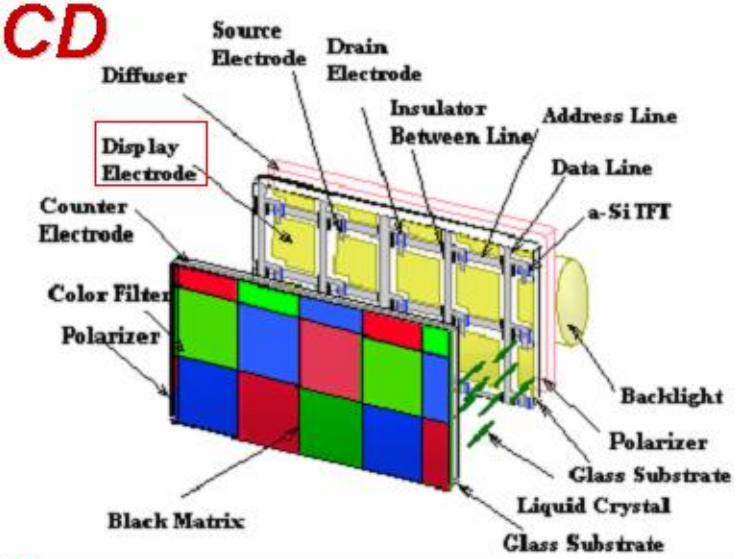
Transparent Organic Electrode

김 철 환

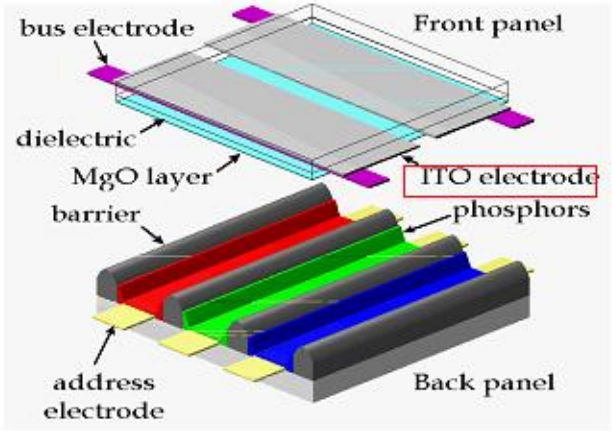
㈜ 디피아이 솔루션스

Structure of FPD

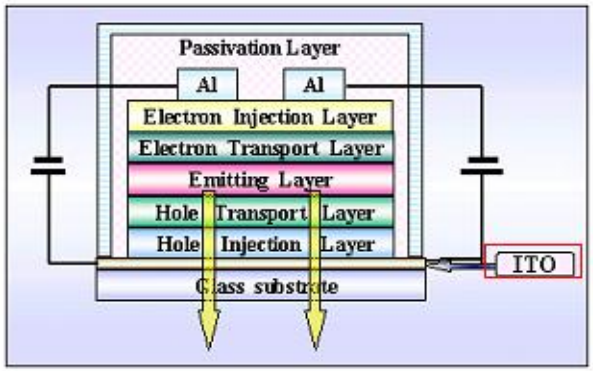
LCD



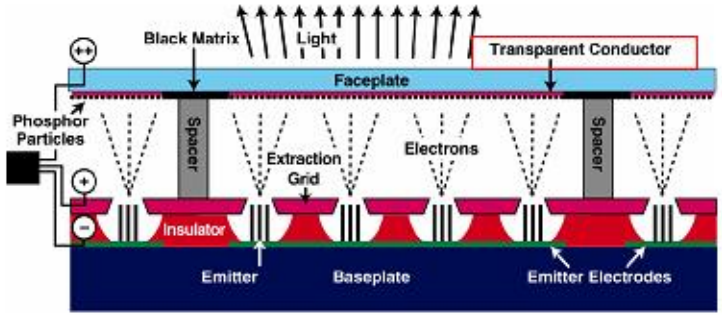
PDP



EL

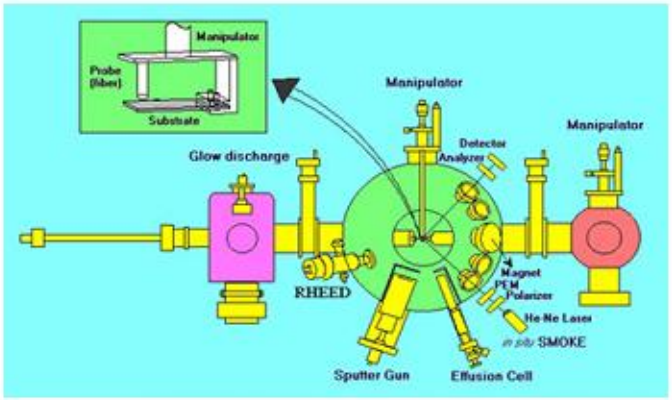


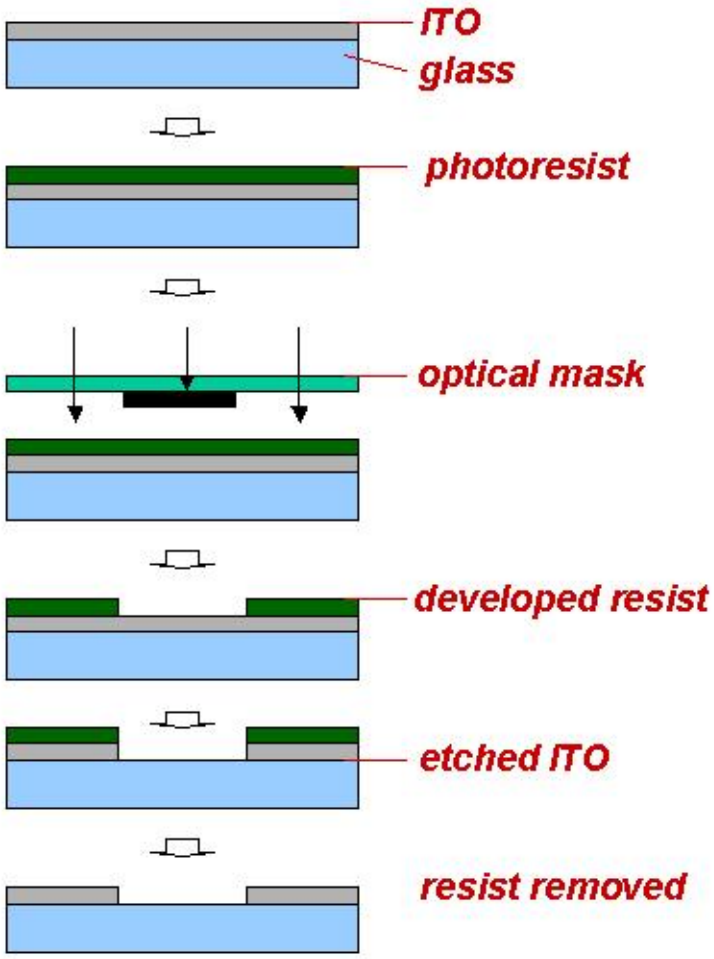
FED



Electrode Fabrication

Deposition - Sputtering →





Etchant : HCl, HNO_3 →

Problems of ITO Electrode

originated from plastic substrate

High processing temperature

Low mechanical property

- *Low flexibility*

  (200Ω/□ $\xrightarrow{\text{Folding}}$ 50X10^{6}Ω/□)

- *Low durability for flexible application*

Thermal expansion mismatching

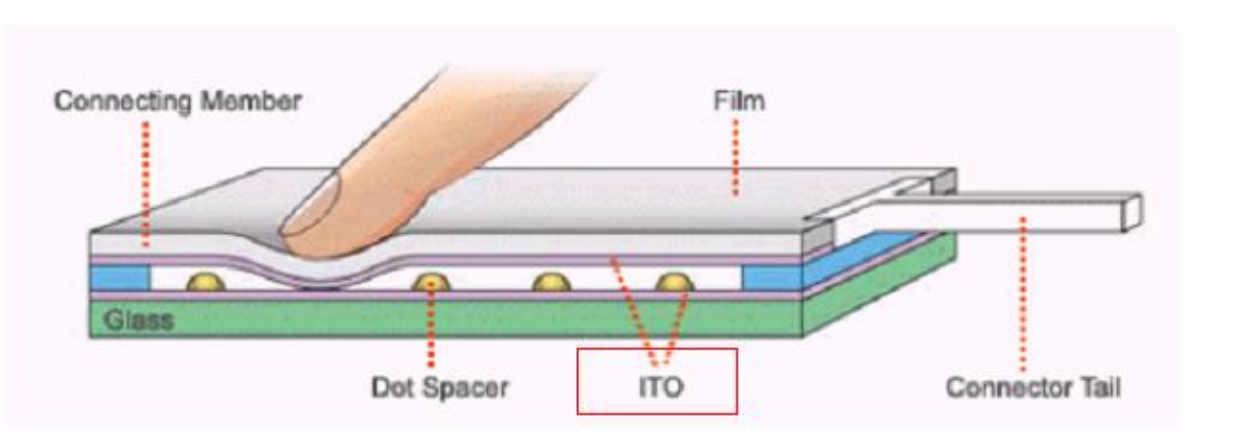
Problems of ITO Electrode

originated from processing conditions

High manufacturing cost

- *Vacuum process*
  (sputtering, vacuum deposition)
- *Photoresist process*
  (etchant disposal)

Structure of Touch Panel






Info-system, OA&FA System, Kiosk, PDA, POS, Hand-terminal,, Web-Pad,
Touch Monitor, Medical, Tablet PC, Industrial Web Phone, Gaming, Industrial Terminal

Requirements of Flexible Electrode

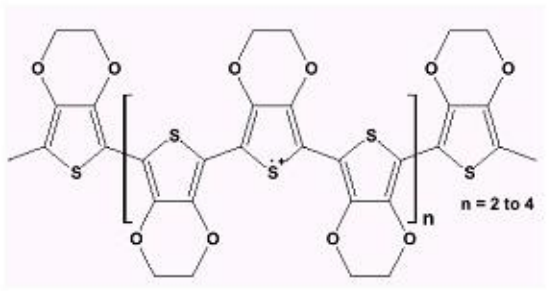
- High Transparency (>80%)
- High Conductivity (<100Ω/□)
- Low Cost
- Flexible Mechanical Property
- Appropriate Thermal Expansion
- Printing & Patterning Capability
- Environmental Stability

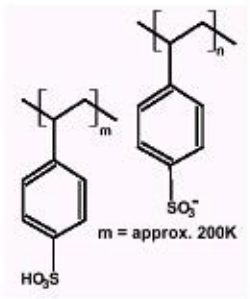
Comparison of Transparent Conductive Coating Technology

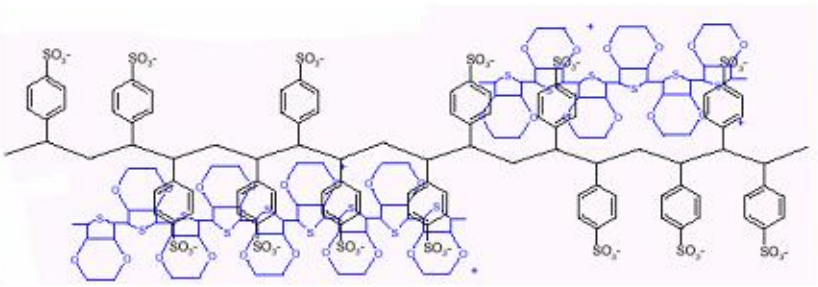
○ Excellent
◉ Good
● Poor

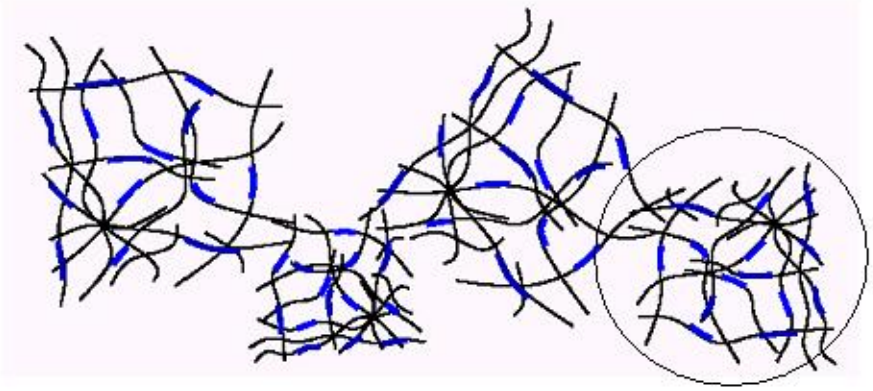
	Sputtered ITO	ITO dispersions	Nano Metal dispersions	ICP dispersions	CNT dispersions
Transparency	○	◉	◉	○	○
Conductivity	○	●	○	◉	◉
Cost	◉	○	●	◉	○
Color	◉	●	○	◉	○
Printing capability	●	◉	●	○	○
Flexibility	●	●	○	○	○
Environmental stability	○	○	○	●	○

PEDOT/PSS System

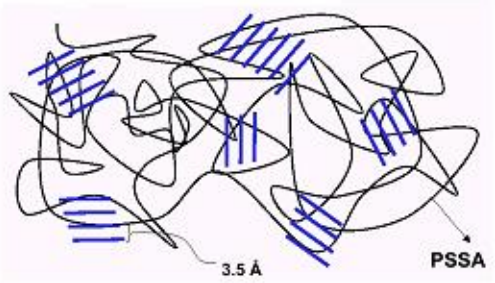




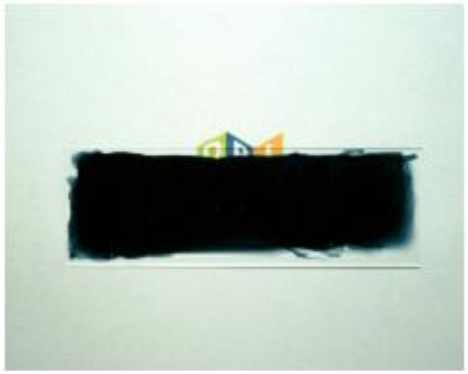




Mean Particle Size : 50nm



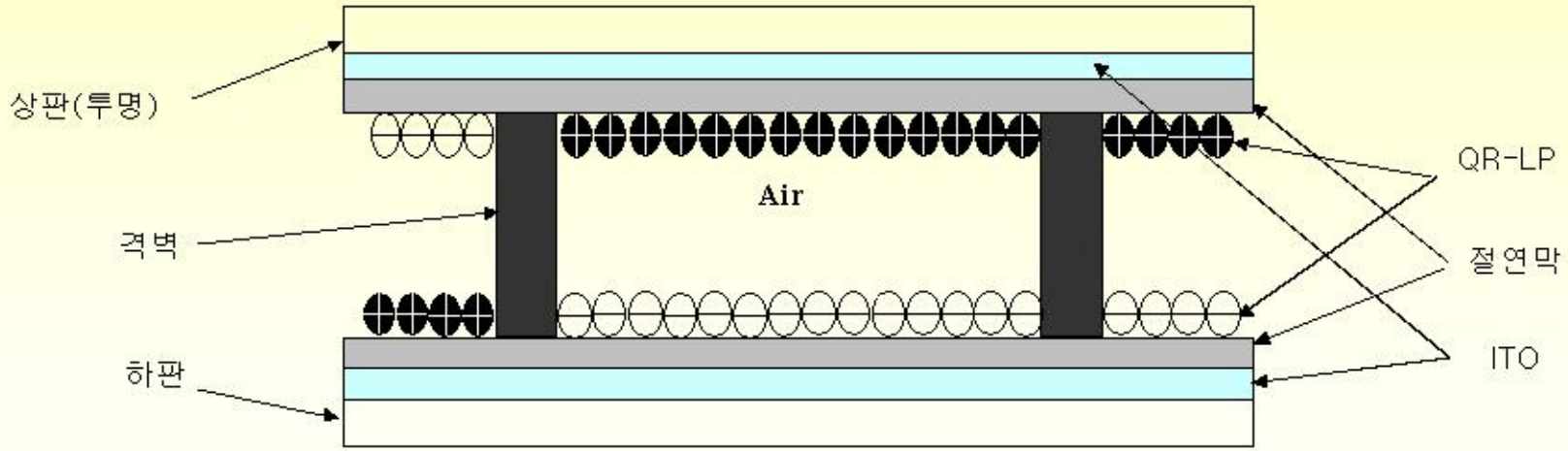
Electrical Properties of ICP System

Pristine ICP	Surface Resistivity ($\Omega/\square$)	Transmittance (%)	Thickness (nm)
	$10^4\ \Omega/\square$	<1%	1000nm
	$10^6\ \Omega/\square$	80%	50nm

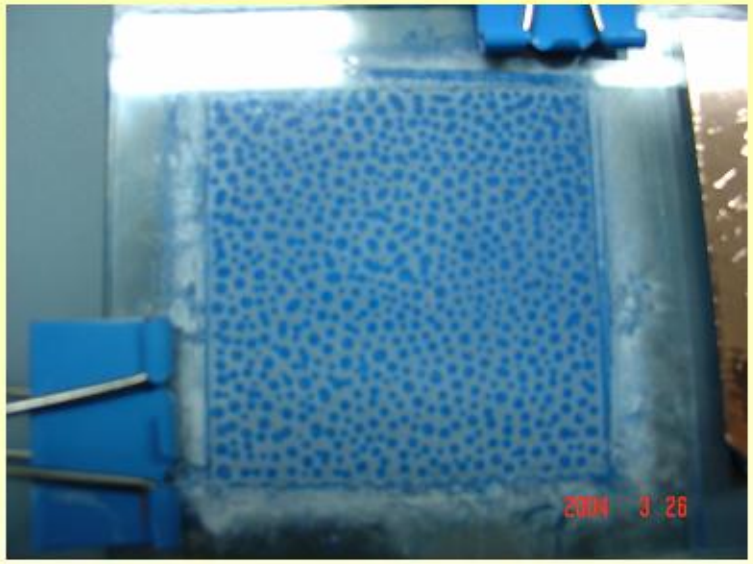
E-Paper(QR-LP Type)

QR-LP type의 셀 구조는 투명 전극이 형성되어 있는 상하 기판과 셀을 구분하는 격벽이 형성되며 투명 전극 표면은 전하의 소멸 방지 및 입자의 표면 부착 에너지를 최소화 하기 위한 절연막이 형성되어 지고 셀내에는 반대 부호로 대전 되어진 2종의 입자가 주입된다.

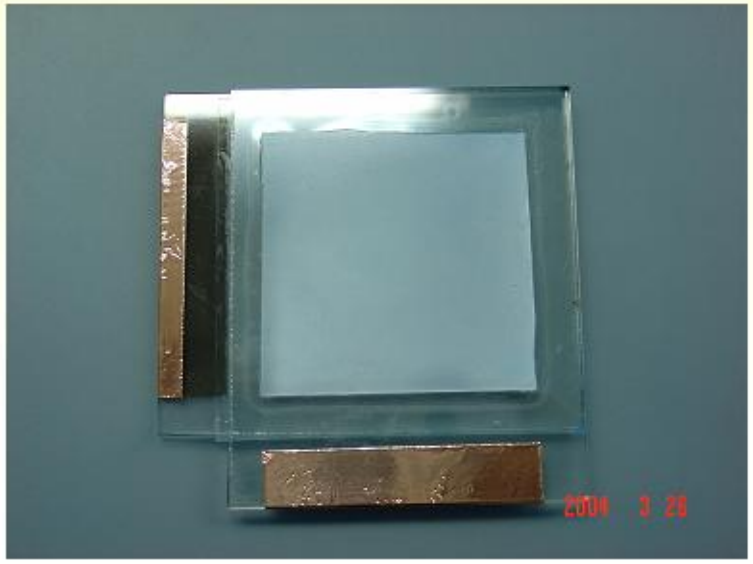
- 응답시간 : 0.2ms
- 구동전압 : 100V
- 광반사율 : 42%

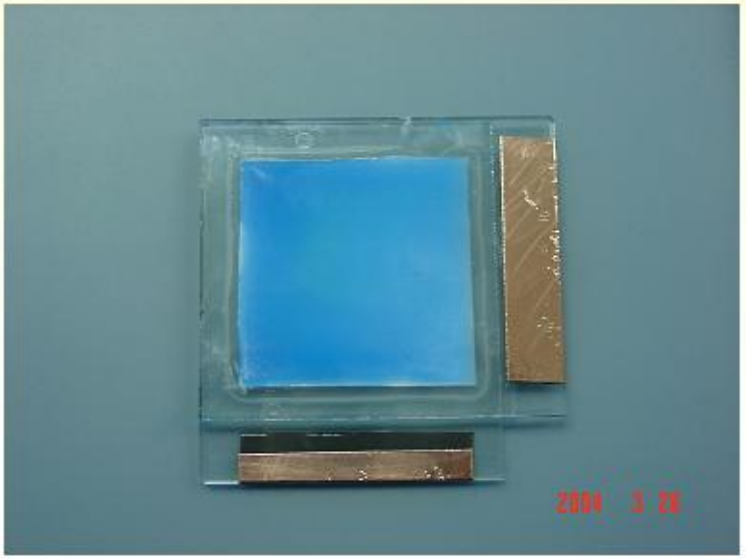


7-1

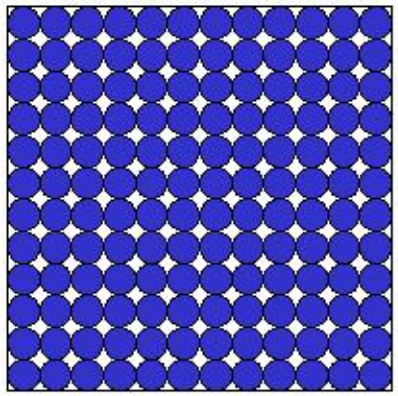


7-2

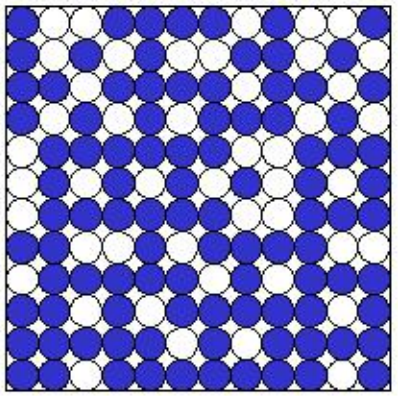




How to Enhance Transparency?



ICP Coated Film

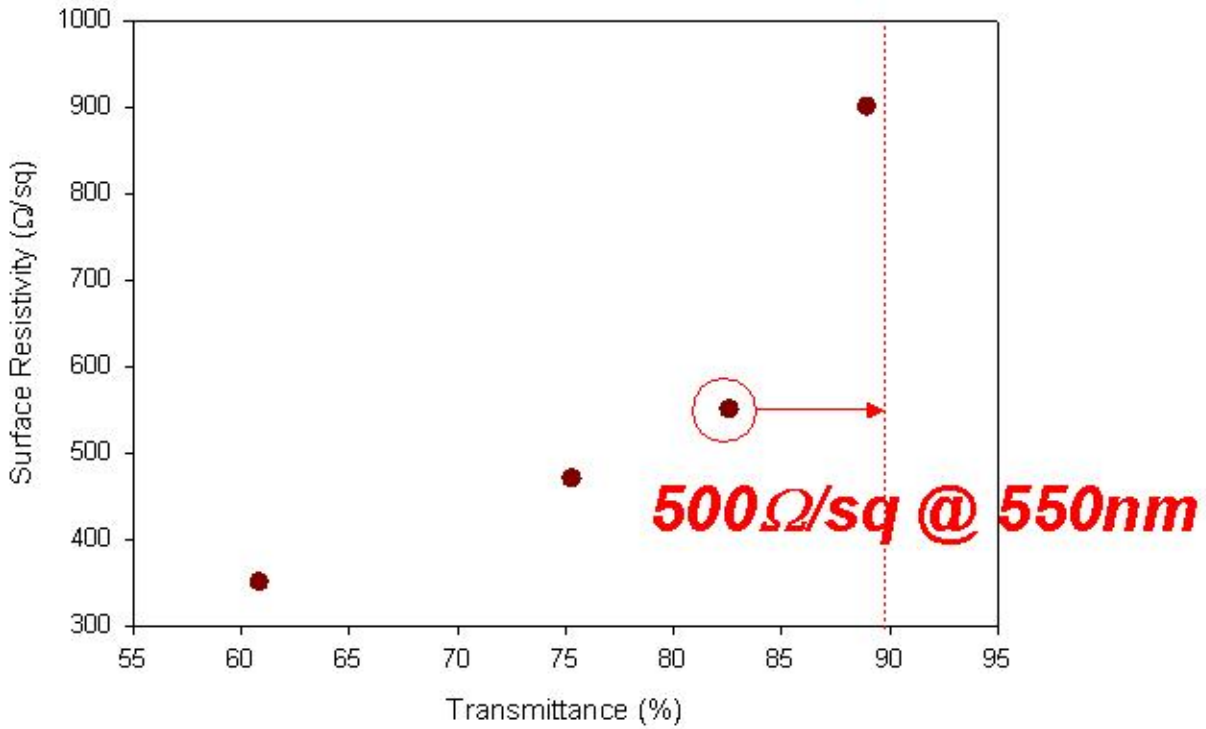


Nanostructured Conducting Film

Nanopore
Nanophase separation
Nanoparticle

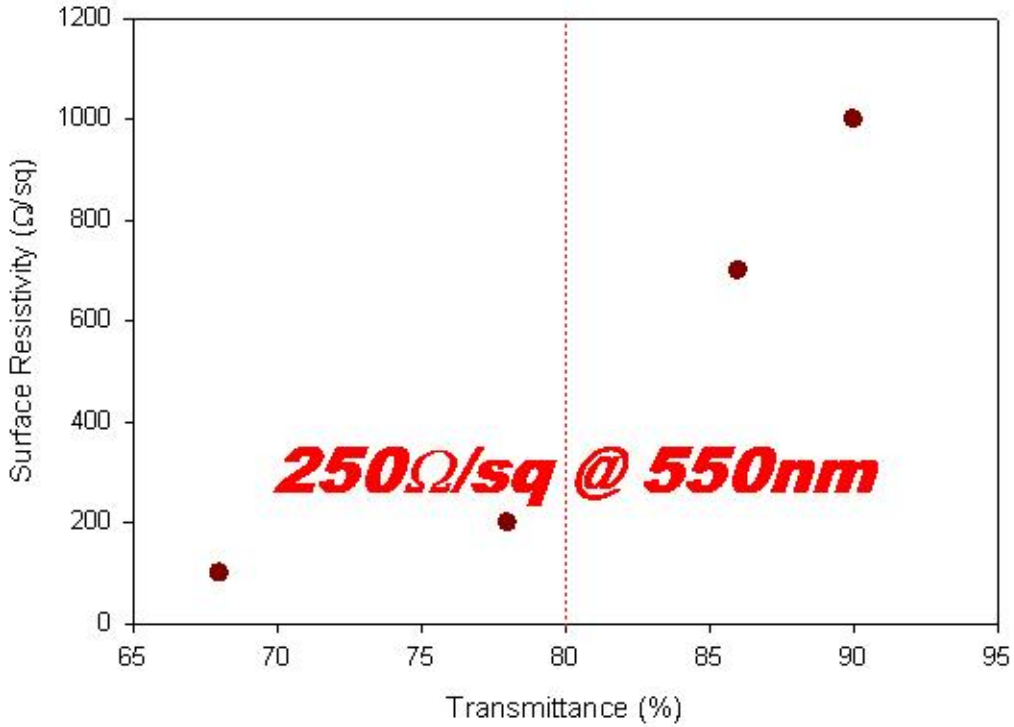
→ *Highly transparent film with high conductivity*

Transparent Electrode



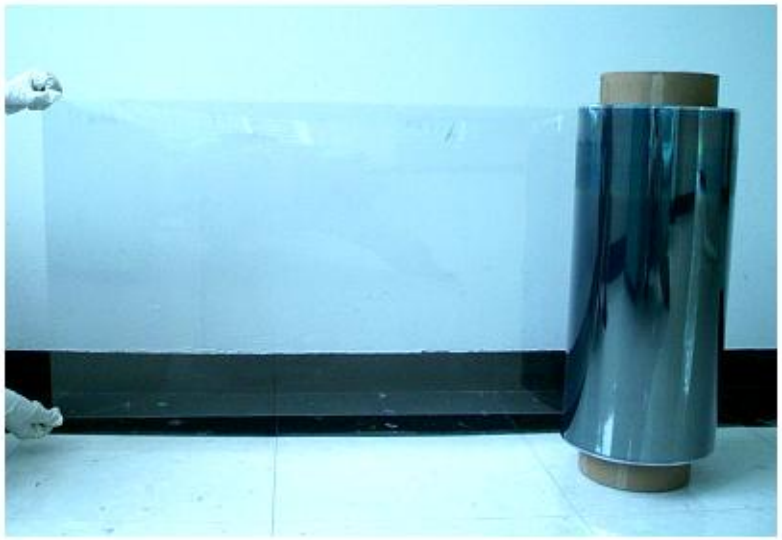
Surface Resistivity vs. Transmittance(including 120μm PET) of Electrode Prepared by ICP/Additive Mixture (65:35)

Transparent Organic Electrode



Surface Resistivity vs. Transmittance(including 120μm PET) of Electrode Prepared by ICP/Additive Mixture

Transparent Organic Electrode



Prepared using Roll-to-Roll Process

Transparent Organic Electrode

		Test Condition	Requirement	Property *
Suface Resistance			500~700Ω/□	700Ω/□
Light Transmittance			85~88%	> 85%
Haze		Haze meter	~ 10	< 1
Film Adhesion		Cross Cut & Tape Peeling Test	100/100	100/100
Solvent Stability	Acetone	25°C, 10min	R/Ro < 1.2	R/Ro : 1.0
	Ethanol	25°C, 10min	R/Ro < 1.2	R/Ro : 1.1
	Toluene	25°C, 10min	R/Ro < 1.2	R/Ro : 1.0
	MEK	25°C, 10min	R/Ro < 1.2	R/Ro : 1.1

** Base Film: 188㎛ PET (T : 85%)*

Thermal Stability

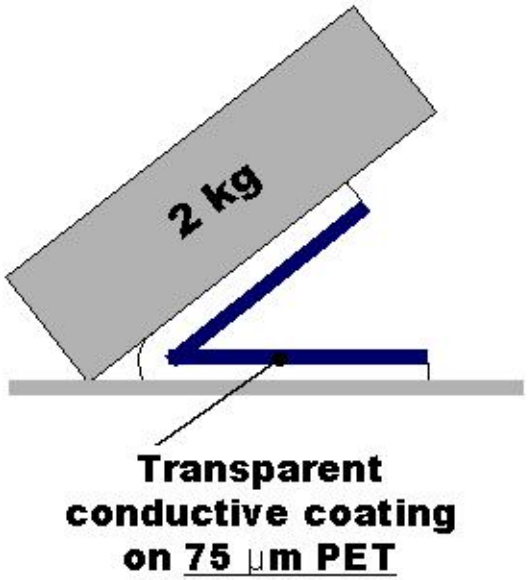
Thermal Shirinkage

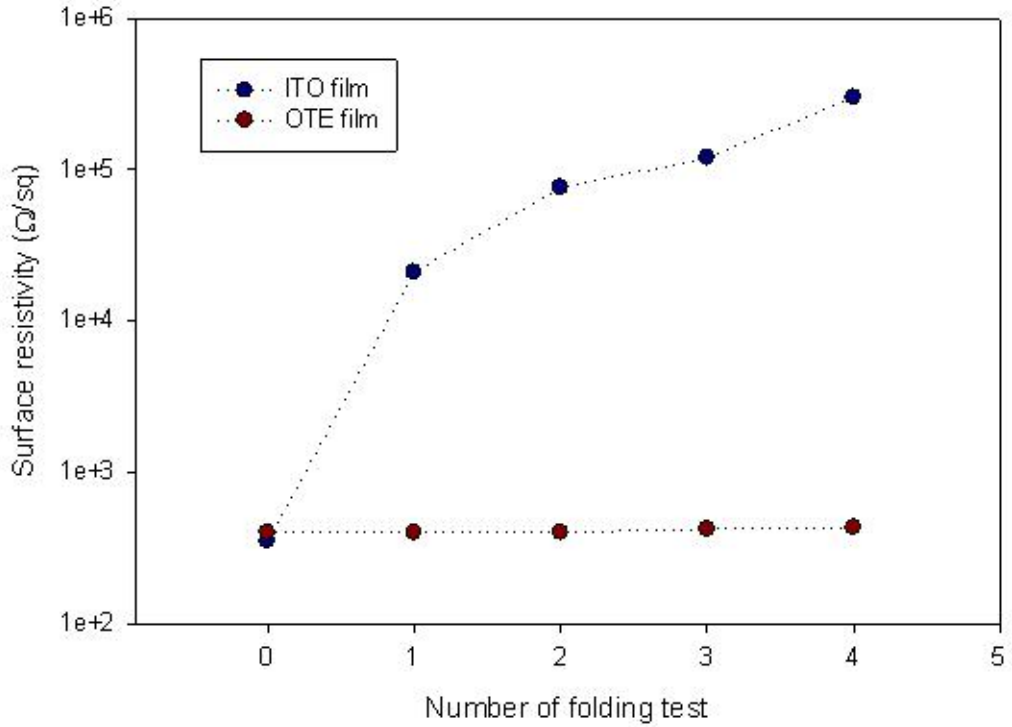
		Test Condition	Requirement	Property
Thermal Shirinkage	MD	150°C, 30min	<1.2	L/Lo<1.03
	TD	150°C, 30min	<1.0	L/Lo <1.0

Thermal Stability

	Test Condition	Requirement	Property
Thermal Stability	140°C, 2hr		R/Ro <1.1
	90°C, 250hr	<1.2	R/Ro <1.2

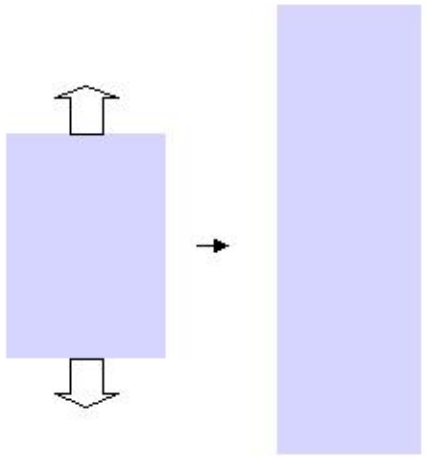
Folding Resistance

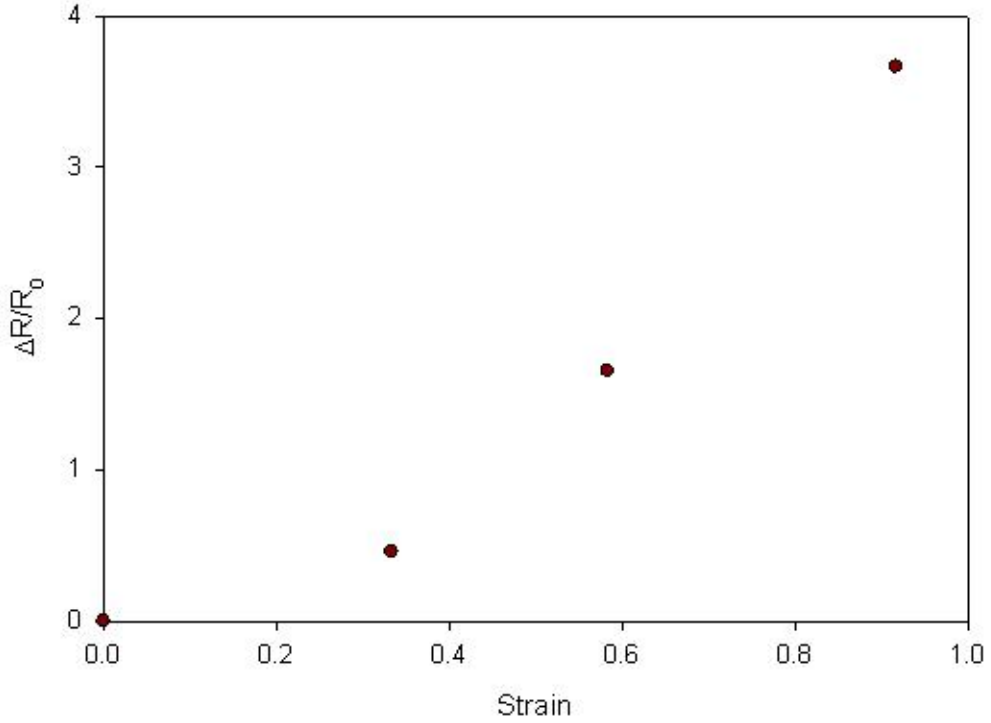




Transparent Organic Electrode shows much higher folding resistance than ITO film

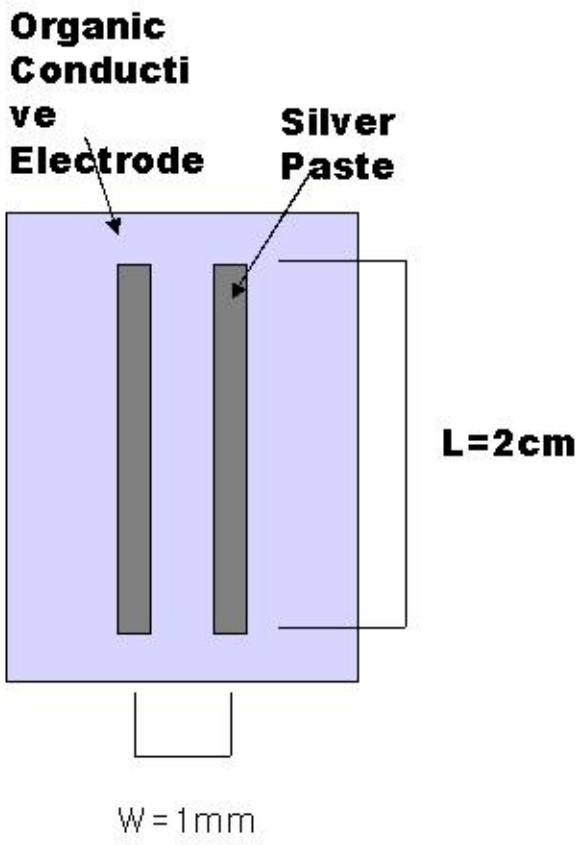
Uniaxial Strain of T.O.E





Transparent Organic Electrode shows slight resistance change (PU substrate, R=700Ω/sq)

Contact Resistance

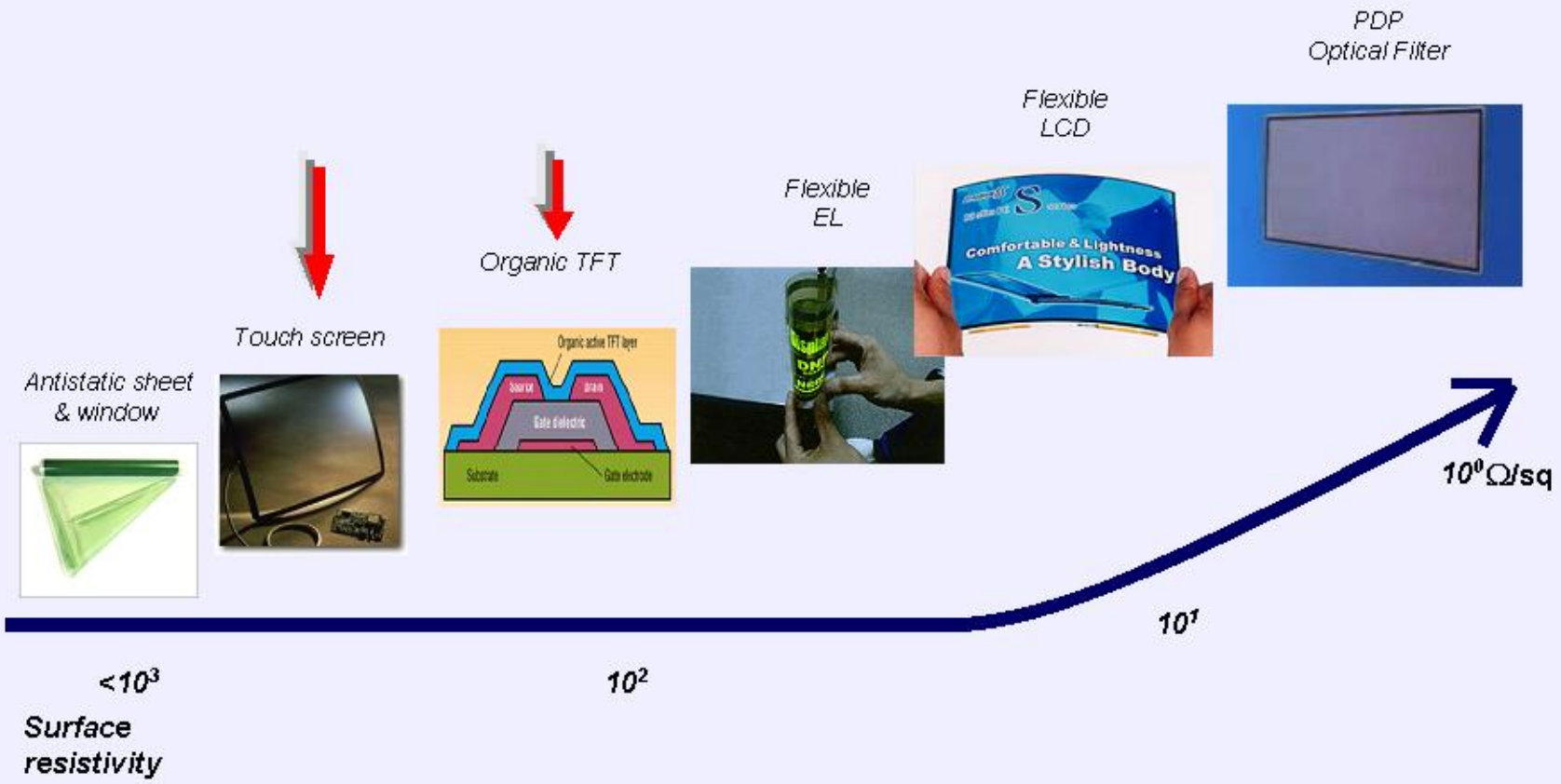


	Rs (Ω)	R(Ω/sq)
A	16.9	338
B	16.7	334
C	14.8	296
D	14.8	296
E	11.4	228
F	19.6	392
G	$5X10^6$	$1.0X10^8$
H	12.3	246
I	11.8	236

Ro = 300 Ω/sq, R=Rs X W/L

Contact Resistance between OTE & Silver paste is quite low

Emerging Application :
Electrode & O-TFT for Flexible Display



Carbon Nanotubes

Mechanical

Tensile Strength
10~100X steel alloy
Resilience

Density

0.5X aluminum

Thermal Stability

~ 2,800 °C

Electrical

~ 1 billion A/cm^2
1000X Cu

Optical

Field Emission
at 1 volt
0.01X Md tips

Thermal

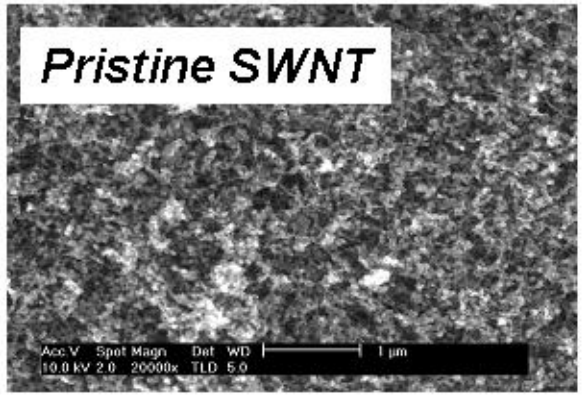
Heat transmission
6000W/mK
2X Diamond

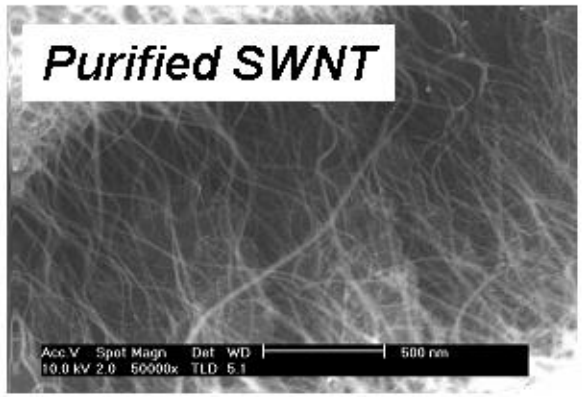
Ref) Scientific American, p62, Dec. 2000

Issues on Carbon Nanotube Electrode

1 Purification

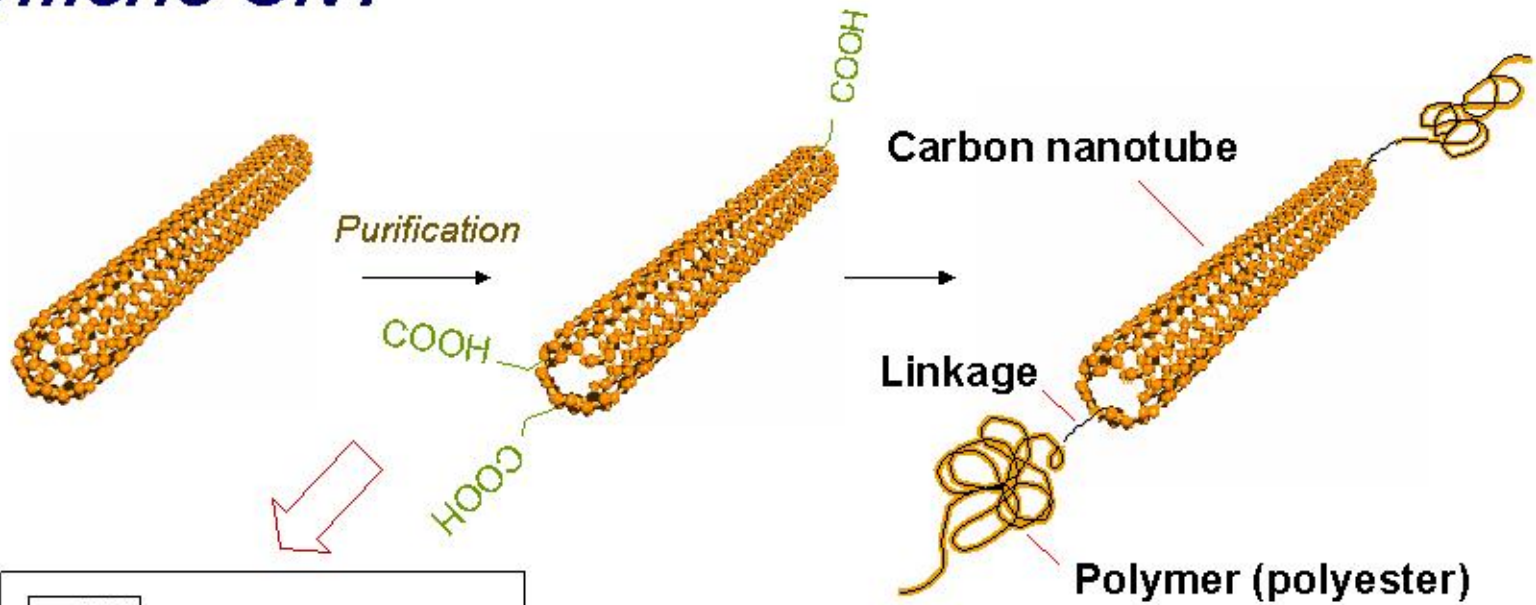
	Surface Resistivity (Ω/sq)
Pristine SWNT	300
Purified SWNT	20
Polished SWNT	1

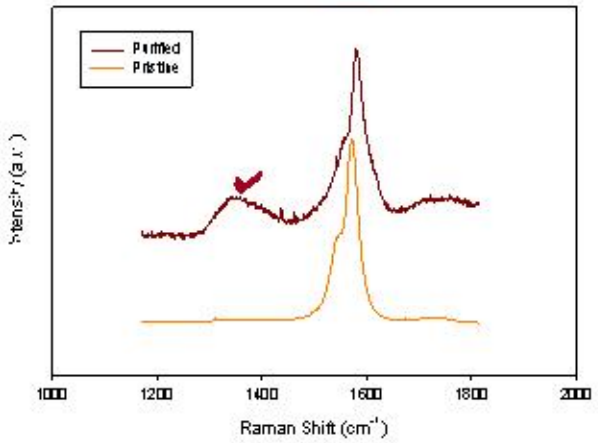




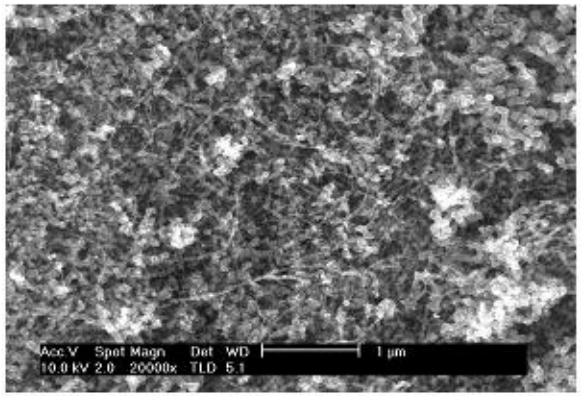
CNT Dispersion (1)

Polymeric CNT

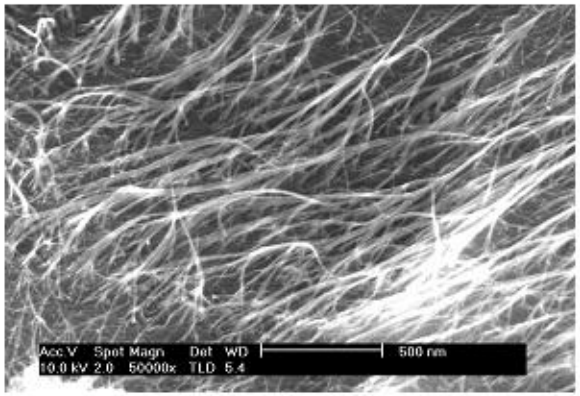




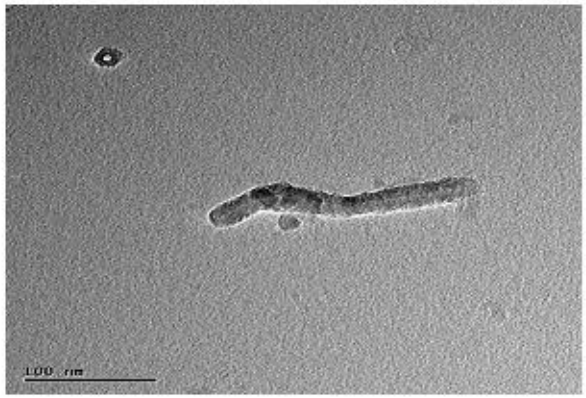
CNT Dispersion (2)



As-prepared CNT



Purified CNT

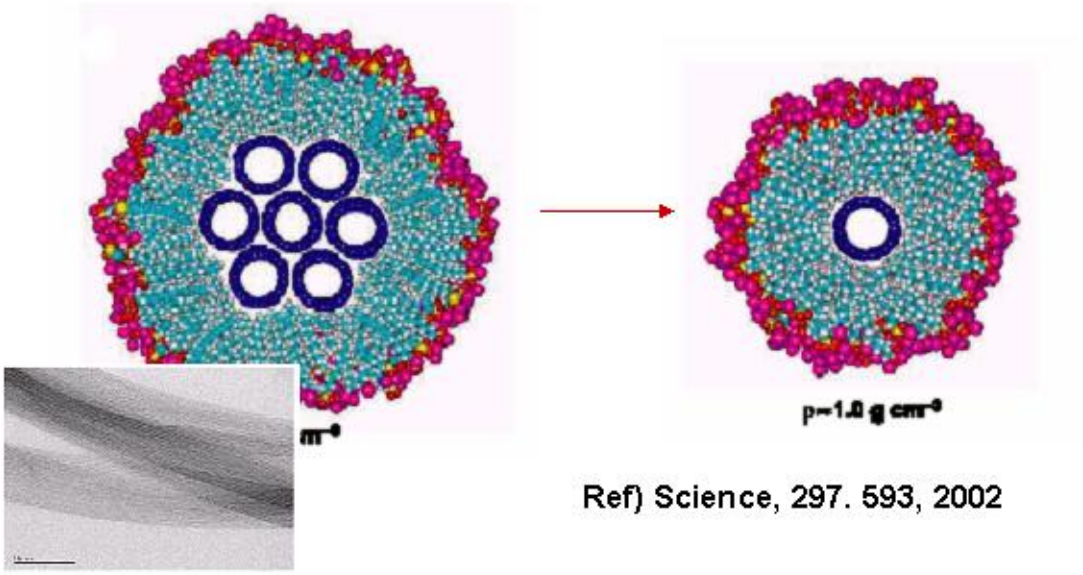


Complexed CNT

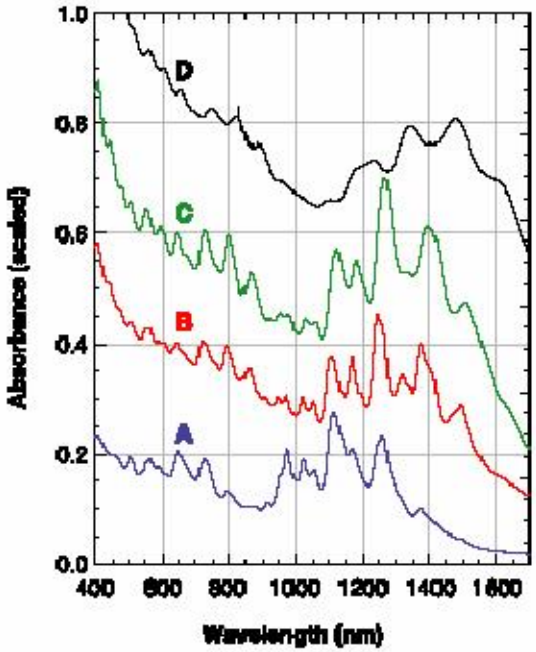
500ppm Cutted CNT in water : 134.6nm
2000ppm Cutted CNT in Water : 7000nm
2000ppm Cutted CNT Complex in water : 197.9nm

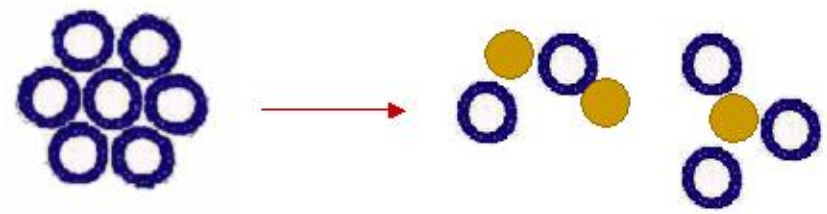
Issues on Carbon Nanotube Electrode

3 Isolation



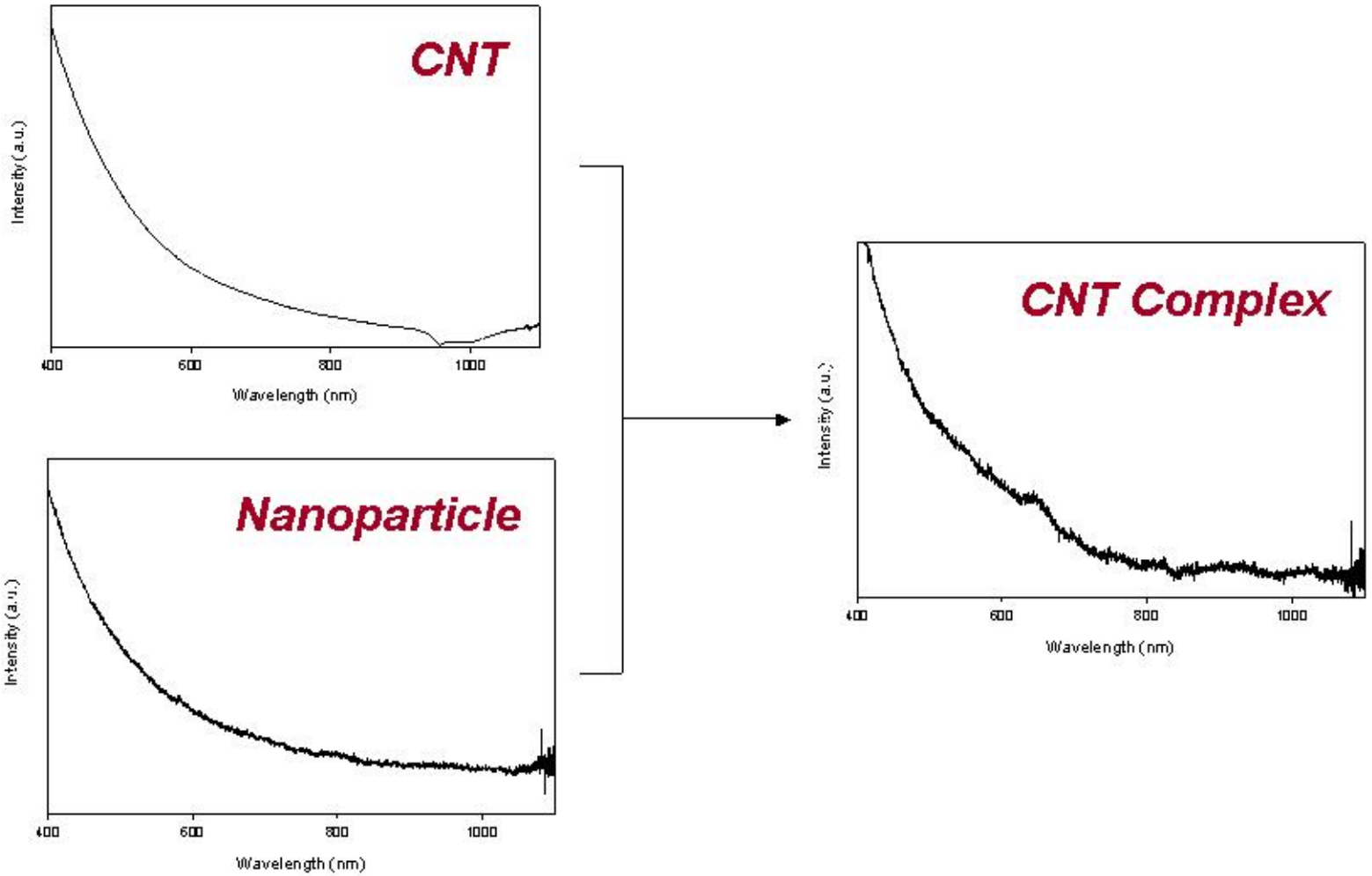
Ref) Science, 297. 593, 2002





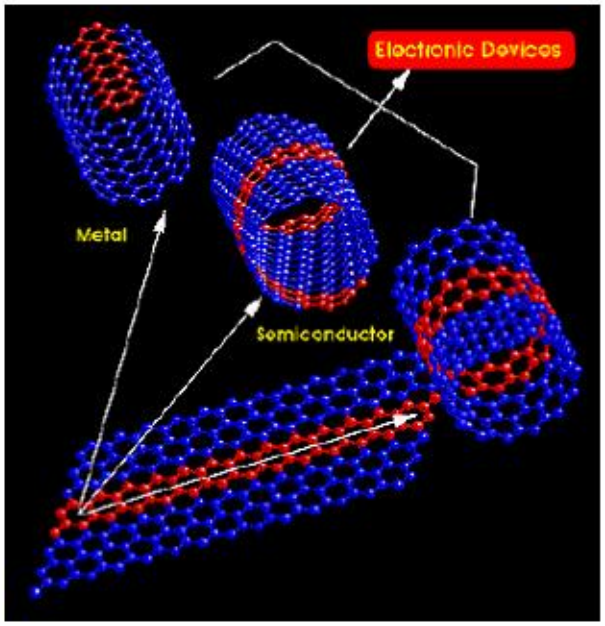
DPI Solutions

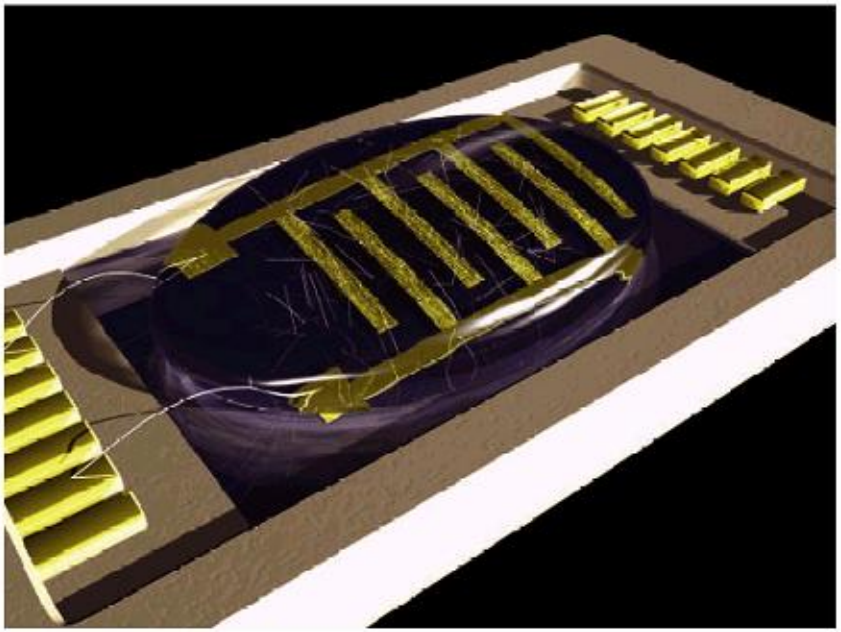
CNT Isolation



Issues on Carbon Nanotube Electrode

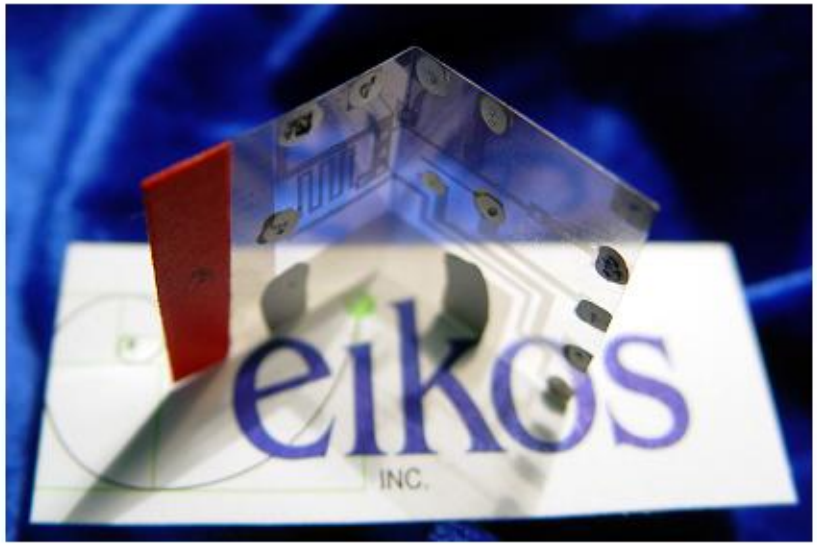
4 Metallic CNT Separation



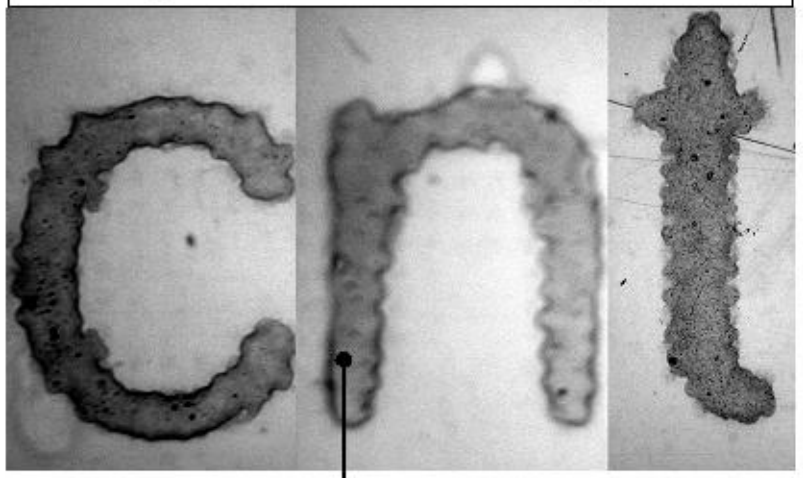


Ref) Science, 301. 344. 2003

CNT Electrode of Eikos Co.



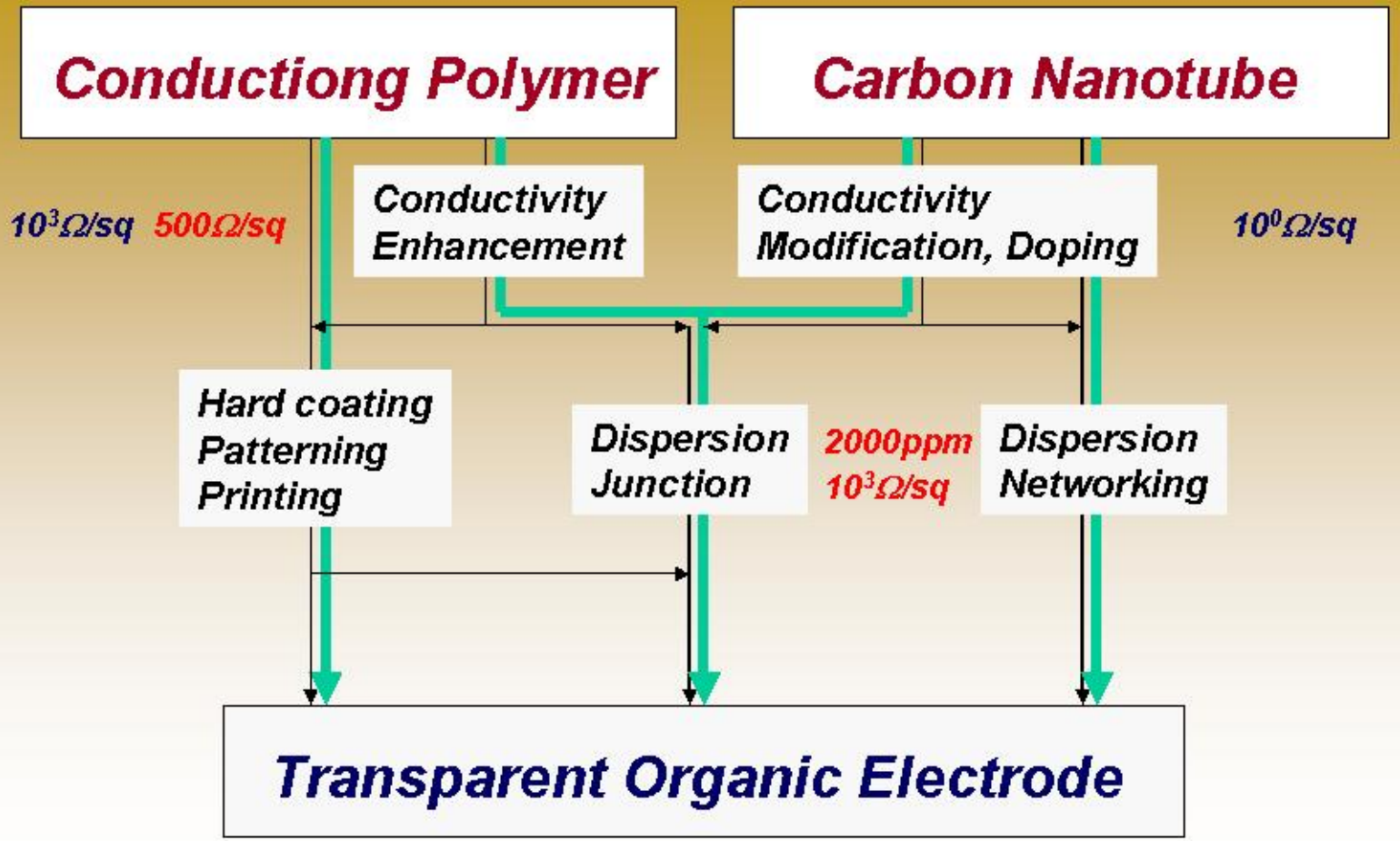
CNT / PVDF*
transparent conductor pattern



~ 125 μm wide
conductor pattern

CNT / Melamine ~ 640 Ω/□.

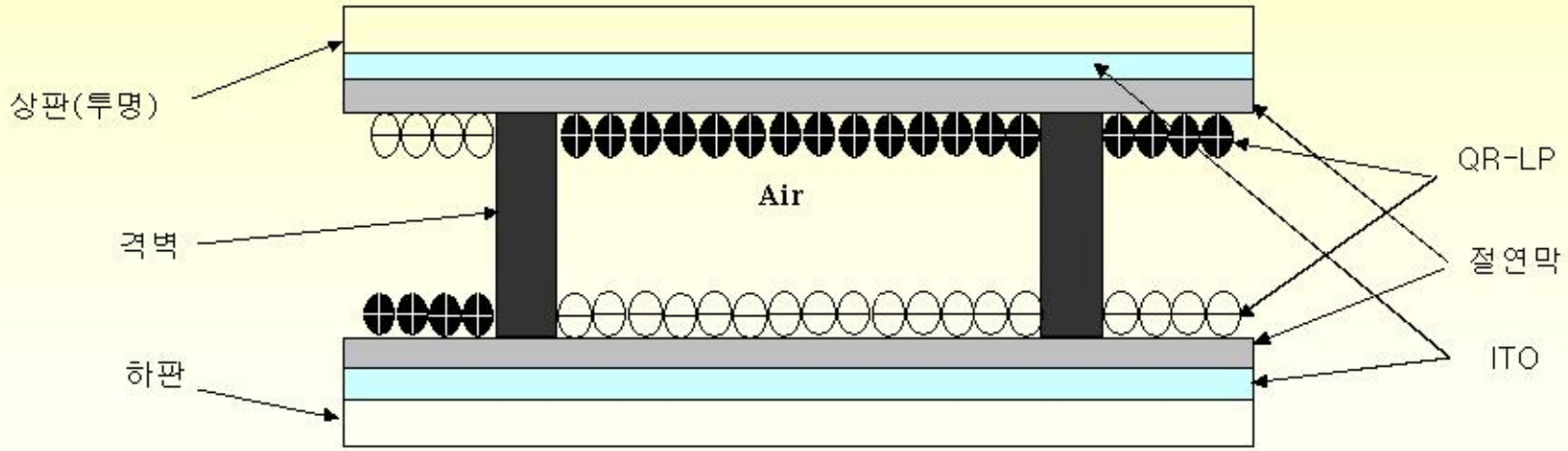
Summary


Conductiong Polymer
Carbon Nanotube
10³Ω/sq
500Ω/sq
Conductivity Enhancement
Conductivity Modification, Doping
10⁰Ω/sq
Hard coating Patterning Printing
Dispersion Junction
2000ppm
10³Ω/sq
Dispersion Networking
Transparent Organic Electrode

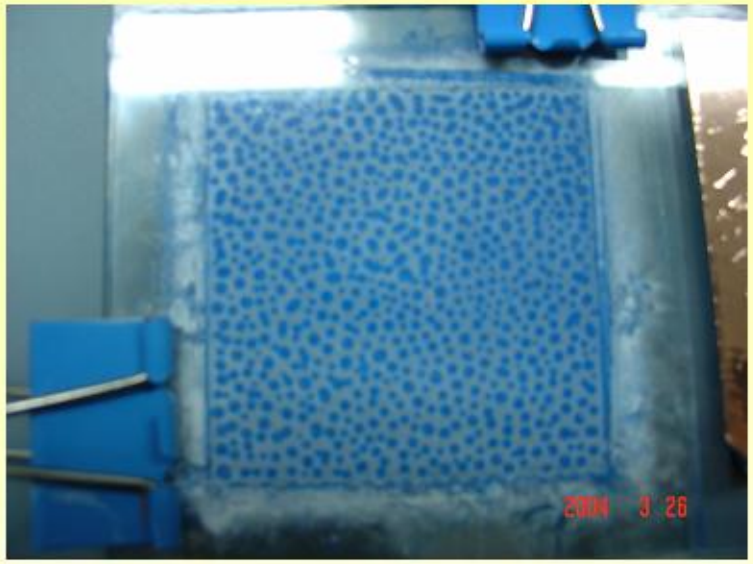
E-Paper(QR-LP Type)

QR-LP type의 셀 구조는 투명 전극이 형성되어 있는 상하 기판과 셀을 구분하는 격벽이 형성되며 투명 전극 표면은 전하의 소멸 방지 및 입자의 표면 부착 에너지를 최소화 하기 위한 절연막이 형성되어 지고 셀내에는 반대 부호로 대전 되어진 2종의 입자가 주입된다.

- 응답시간 : 0.2ms
- 구동전압 : 100V
- 광반사율 : 42%



7-1



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