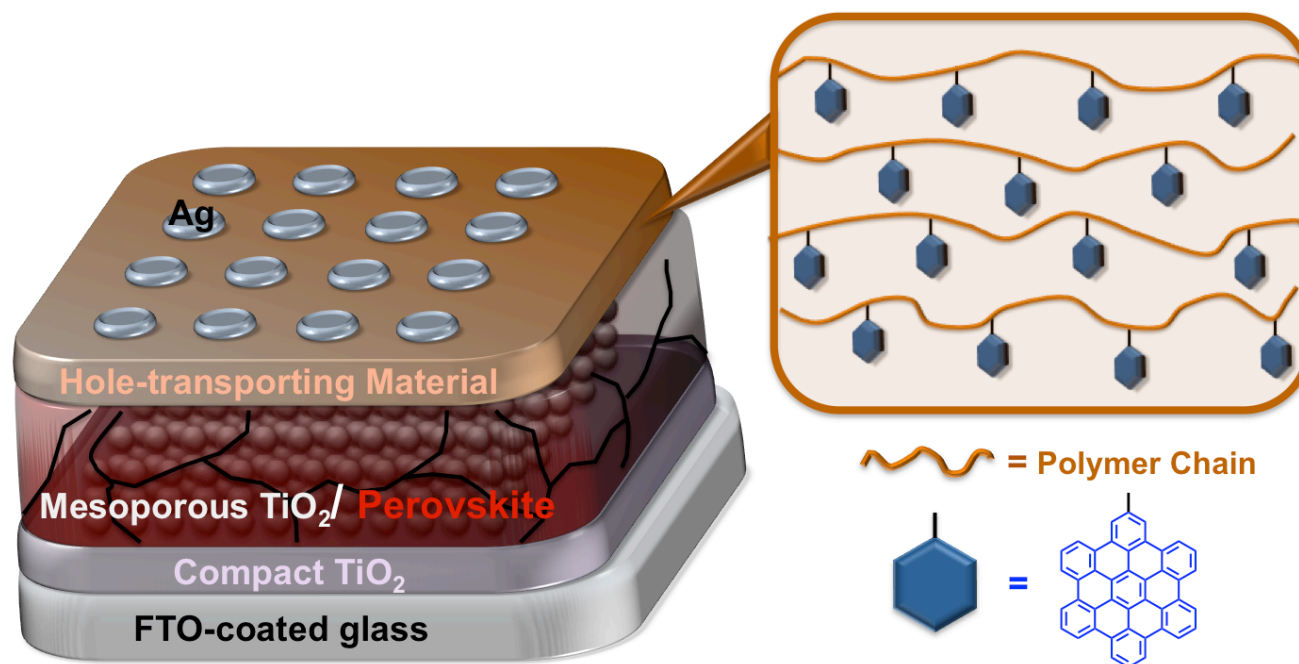
Summary

- 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



未來規劃2



欲授課程

- 化學
- 有機化學
- 儀器分析
- 合成化學
- 高分子奈米複合材料
- 高分子化學
- 電化學
- 高分子分析特論
- 高分子合成
- 有機光譜分析

General Chemistry
Organic Chemistry
Instrumental Analysis
Synthesis Chemistry
Polymer Nanocomposites
Polymer Chemistry
Electrochemistry