Sensing and Other Functionalities in Smart Coatings

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Smart Coatings

- Conventional Coatings are “passive”, they provide corrosion protection & aesthetics

- Active or Smart Coatings:
- Sense
- Self-heal
- Monitor Structural Health
- Change Color
- Generate Energy

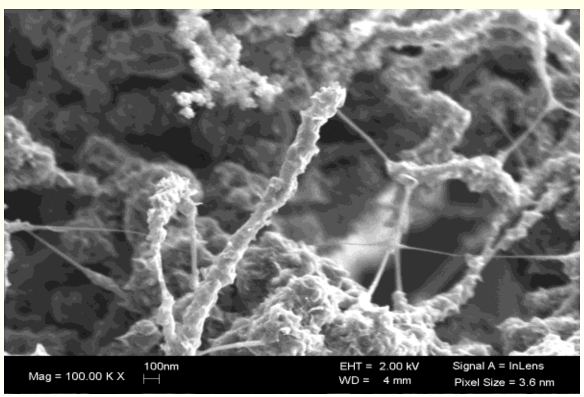
SWNT-Composites

- Key SWNT Processing Technology:
- Purification
- Chemical Functionalization
- Dispersion in solvent
- Dispersion in polymers

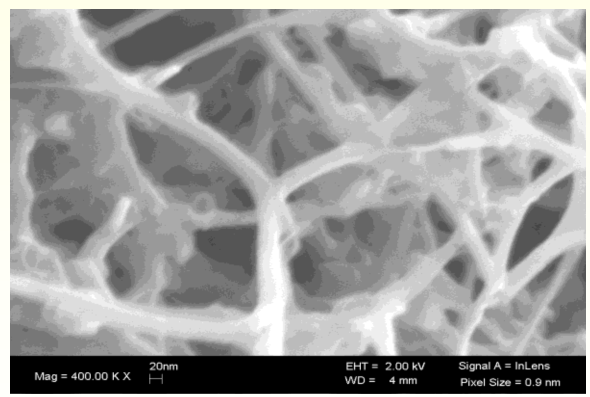
Nanotube Purification

- Metal removal close to 90+%
- No functionalization
- Disordered carbon removal 90+%

Original Nanotube

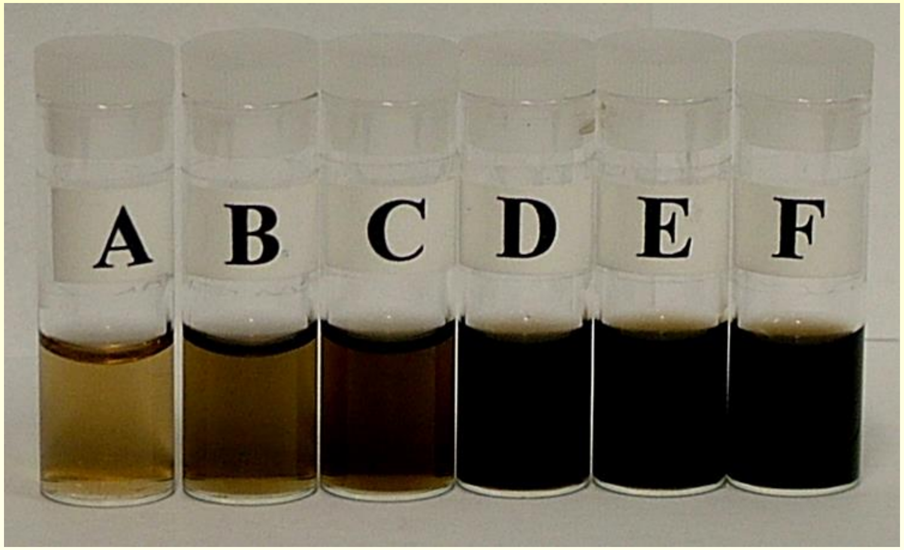


Purified



Chen, Mitra et. al. *Adv. Func. Matl*. 2007

Synthesis of highly water soluble SWNTs

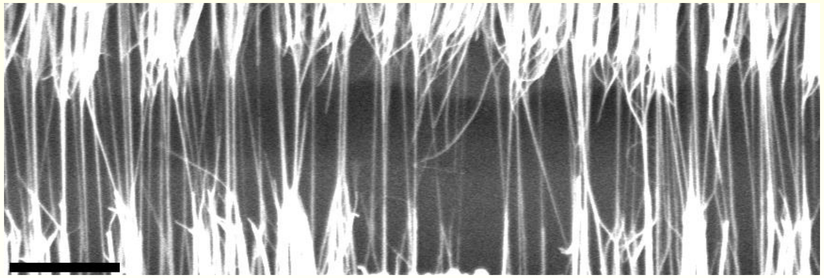


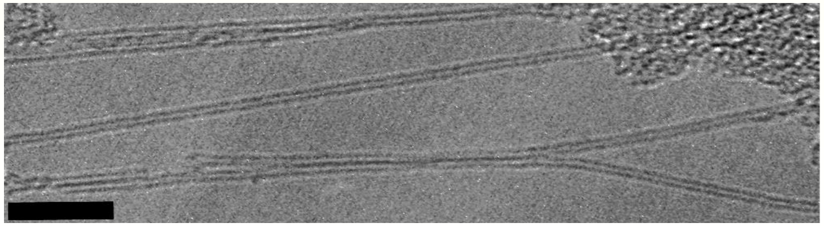
Solubility- *10-20mg/ml in DI water*

DLS- *Original 100-600nm, max 300*

Stable *– Months*

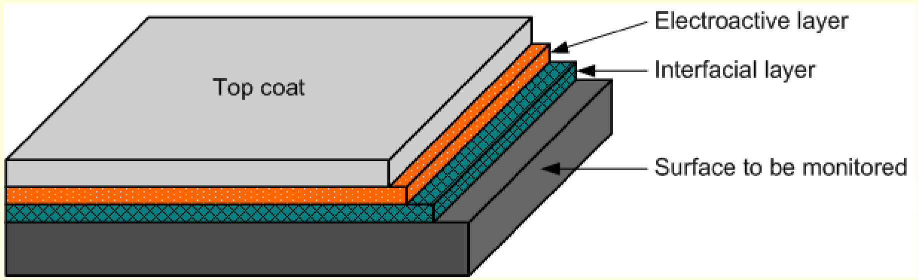
Ionic Conductivity *– 215.8 uS compared to 1.5 for DI water*



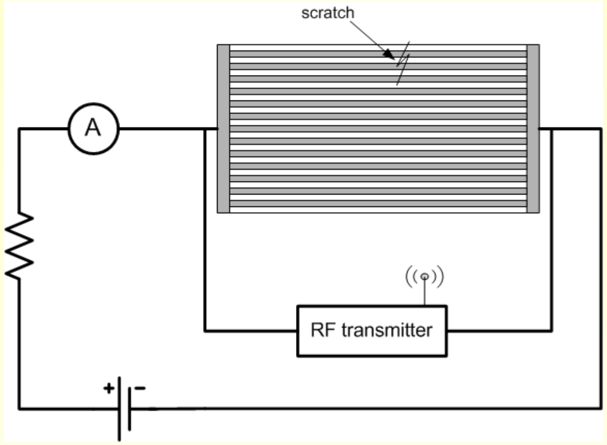


(A) 0.05mg/ml, (B) 0.1 mg/ml, (C) 0.2 mg/ml, (D) 0.3 mg/ml, (E) 0.5 mg/ml and (F) 10mg/ml. All the SWNTs were from three minutes microwave reaction. ***JACS* (2006).**

Electroactive Thin-film for Scratch, Damage and Corrosion Sensing

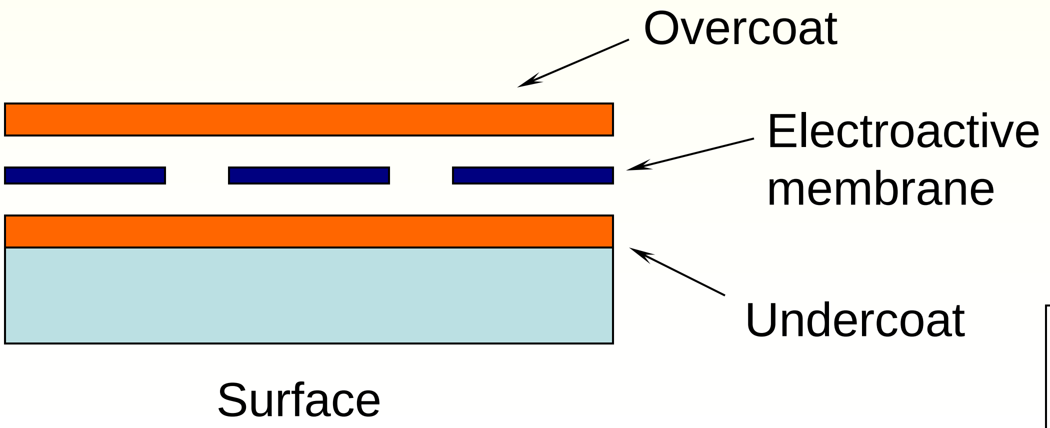


Active Coating with embedded sensor.



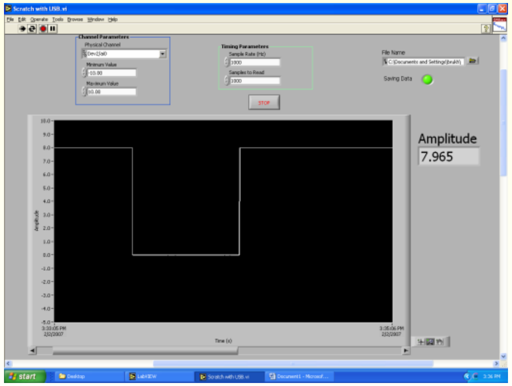
A Sensor Cell Acting as a Transducer for Surface Damage.

Electroactive Film on a Decal



Pat. Pending (2006)

Real-World Applications

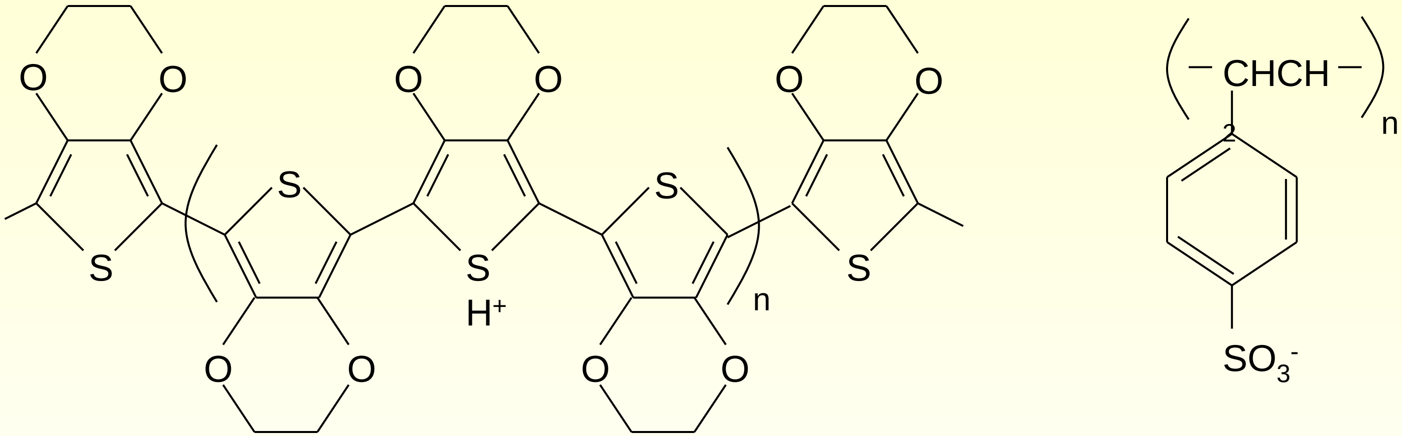


Automobile with a Scratch sensor

LED array to locate coating damage

(a) The tail of a proto-type helicopter with a scratch sensor built in. (b) Real-time sensing,

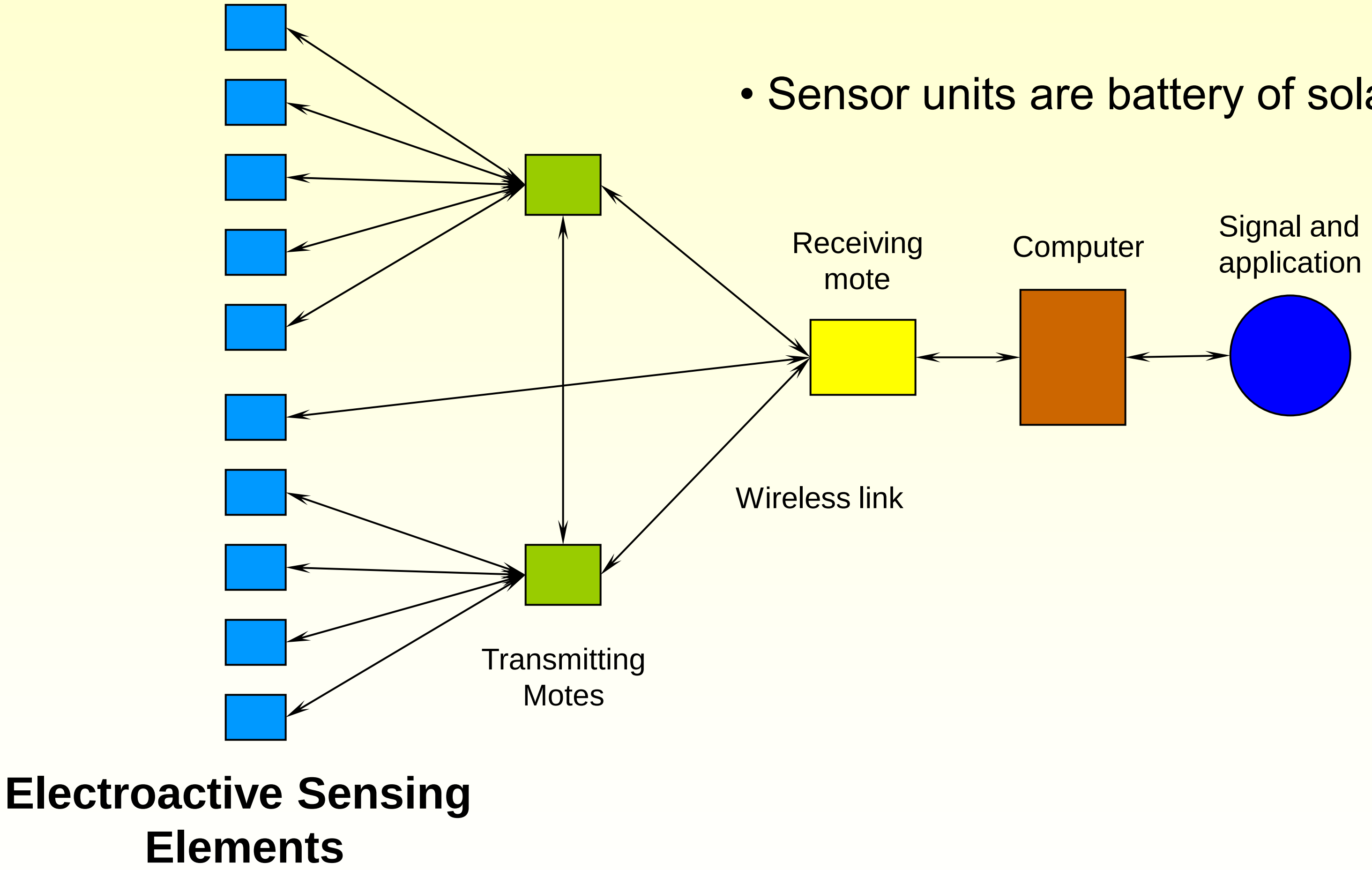
Conducting Polymers



The structure of poly(styrenesulfonate)/poly-(2,3-dihydrothieno-[3,4-*b*]-1,4-dioxin) - PEDOT/PSS

Incorporating microwave-soluble carbon nanotubes into the conducting polymer matrix can significantly increase the compound’s conductivity and applicability. The thermal resistivity of the CNT-conducting polymer composite is expected to decrease.

Wireless Network

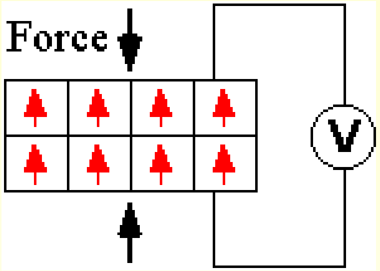


- Sensor units are battery of solar operated

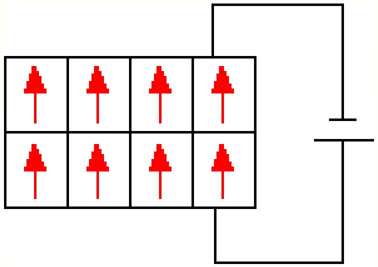
Important Features

- Optimizing electroactive films
- Developing real-world applications
- Wireless network and interface

Piezoelectric impact sensor

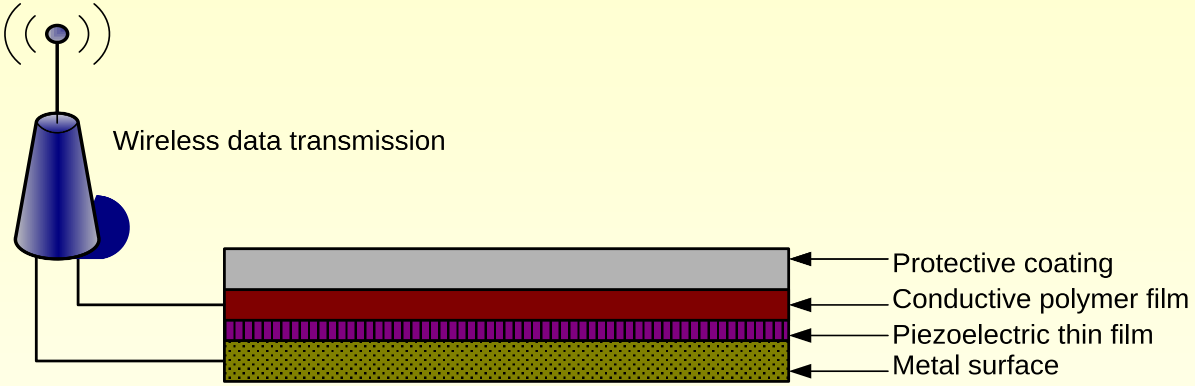


Permanently-polarized materials produce an electric field when the material changes dimensions as a result of an imposed mechanical forces, which effects charge assymetry.

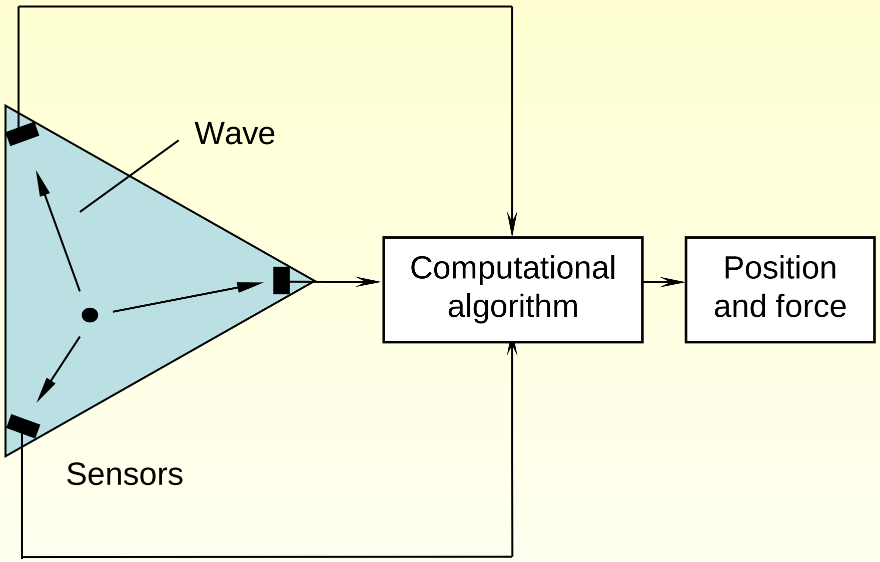


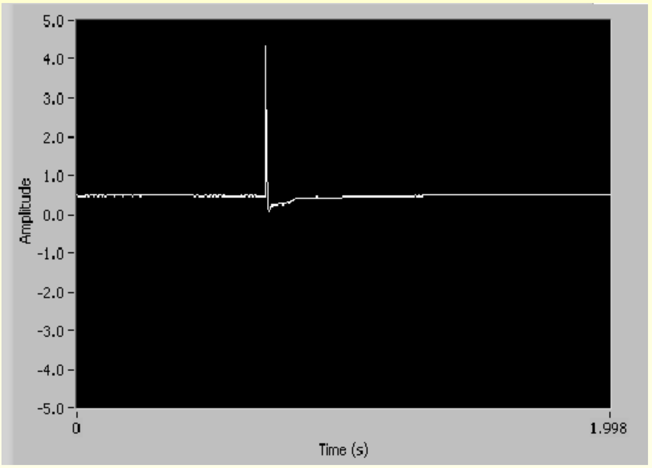
Conversely, an applied electric field can cause a piezoelectric field to change dimensions.

Piezo-Sensor for Impact Detection



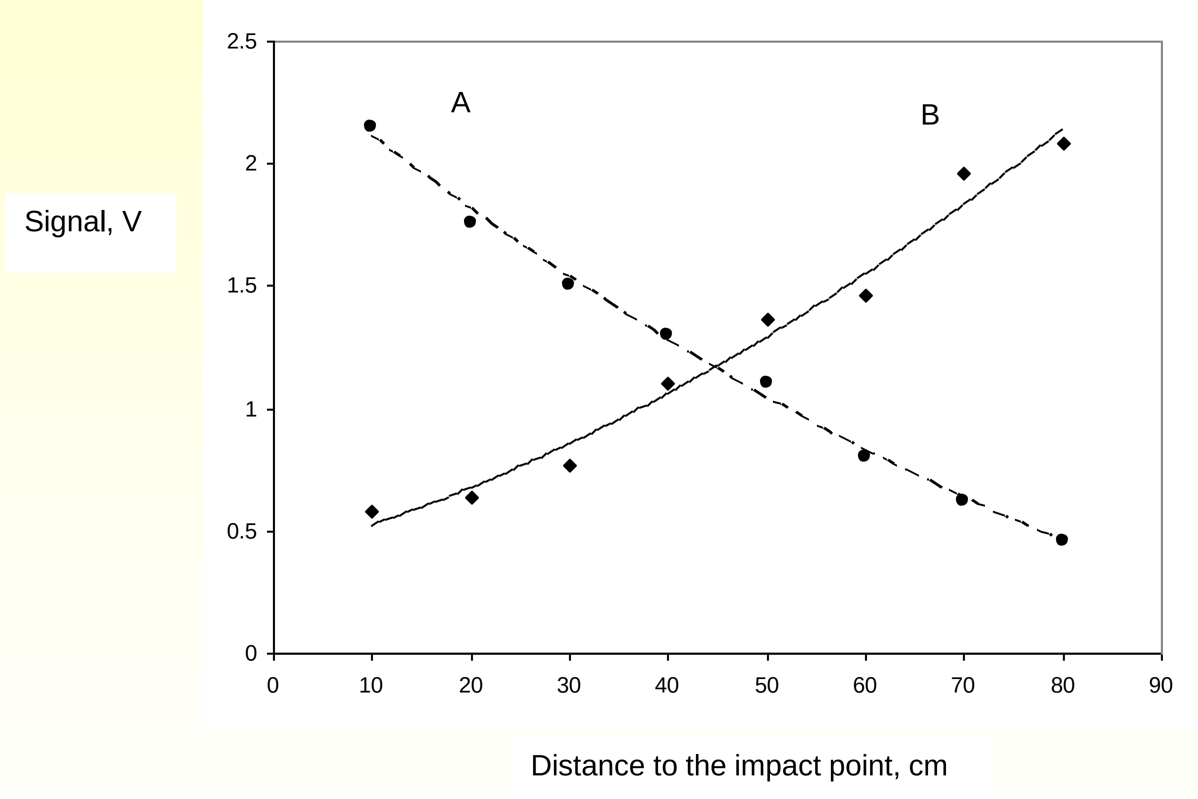
Sensor Array



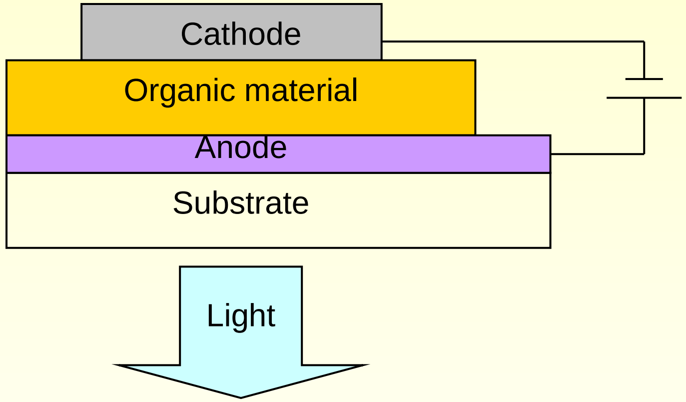


- Using data on time delay and signal intensity from the sensors, the magnitude and location of the impact will be computed.
- This information can be wirelessly transmitted.

Response as a Function of Distance



Color Change and Power Generation



Substrate / conducting polymer emissive coating /Al

- The emissive layer (EML) is sandwiched between two electrodes.
- The ITO (indium tin oxide) anode is transparent.

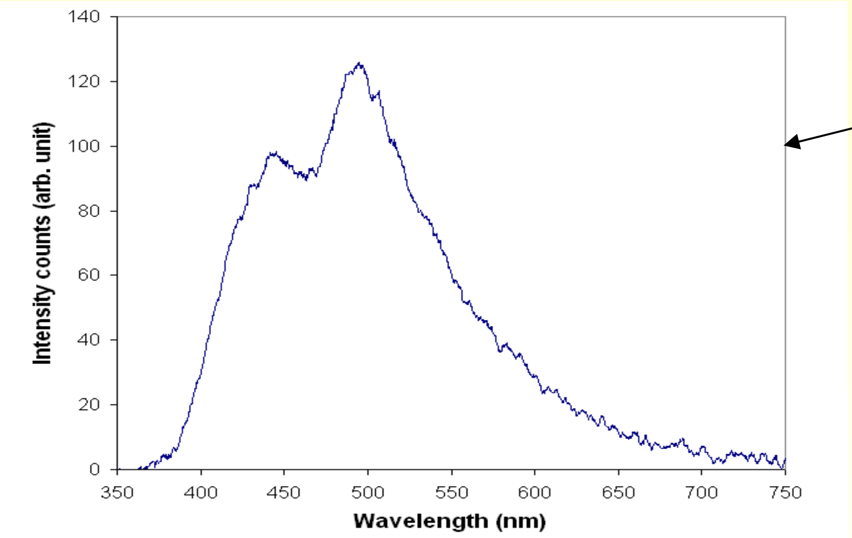
Under applied voltage, opposite charge carriers are injected into the polymer coating and their recombination leads to electroluminescence (light emission). The color of the emitted light is controlled by the energy gap of the chromorphoric polymer.

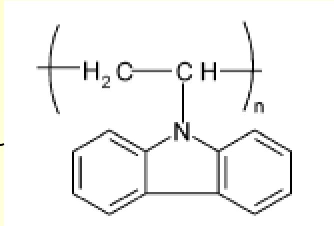
EL for Color Change and Camouflage

- Material selection
- Using Dyes to alter color
- EL device on flexible substrate

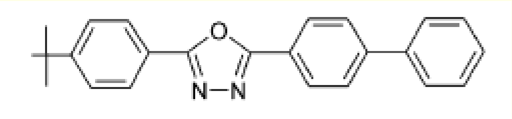
EL for Color Change and Camouflage

Materials for EML





PVK: poly(9-vinyl carbazole)



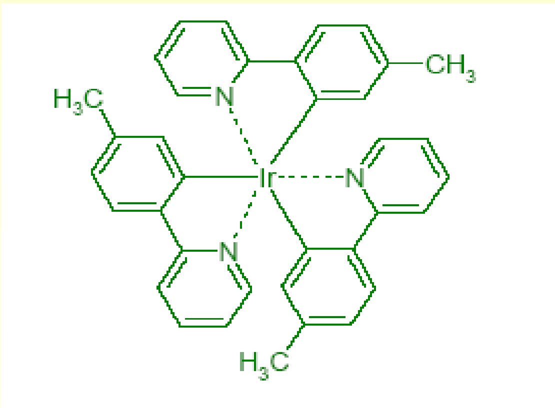
PBD: 2-(4-biphenylyl)-5-(4-tert-butylphenyl)-1,3,4-oxadiazole

Host polymer matrix

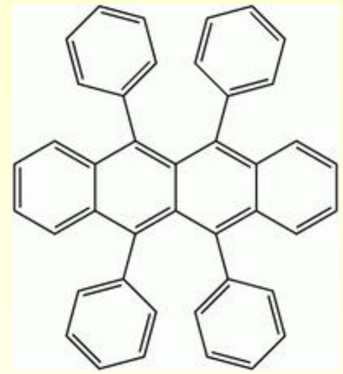
- Polymer PVK - good film forming property, hole transporting
- PBD molecules: electron transporting
- Proper PVK:PBD ratio to ensure balanced hole/electron injection into EML

EL for Color Change and Camouflage

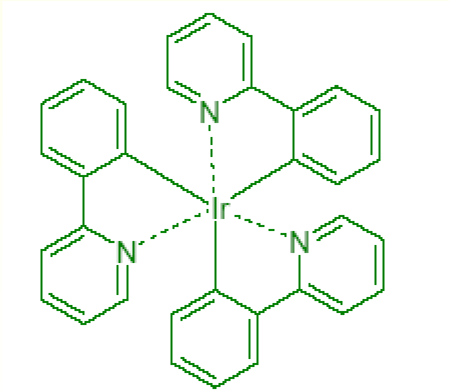
Different light colors can be emitted from fluorescent or phosphorescent dyes doped in the host material.



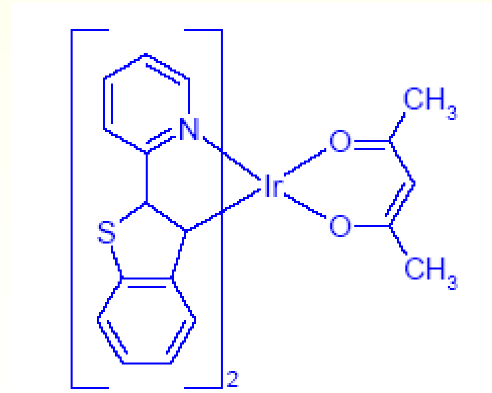
Ir(mppy)$_3$: Iridium (III) tris(2-(4-totyl)pyridinato-N,C^2



Rubrene:: (5,6,11,12-tetraphenylnaphthacene)



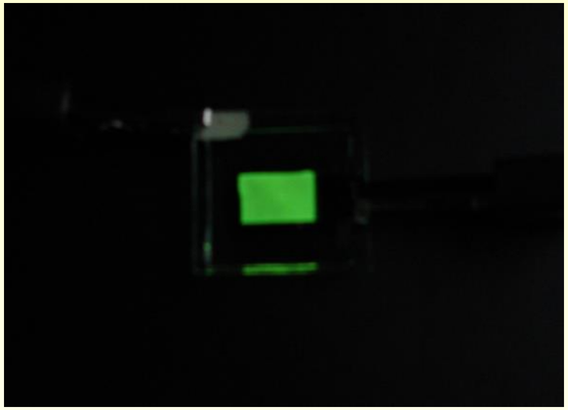
Ir(ppy)$_3$: Tris(2-phenylpyridine) iridium (III)

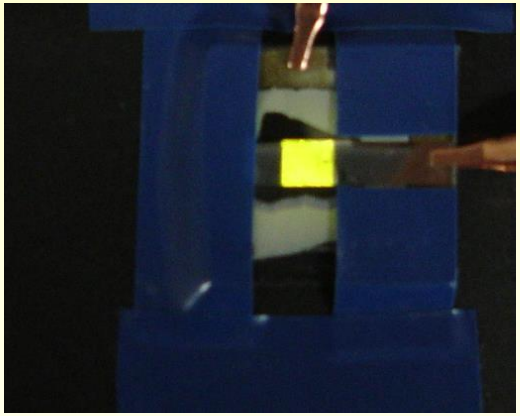


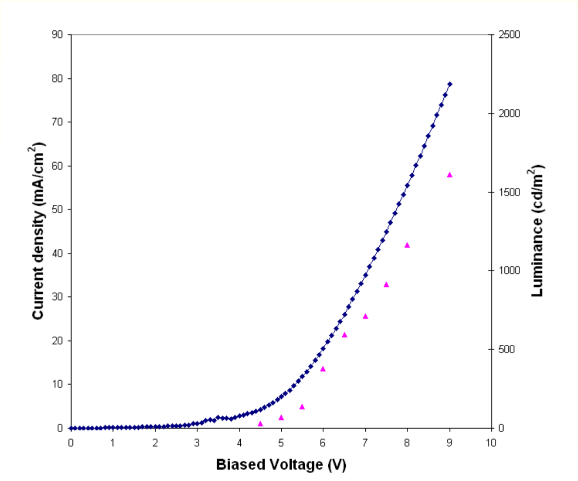
(btp)$_2$Ir(acac): Iridium (III) bis(2-(2'-benzothienyl) pyridinato-N,$C^{3'}$)(acetyl-acetonate).

EL Smart Coatings for Color Change and Camouflage

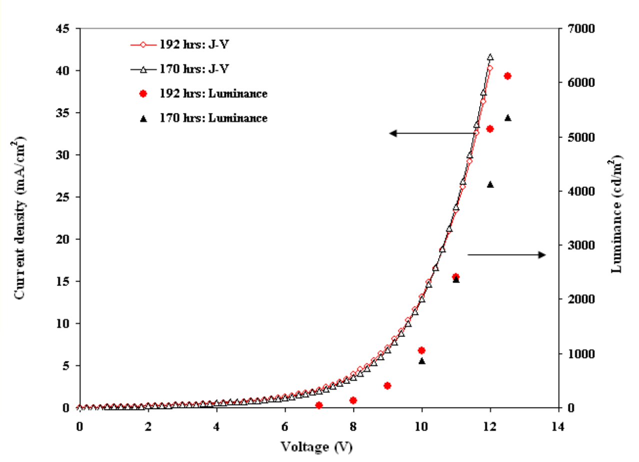
Light emission from EL devices under applied voltage







Ir(ppy)$_3$ doped: 1600 cd/cm^2 at 9 V

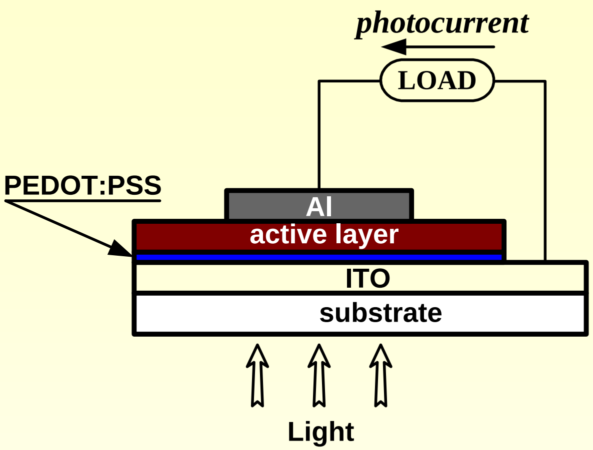


rubrene doped: 400 cd/cm^2 at 9 V

EL for Color Change and Camouflage

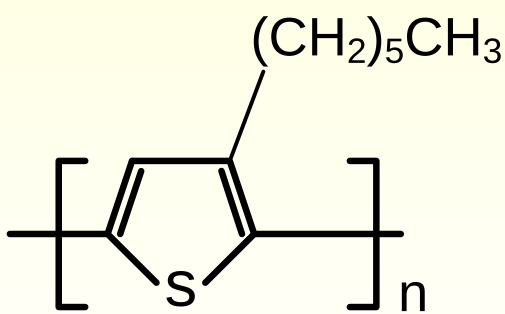
- **EL devices based on dye-doped polymer coatings**
- **Color tuning via co-doping of different dyes**
- **EL devices on flexible substrate**

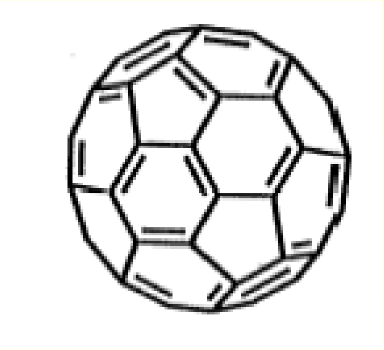
SWNT-C60 Composite for Bulk-heterojunction Photovoltaic Cells

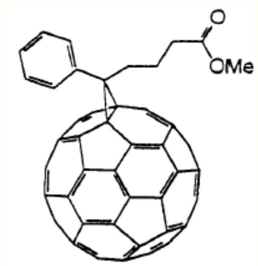


ITO - Indium-Tin-Oxide

PEDOT:PSS - Poly(3,4-ethylenedioxythiophene) poly(styrenesulfonate)







P3HT: poly(3-hexylthiophene)

PCBM: [6,6]-phenyl-C61-butyric acid methyl ester

- P3HT and P3OT are more stable in air.
- P3HT has higher hole mobility and higher degree of structural ordering than P3OT.

Functionalized Carbon Nanotubes in Photovoltaic Coatings

- Limited electron transport property and high cost of PCBM (usually 50 wt% or more is needed in the active coating).
- Excellent electrical conductivity of single walled carbon nanotubes (SWNTs).
- Low cost of fullerene C60.

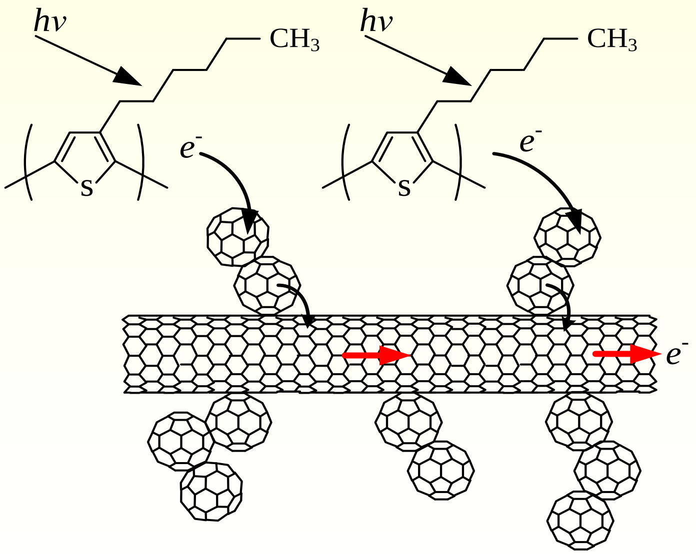
Strategy: combination of strong electron accepting ability of C60 (or PCBM) molecules and superior electron transport property of SWNTs.

❑ SWNTs decorated with C_{60} molecules via microwave processing.

❑ C_{60} molecules serves as electron acceptor

❑ Efficient electron transport through nanotubes

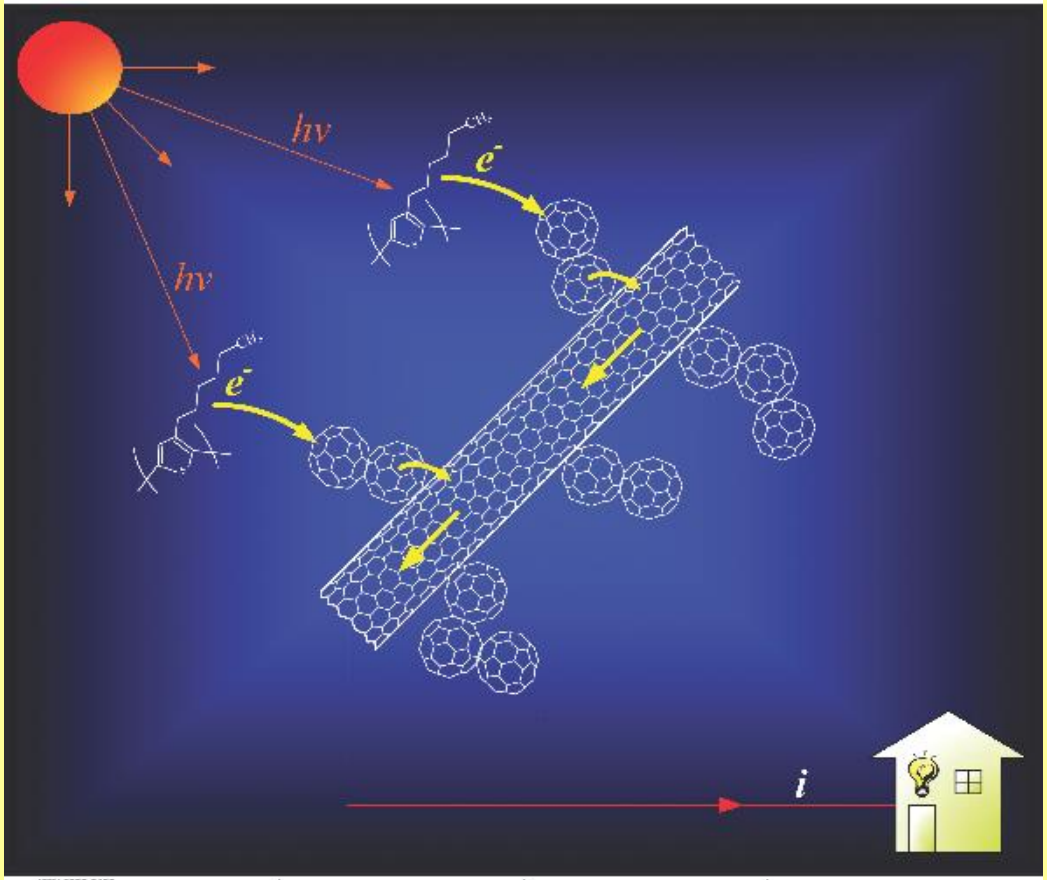
❑ SWNTs may also be involved in dissociation of photo-generated excitons.



Journal of Materials Chemistry

www.rsc.org/materials

Volume 17 | Number 23 | 21 June 2007 | Pages 2377–2468



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0959-9428(2007)17:23;1-0