제주대학교
JEJU NATIONAL UNIVERSITY

E-Printed Technologies

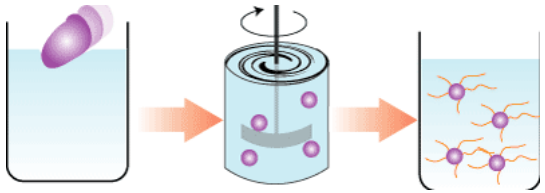
Jinho Bae

Ocean System Engineering

Ocean Information System Group

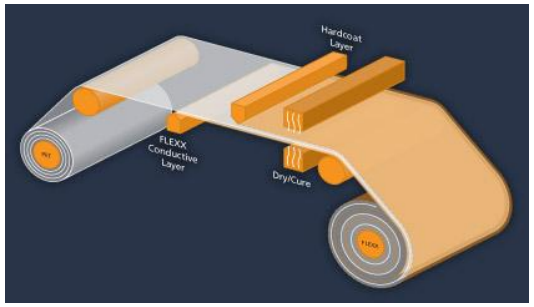
Processing

- Ink synthesis
  - Mixing ink with solvent



- Substrate formation
  - Cutting and cleaning
  - UV treatment

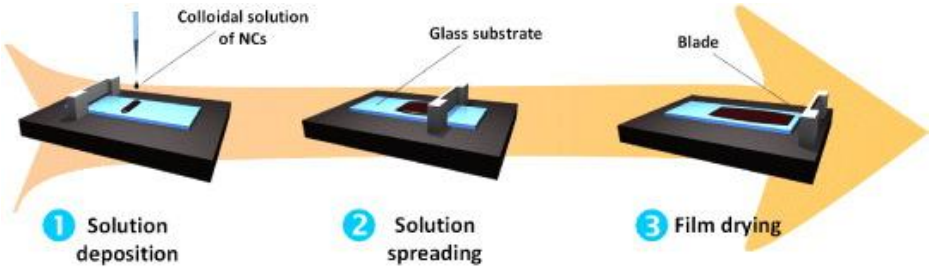
Roll-to-Roll



Screen

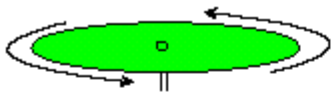
- Materials deposition
  - Spin coater
  - EHD
  - Roll-to-Roll
  - Roll-to-Plate
  - Screen
  - Doctor blade

Doctor blade

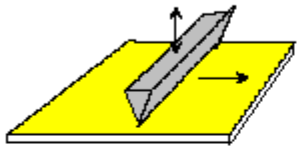


Comparison Printed Tech and Vacuum Based Tech

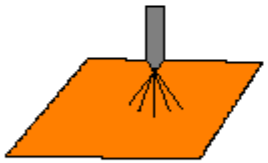
Solution processing (polymers):



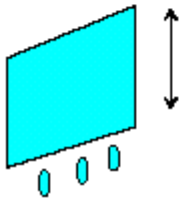
Spin Coating



Doctor Blade

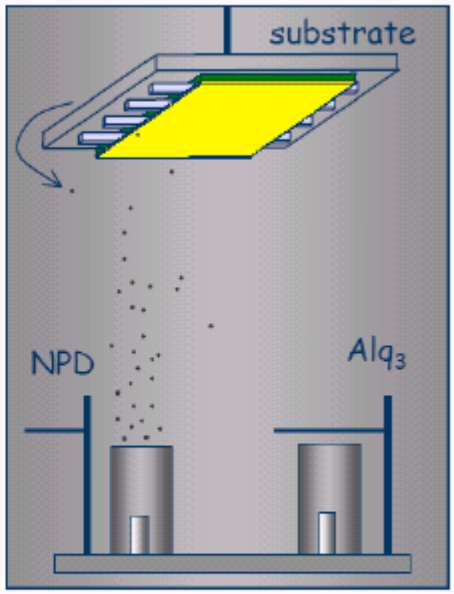


Ink Jet Printing



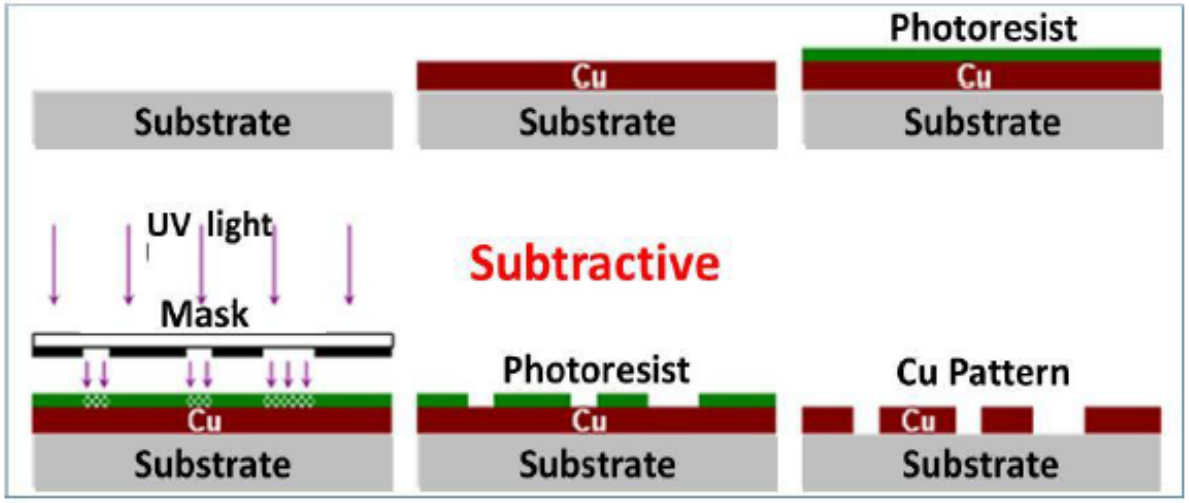
Dipping

Evaporation (small molecules):

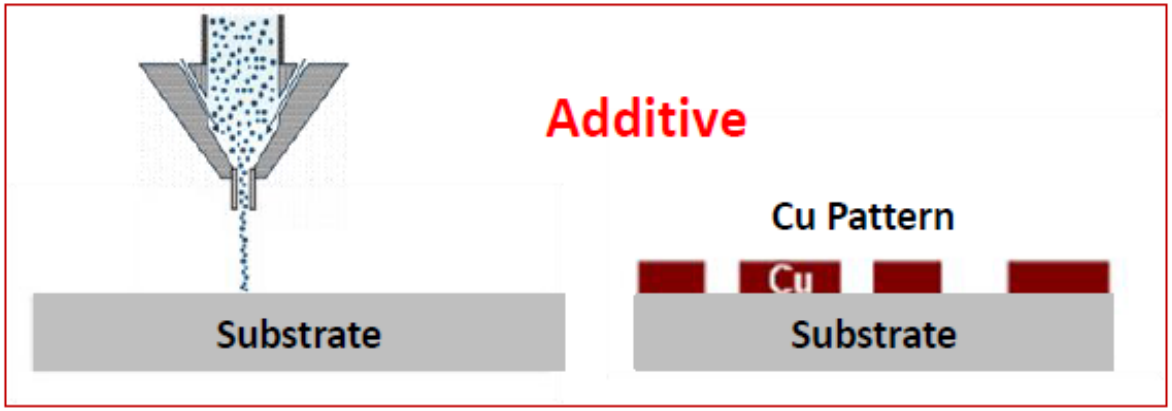


Small molecules are thermally evaporated in vacuum

CMOS Tech. vs Printed Tech.

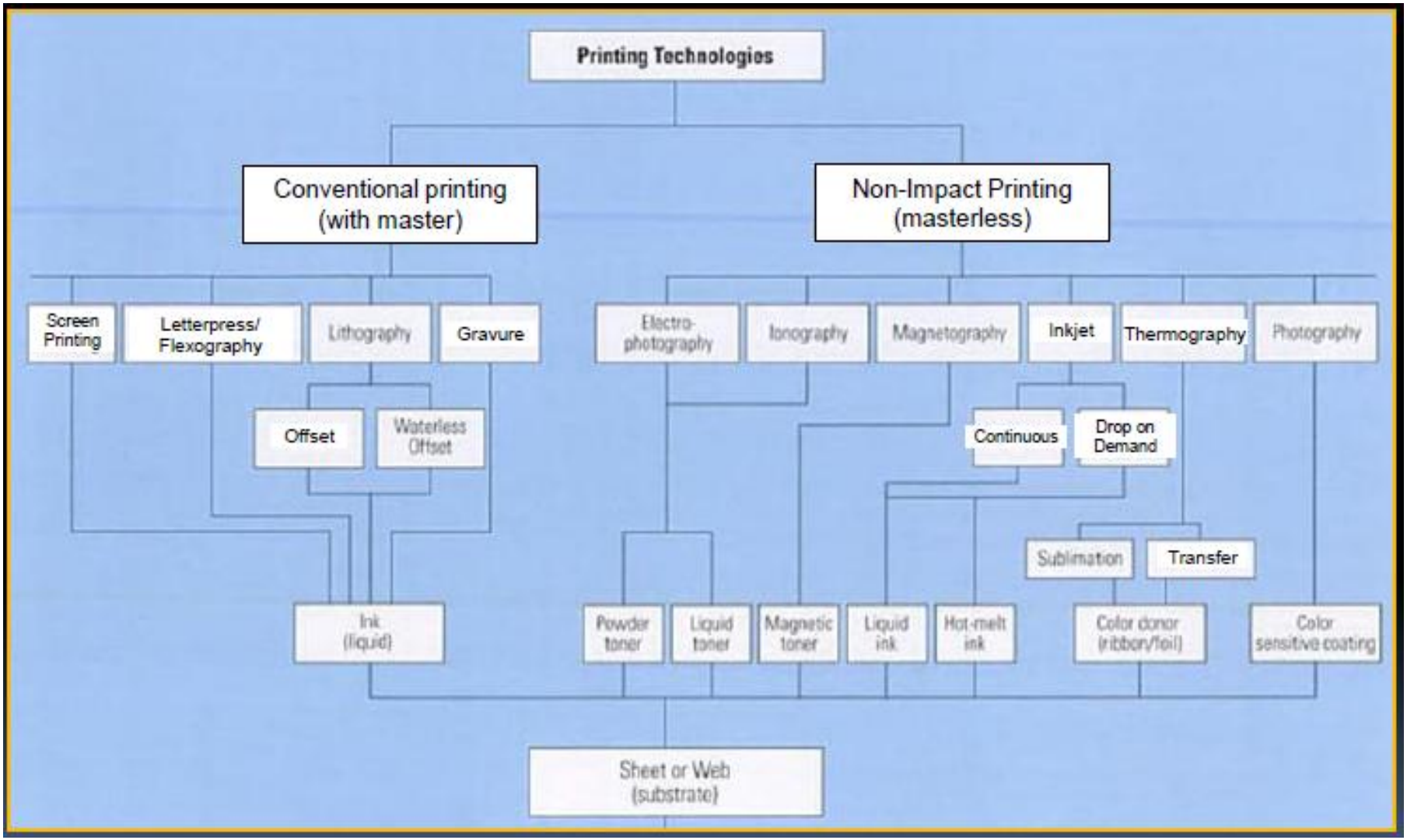


- High equipment investment
- Lengthy, complex process steps
- High production volume to justify equipment/process cost



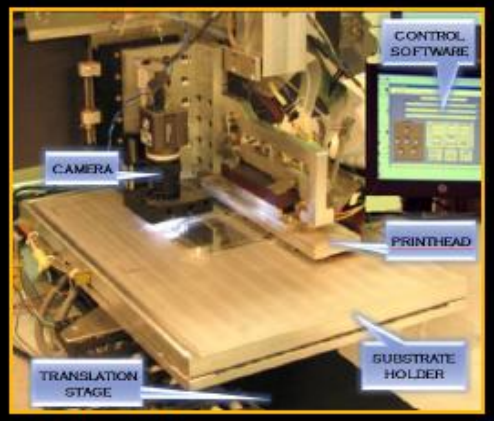
- 3D curvature surfaces
- Rapid production
- Cost independent of production lot size
- Environmentally friendly

Printed Tech.

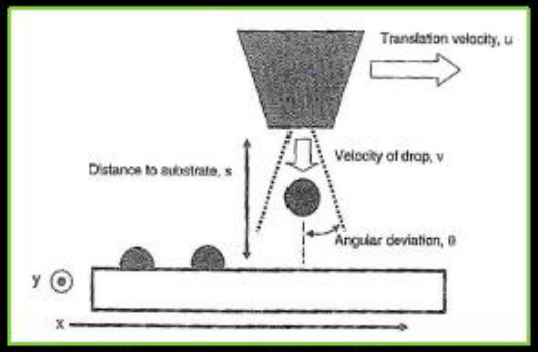


Jet Printing Tech. (1)

Inkjet Printing – Drop Formation



PARC inkjet system

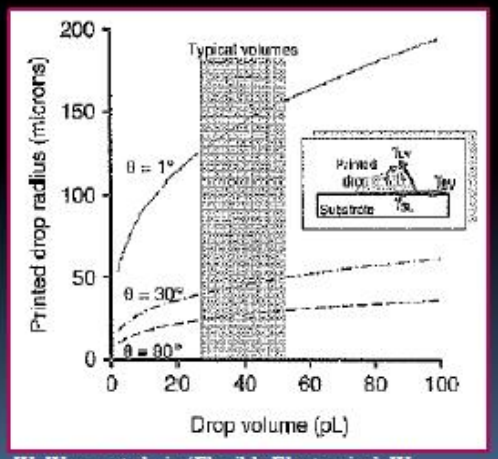


$\Delta y \sim s \cdot \Delta\theta$

For high accuracy keep distance low !

Piezo-inkjet

Feature size:
depends on printed volume and drop interaction with surface



W. Wong, et al., in 'Flexible Electronics', W. Wong, A. Salleo, edt., Springer

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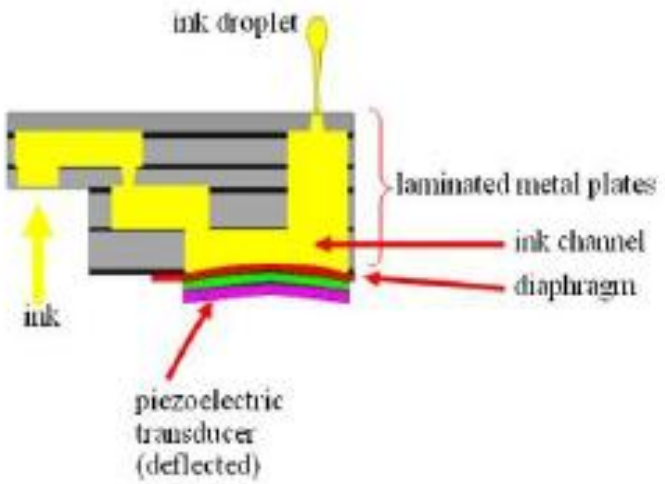
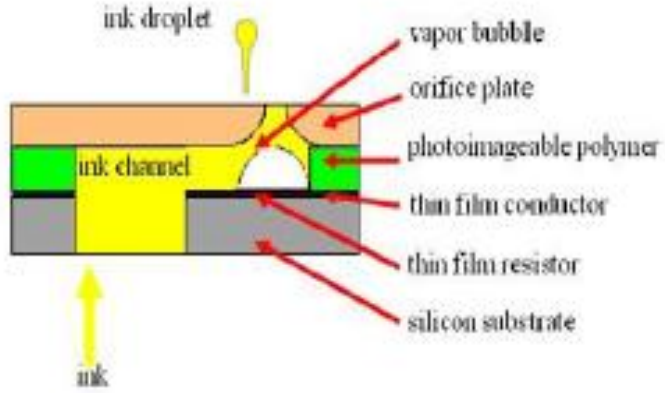
parc

Jet Printing Tech. (1)

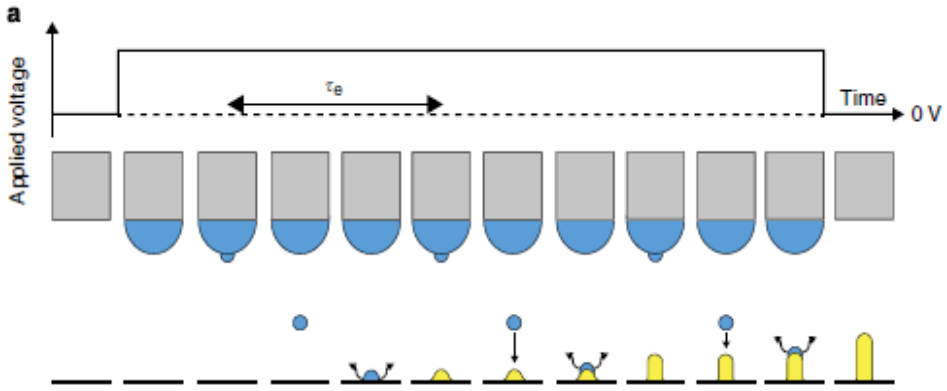


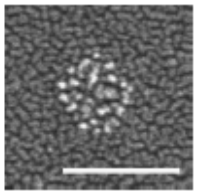
(a)

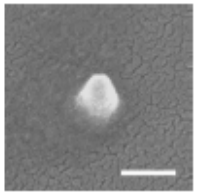


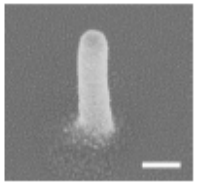
(b)

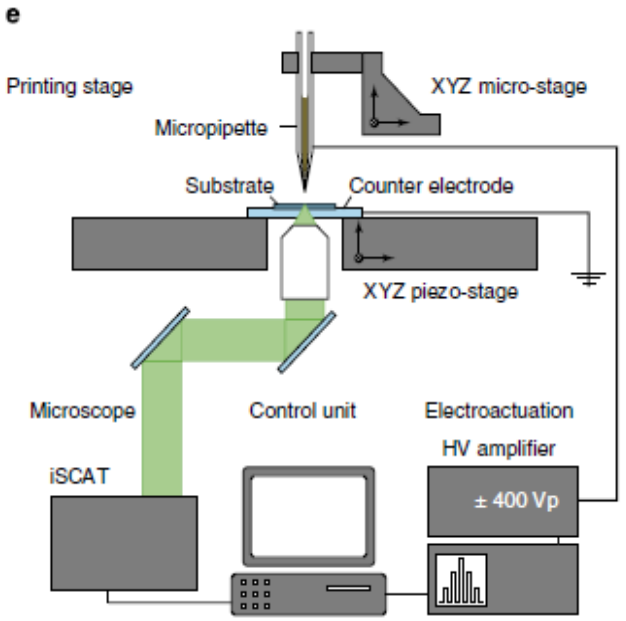
. Conventional inkjet printers (a) Piezoelectric inkjet printer (b) Thermal inkjet printer [9]



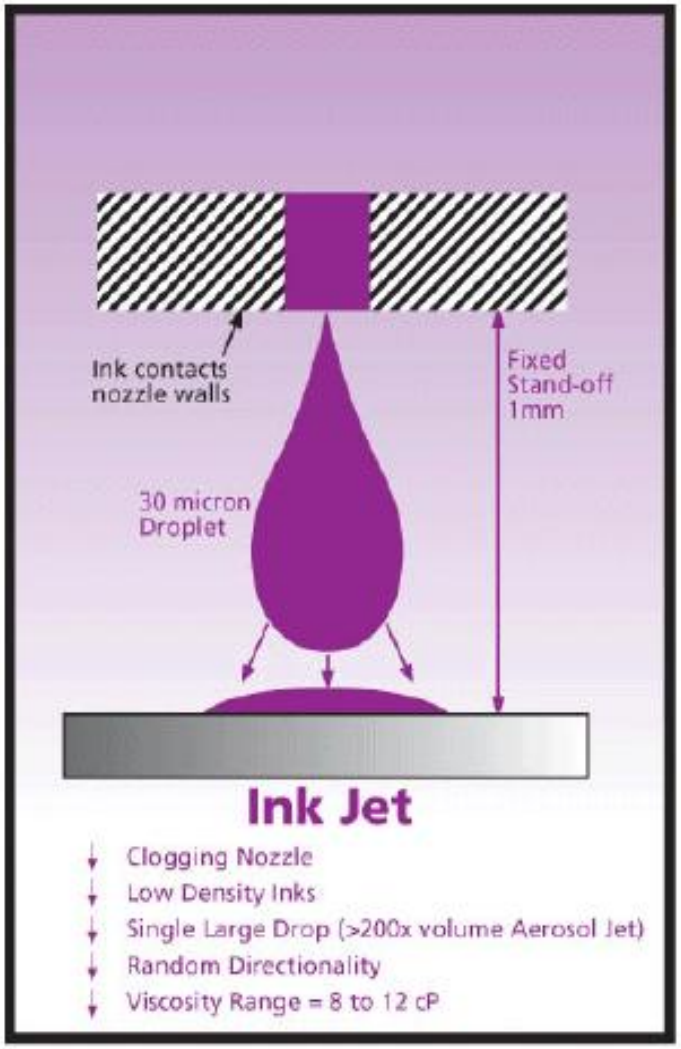


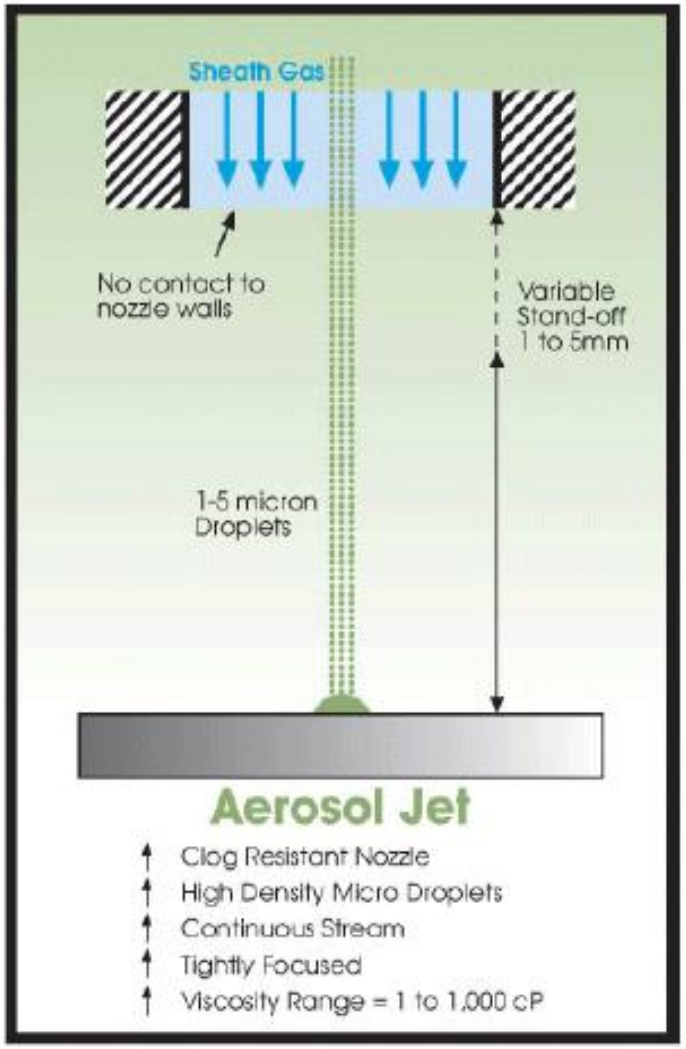






Ink jet Tech. vs Aerosol jet Tech.

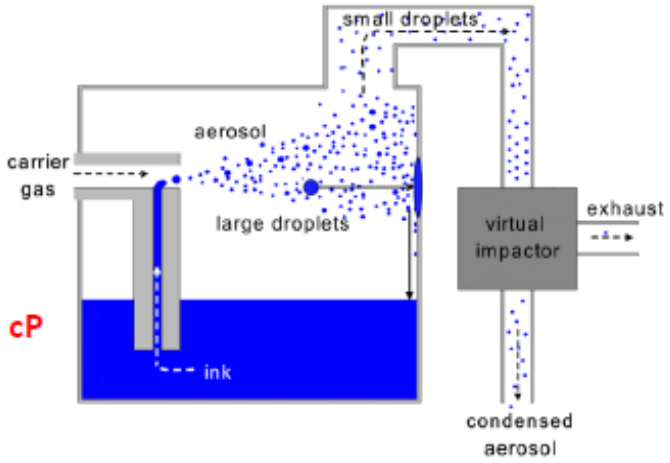




Aerosol jet Tech.

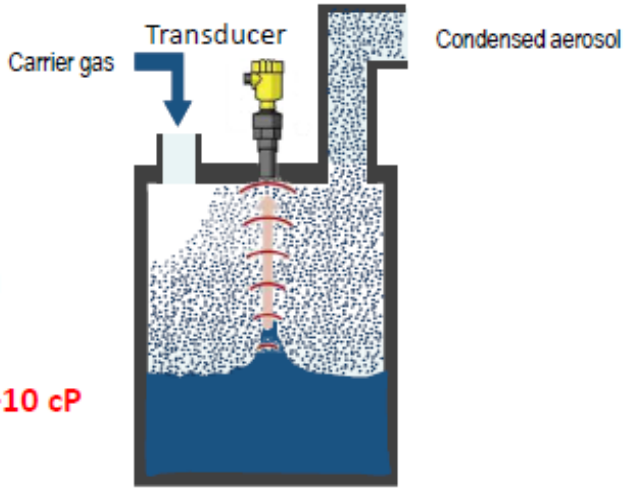
Pneumatic Atomization

Ink viscosity: 1-2,500 cP

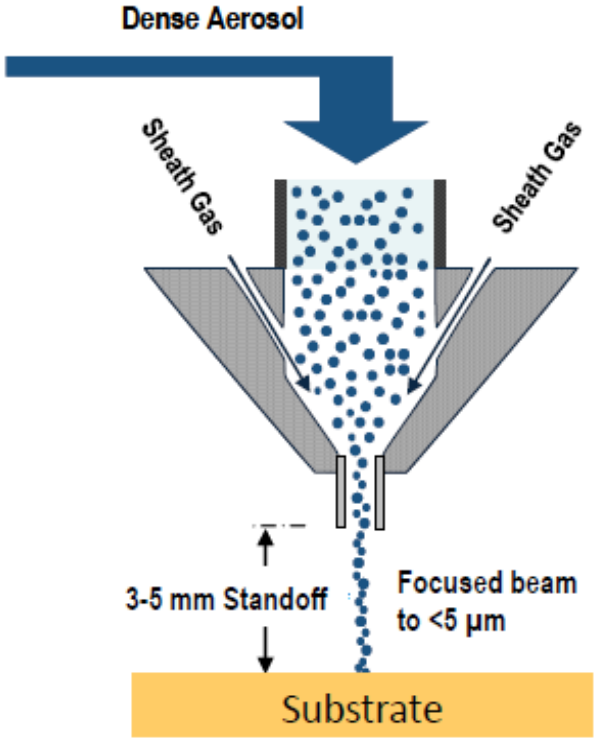


Ultrasonic Atomization

Ink viscosity: 0.7-10 cP



Printing Head



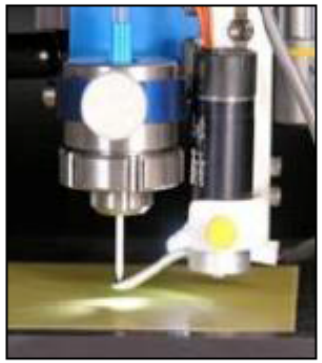
Nozzle Output:

Small Aerosol Droplets ~ 1-5um

Up to 0.25 microliter/sec dispensing speed

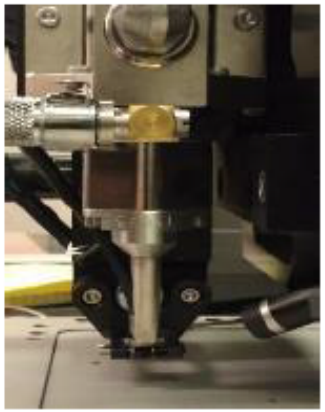
<10-150 µm line width printing capability

Aerosol jet Tech.



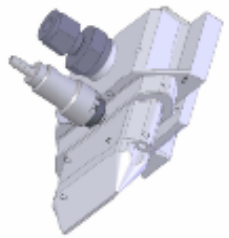
Fine Feature Printhead

- Fine Features from ~10µm to >200um
- Thicknesses ranging from 100nm to microns (material dep.)
- 5 interchangeable nozzle sizes
  - 100, 150, 200, 250, 300µm
- Integrated dispense shutter



Wide Feature Printhead

- Features from ~500µm to ~2.5mm
- Thicknesses ranging from 100nm to microns (material dep.)
- 3 standard nozzle sizes
  - 0.75mm round, 1.5 & 3.0mm slotted
- Integrated dispense shutter

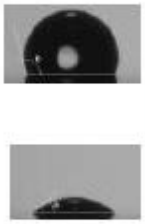


1 to 5cm Wide Nozzle Heads
(In Development)

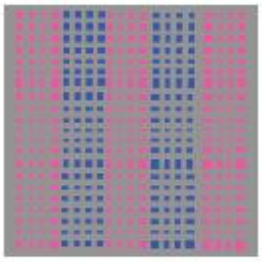
Patterning

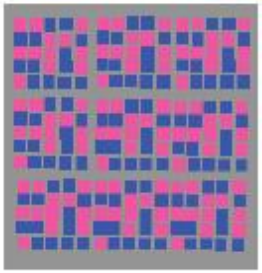
INKS
- Viscosity
- Surface tension
- Localization
- Solvent evaporation

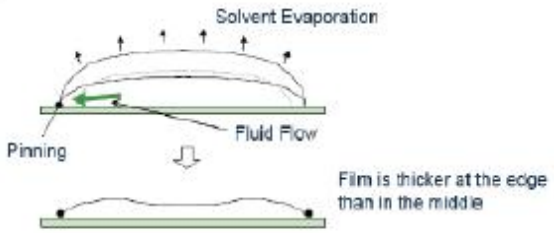
SUBSTRATE
- Wettability
- Surface state
- Thermal behavior



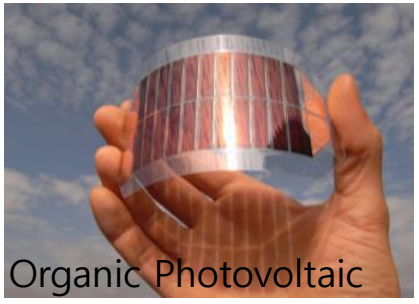
TOOLS
- Alignment
- Throughput
- Handling
- Drying



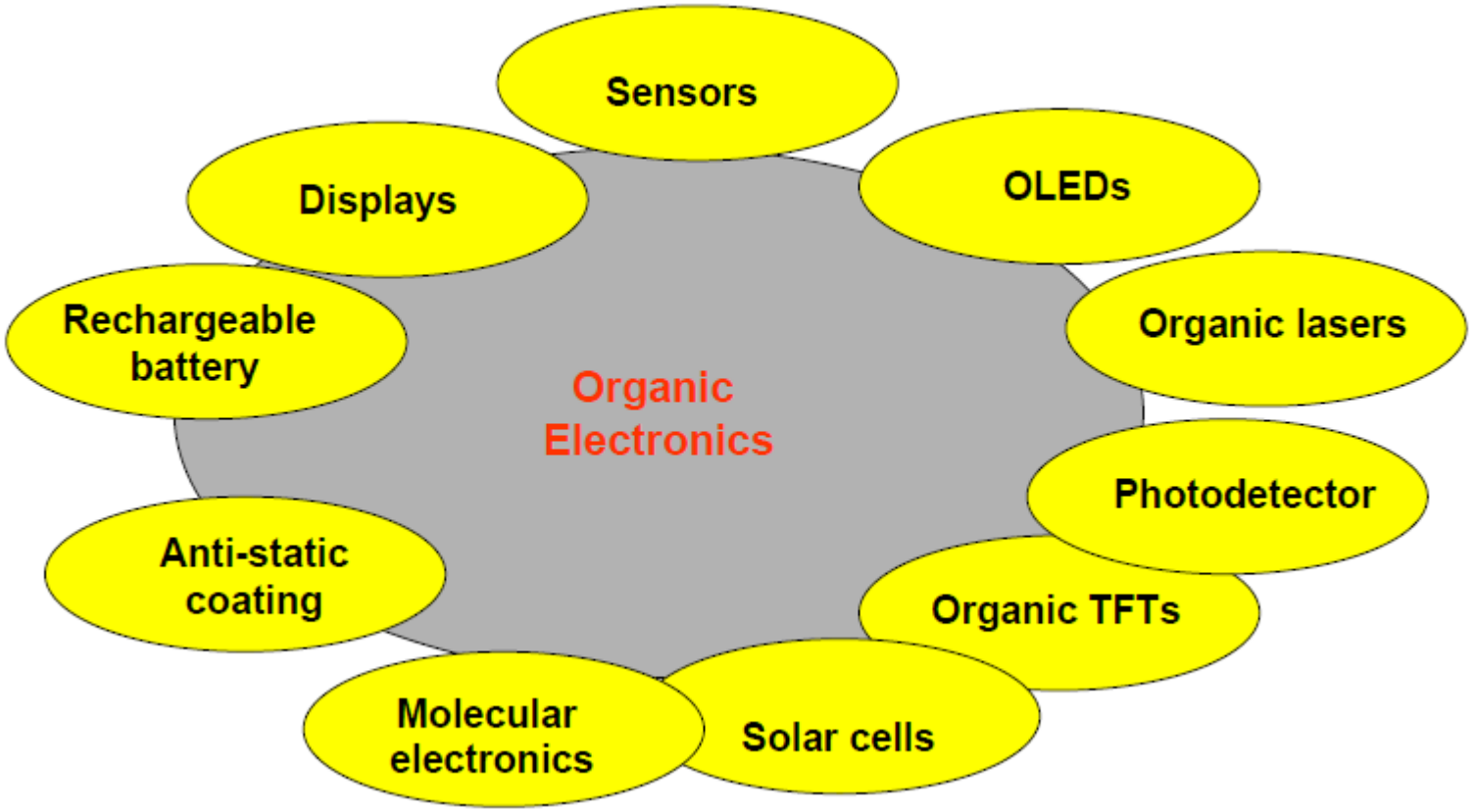




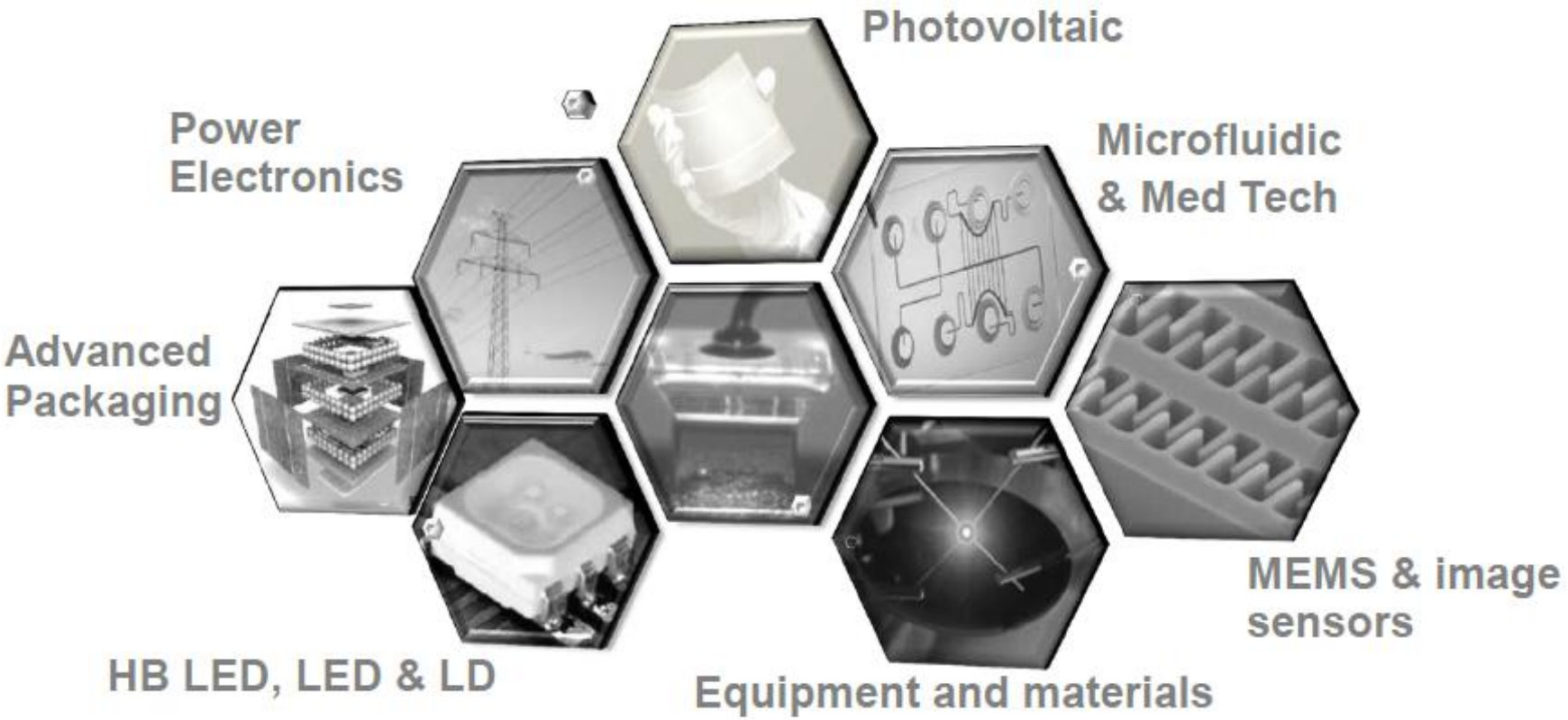
Organic Devices



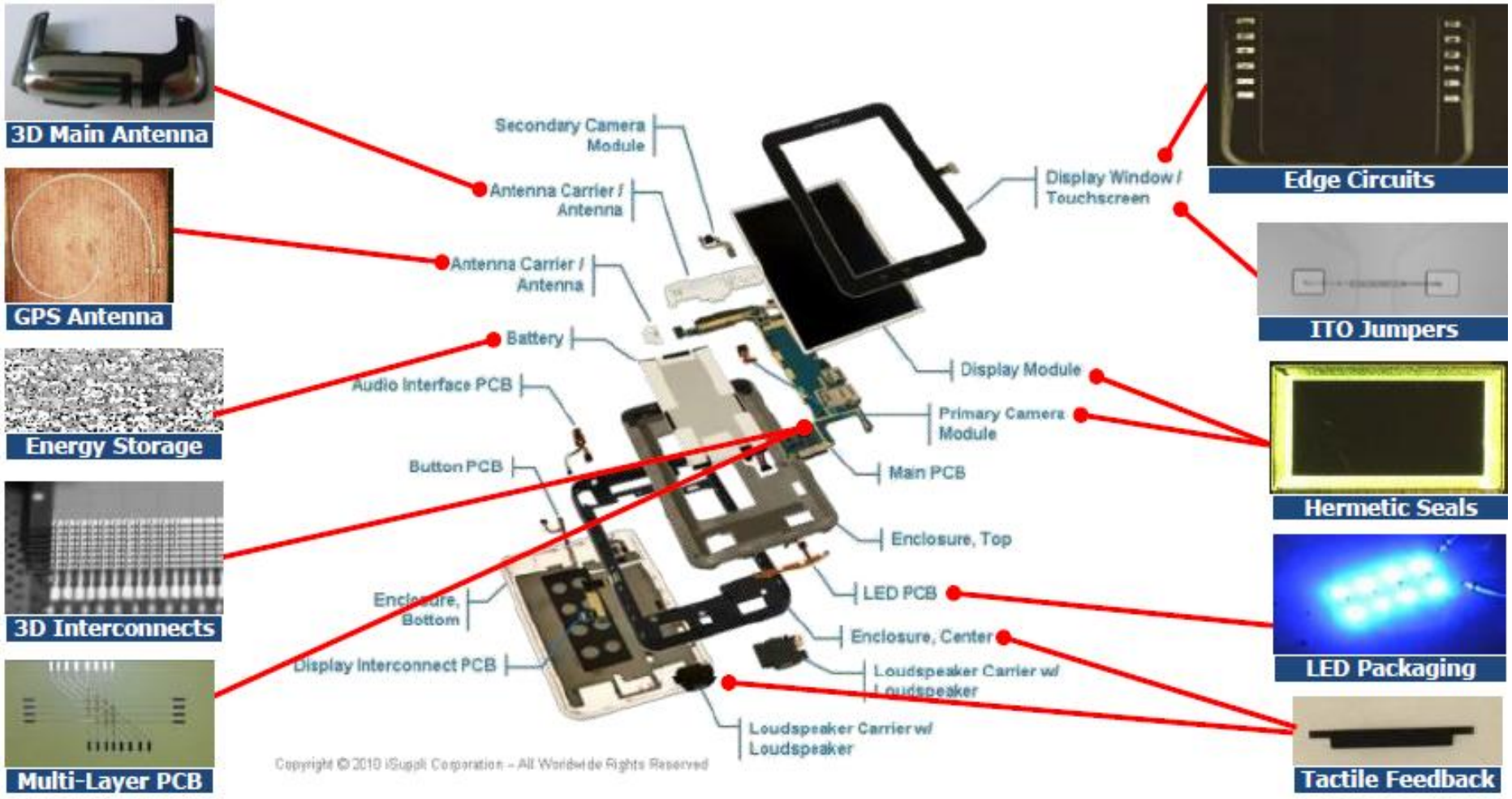
Applications of Organic Electronics



Organic Device



Example: Application Printed Tech. (1)

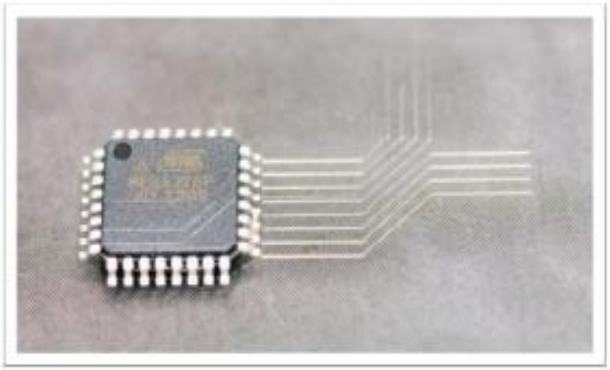


Active customer projects in the above areas, and more…

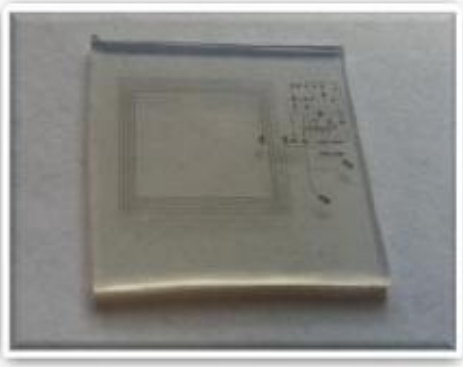
Housing by 3D printing tech is also manufactured.

Example: Application Printed Tech. (2)

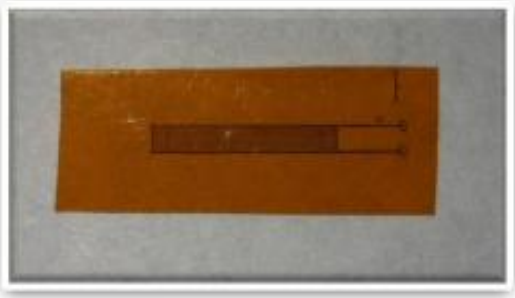
Strain sensor array printed with silver ink



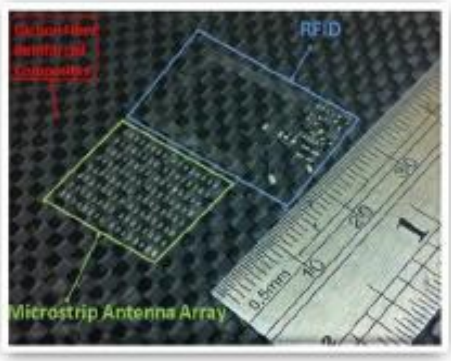
Interconnects linked with IC chip pins



RFID tag on silicone



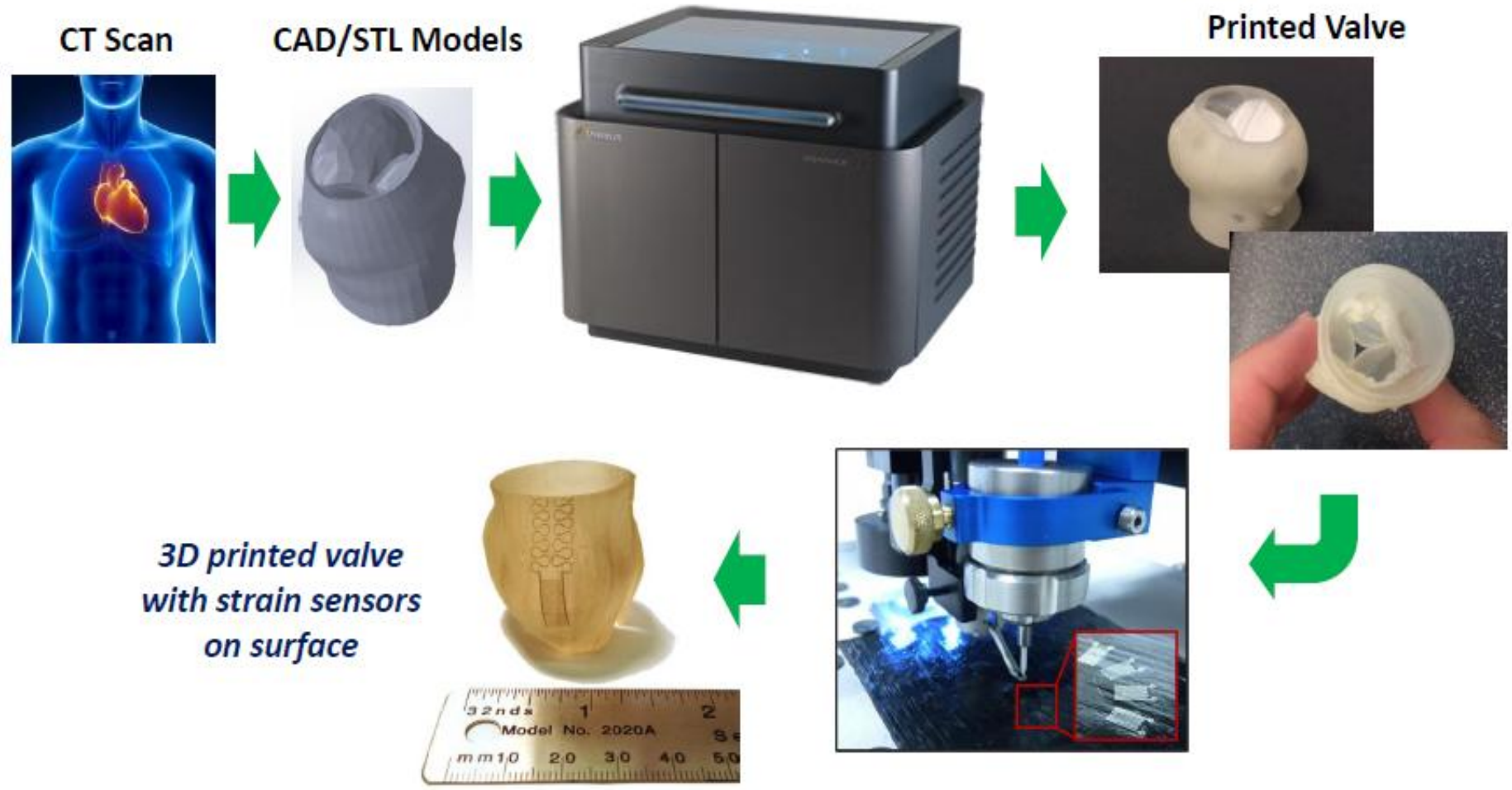
Temperature sensor printed with carbon nanotubes



RFID tag and antenna array on carbon fiber prepreg

High frequency antenna

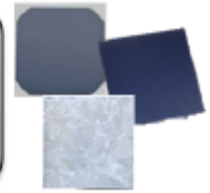
Example: Application Printed Tech. (3)

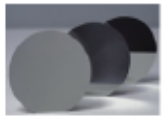


PV

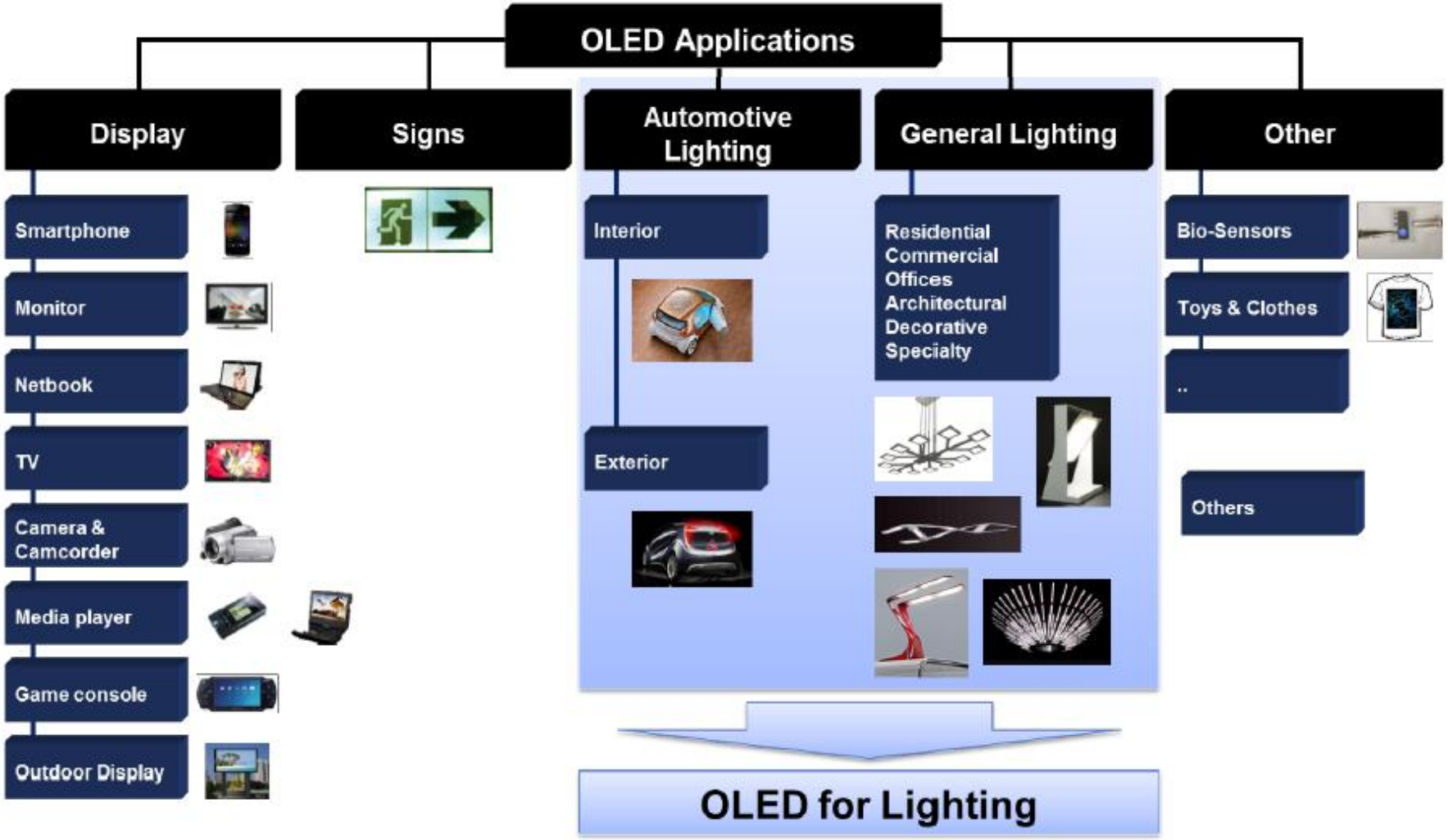
The potential for flexible devices is determined mainly by the nature of substrate used

Material used	Name of PV technology	Substrate
Silicon Wafer	Monocrystalline (mono-Si, HIT) Quasi-monocrystalline (qm-Si) Multicrystalline (mc-Si)	Si wafer (rigid)
Thin silicon films	Amorphous (a-Si) Tandem: a-Si/µc-Si, a-Si/a-Si… Thin Film c-Si (c-SiTF)	Glass sheet / flexible metallic sheet
II-VI materials	CIS CdTe	Glass sheet / flexible polymer sheet / flexible metallic sheet
III-V materials	GaAs InGaP/InGaAs/Ge	Wafer (rigid)
Organic polymer	Full Organic Hybrid	Glass sheet / flexible polymer sheet / flexible metallic sheet
Dye	Dye Sensitized Solar Cells (DSSC)	



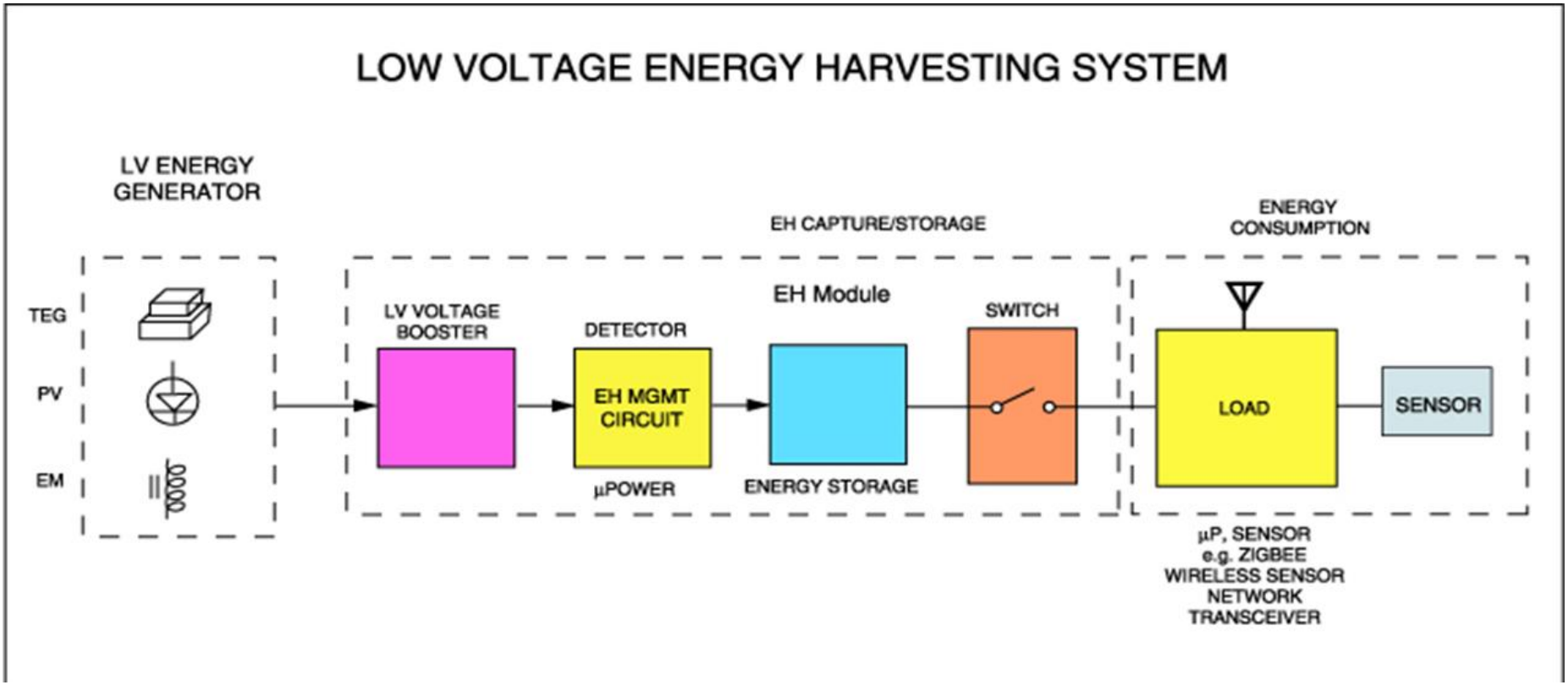

OLED


OLED Applications
Display
Signs
Automotive Lighting
General Lighting
Other
Smartphone
Monitor
Netbook
TV
Camera & Camcorder
Media player
Game console
Outdoor Display
Interior
Exterior
Residential
Commercial
Offices
Architectural
Decorative
Specialty
Bio-Sensors
Toys & Clothes
..
Others
OLED for Lighting

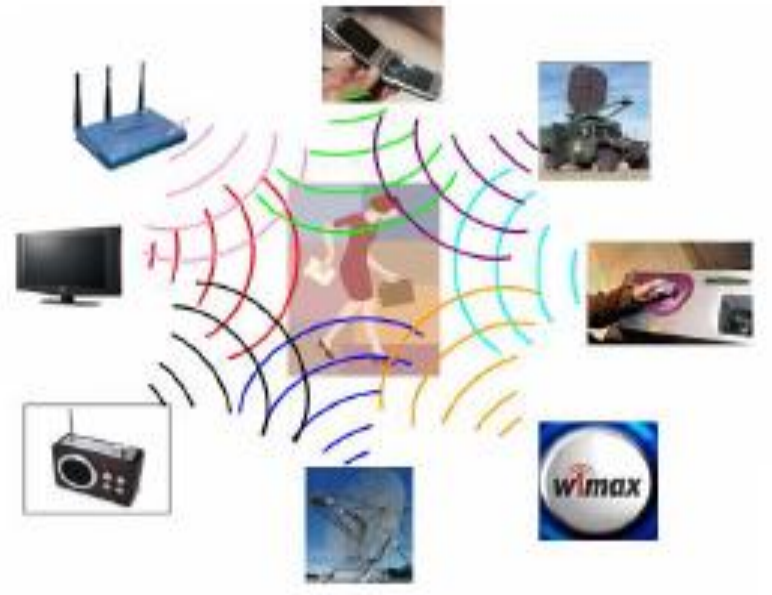
OLED

	Incandescent	Fluorescent	LED	OLED
Efficacy	10 - 15 lm/W	40 - 100 lm/W	80 - 130 lm/W (cold white) 65 - 90 lm/W (warm white)	12 - 40 lm/W
Lifetime LT 70 (hours)	1,000 - 2,000	5,000 - 50,000	10,000 - 50,000	4,000 - 10,000
CRI	> 95	80 - 85	80 (cold white) 90 (warm white)	> 80
Form factor	Heat generating	Linear or compact gas filed glass tube	Point source high intensity lamp (glare)	Large area thin diffuse source - Can be flexible, transparent…
Dimmable	Yes - But much lower efficacy	Yes - But efficiency decreases	Yes - But efficiency decreases	Yes - And efficiency increases
Noise	No	Yes	No	No
Switching time	Good	Poor	Excellent	Excellent
Tunable color	No	No	Yes	Yes
Environmental issues	Low efficiency	Contains mercury vapor	None	None
Manufacturing costs	Low	Medium	High	Very high

Energy Harvesting



RF Energy Harvesting



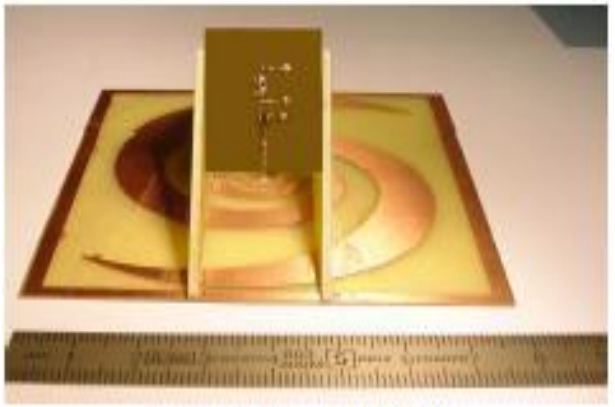


Fig.15 Rectenna prototype

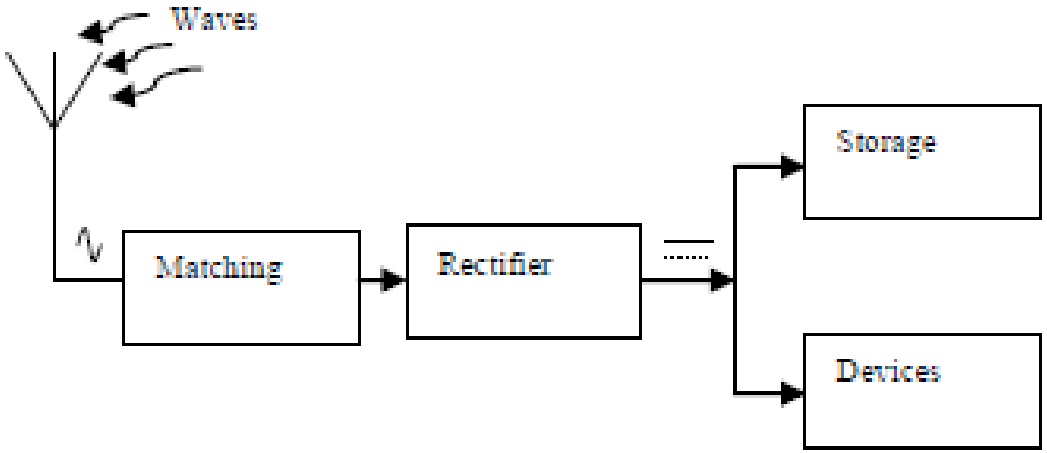
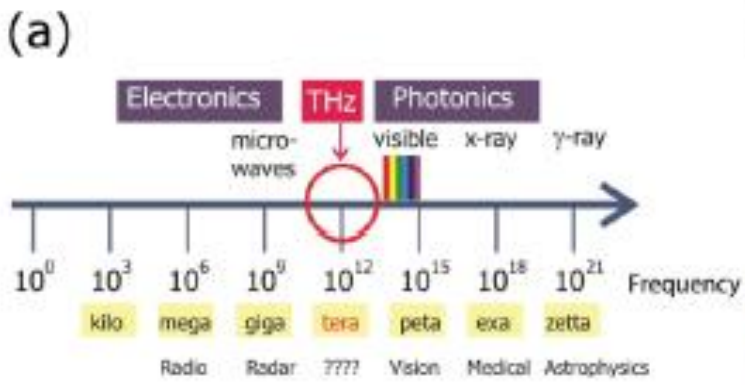
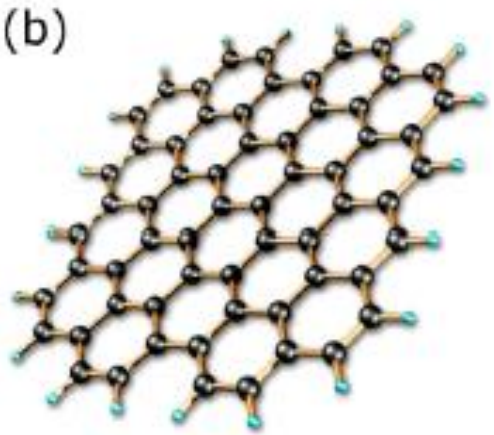


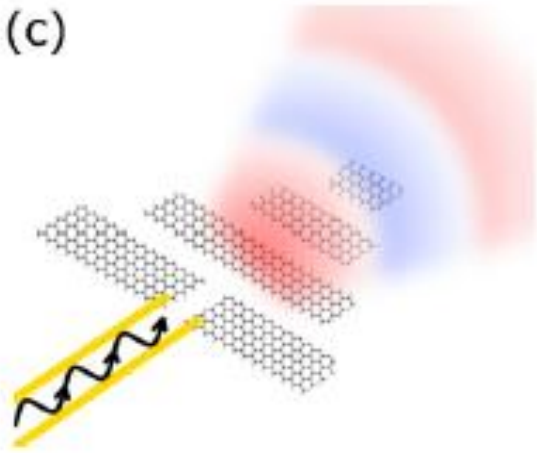
Fig.5. Principle of RF energy harvesting system

The goal: Wideband antenna

Graphene Based THz Antenna







The goal of this project is to design the graphene based antenna for terahertz radiation.

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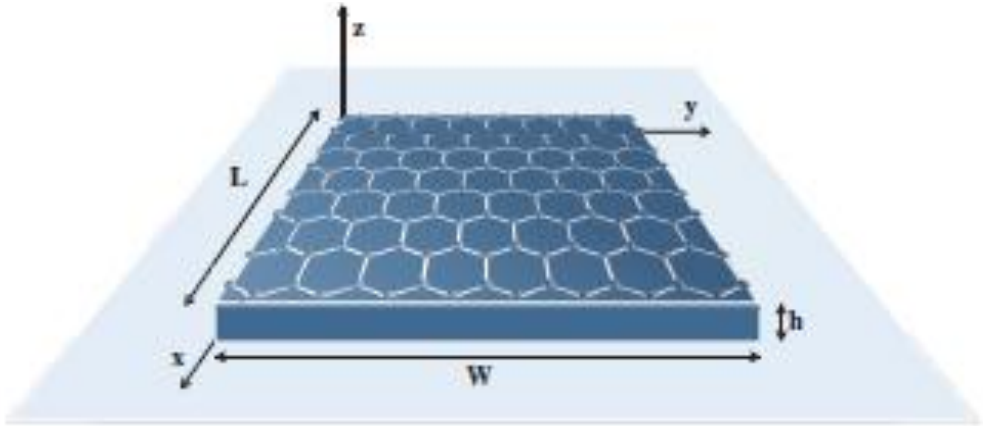
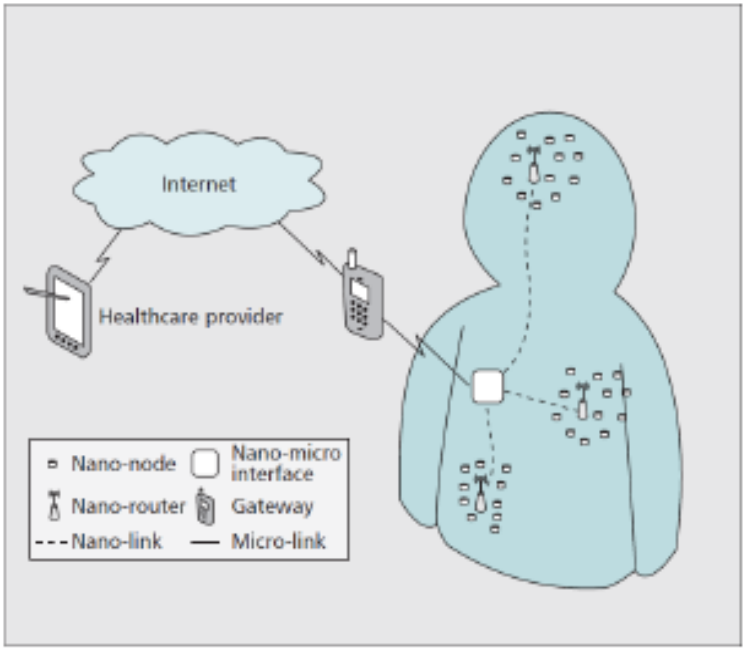
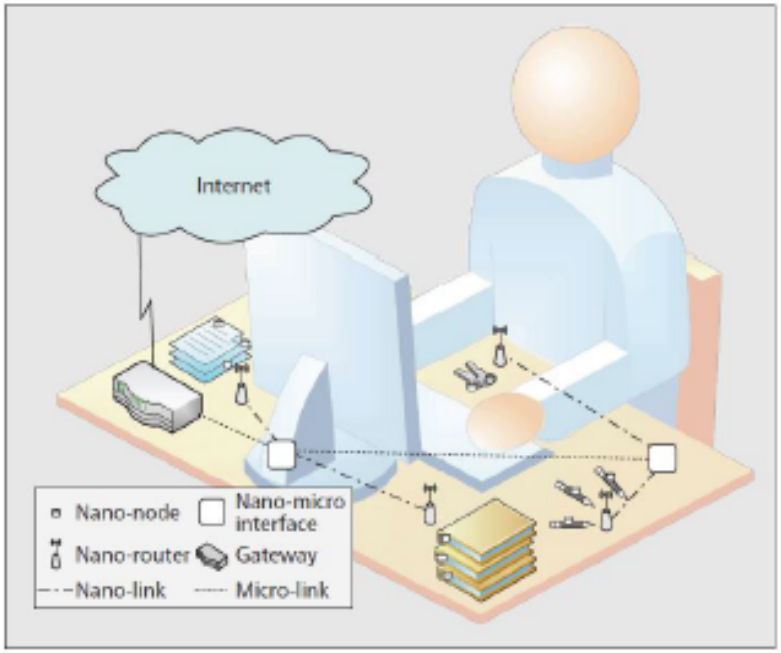


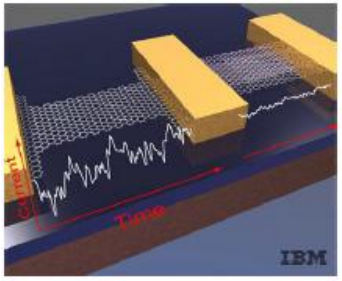
Fig. 1. A graphene-based plasmonic nano-patch antenna.

Nano network using nano antenna

- Wireless Sensor Networks at the nanoscale: Wireless Nanosensor Networks







- Health monitoring
- Internet of nano-things

liz, Josep Miquel Jornet, "The Internet of Nano-Things", *IEEE Wireless Communications*, 2010.

Organic Light Emitting Diodes (OLEDs) (1)

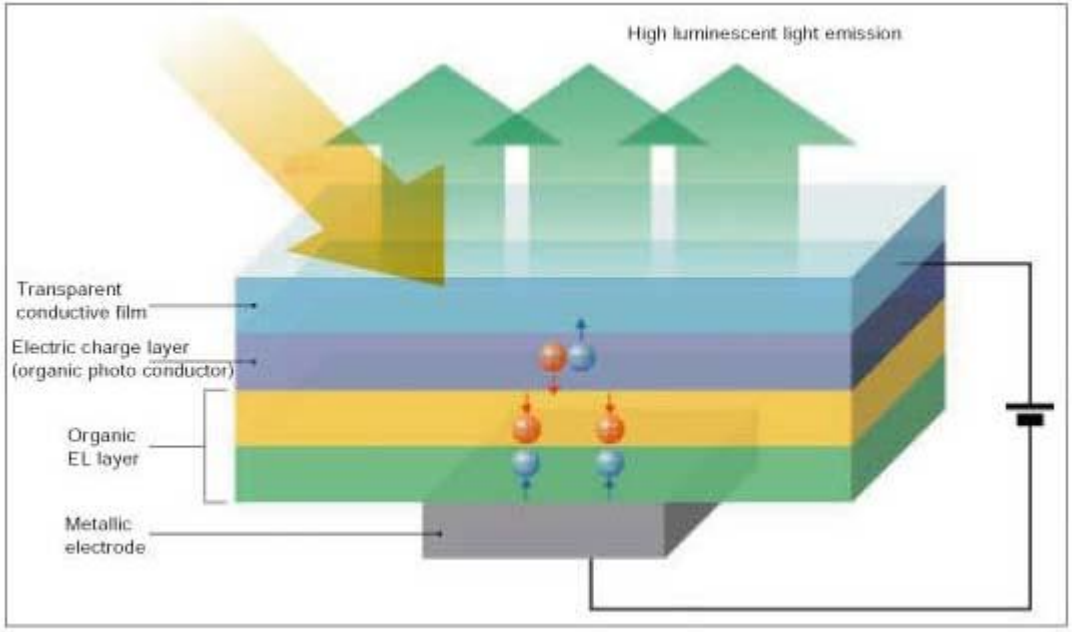
- An OLED is a thin film LED in which the emissive layer is an organic compound.
- When this layer is polymeric (or plastic), OLEDs can be deposited in rows and columns on a screen using simple printing methods that are much more efficient than those used in manufacturing traditional LEDs.
- A key benefit of OLEDs is that they don't need a backlight to function.

Organic Light Emitting Diodes (OLEDs) (2)

- An electron and hole pair is generated inside the emissive layer by a cathode and a transparent anode, respectively.

- When the electron and hole combine, a photon is produced, which will show up as a dot of light on the screen.

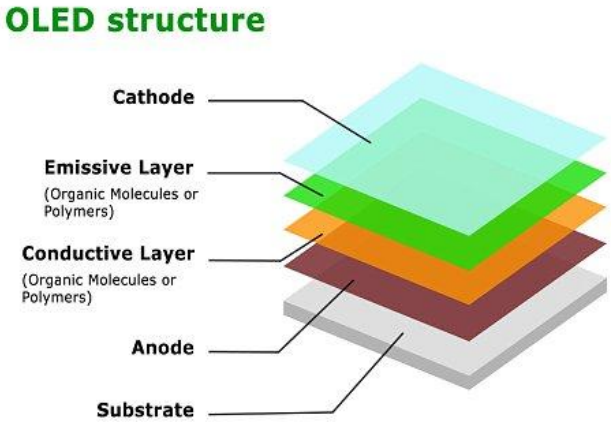
- Many OLEDs together on

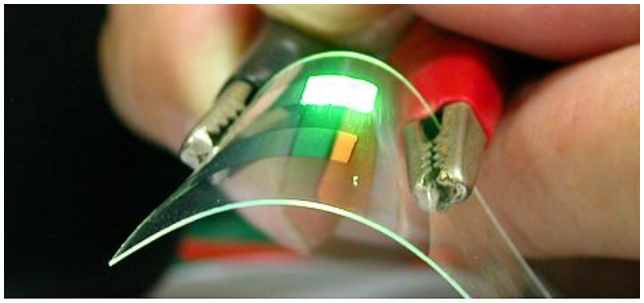


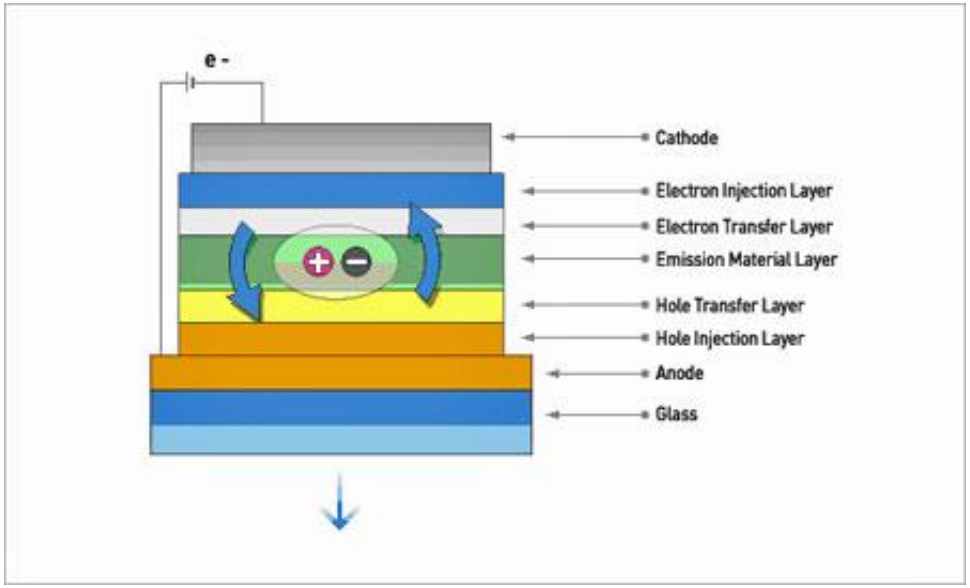
Photoresponsive Organic EL Device

Organic Light Emitting Diodes (OLEDs) (3)

Basic



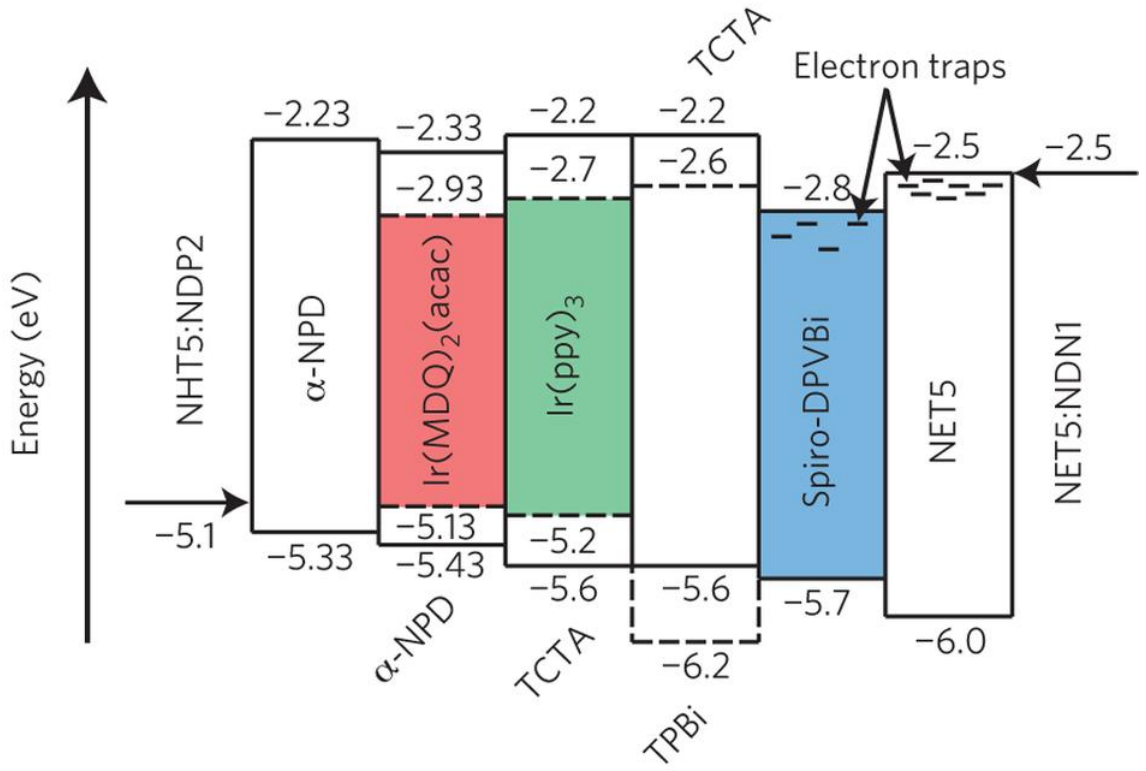




Light intensity is proportional to current density

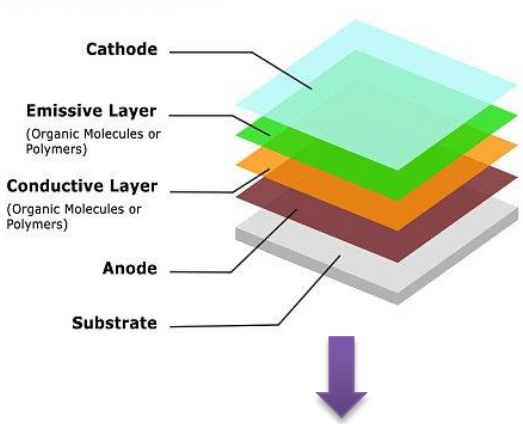
Organic Light Emitting Diodes (OLEDs) (4)

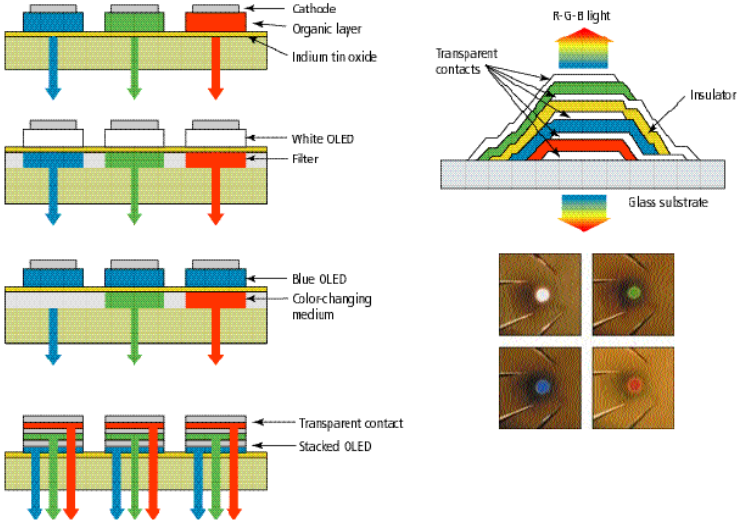
Energy diagram



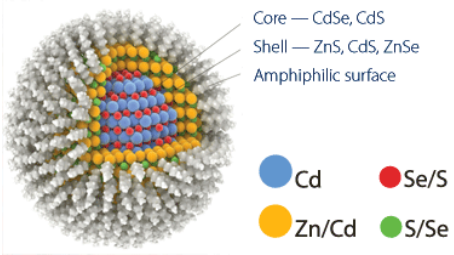
Organic Light Emitting Diodes (OLEDs) (5): Color

Replace the conductive layer with QDs.

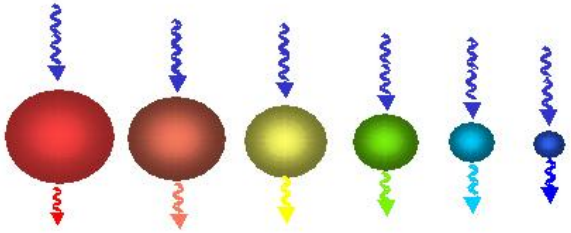




Quantum dots size = (1~20 nm)



When excited, it emits light



Nanocrystals absorb light then re-emit the light in a different color – the size of the nanocrystal (at the Angstrom scale) determines the color

Six different quantum dot solutions are shown excited with a long wave UV lamp

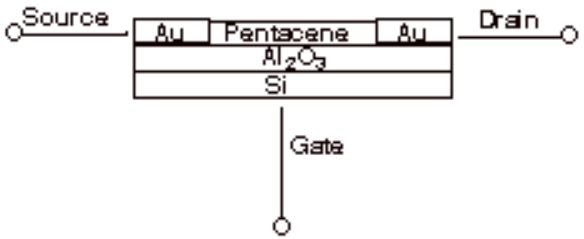
Organic Light Emitting Diodes (OLEDs) (6)

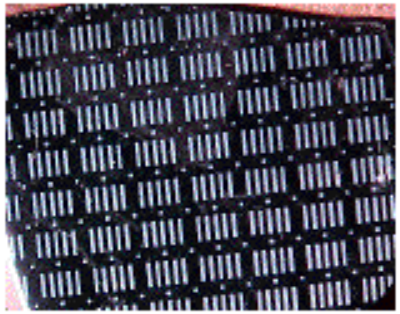
- Less expensive to produce
- Wide range of colors and viewing angle
- Consumes much less energy than traditional LCDs.
- Flexible and extremely thin
- Limited lifetime of about 1,000 hours.
- Susceptible to water

Organic Thin film transistors(OTFTS) (1)

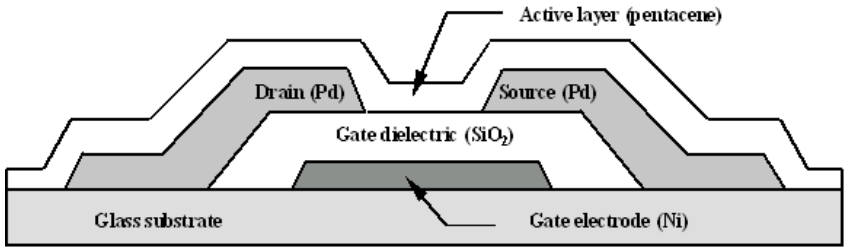
- TFTs are transistors created using thin films, usually of silicon deposited on glass. The deposited silicon must be crystallized using laser pulses at high temperatures. OTFTs active layers can be theramlly evaporated and deposited on any organic substrate (a flexible piece of plastic) at much lower temperatures.

- **Benefits of an OTFT:**
  - Does not require glass substrate as amorphous Si does. It could be made on a piece of plastic.
  - Manufactured at lower temperatures
  - Deposition techniques could reduce costs dramatically.

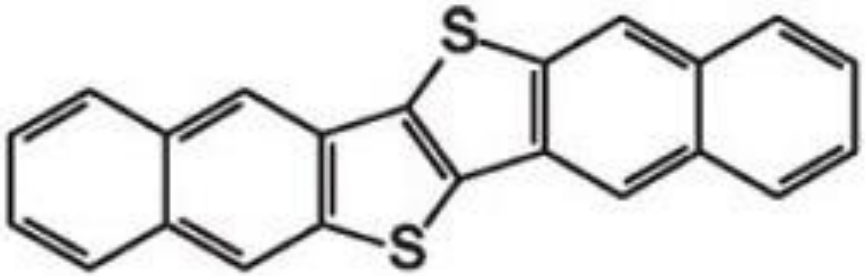


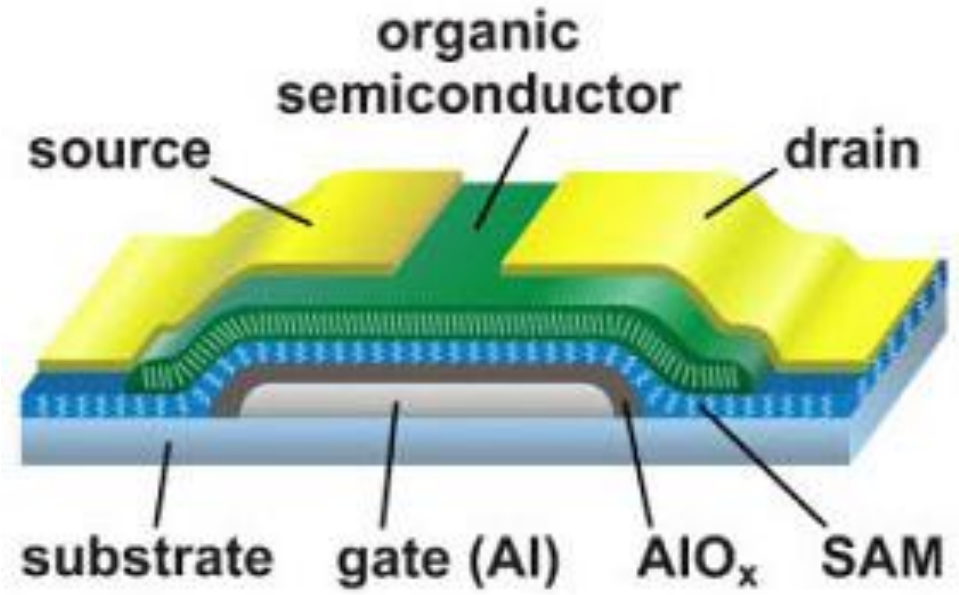


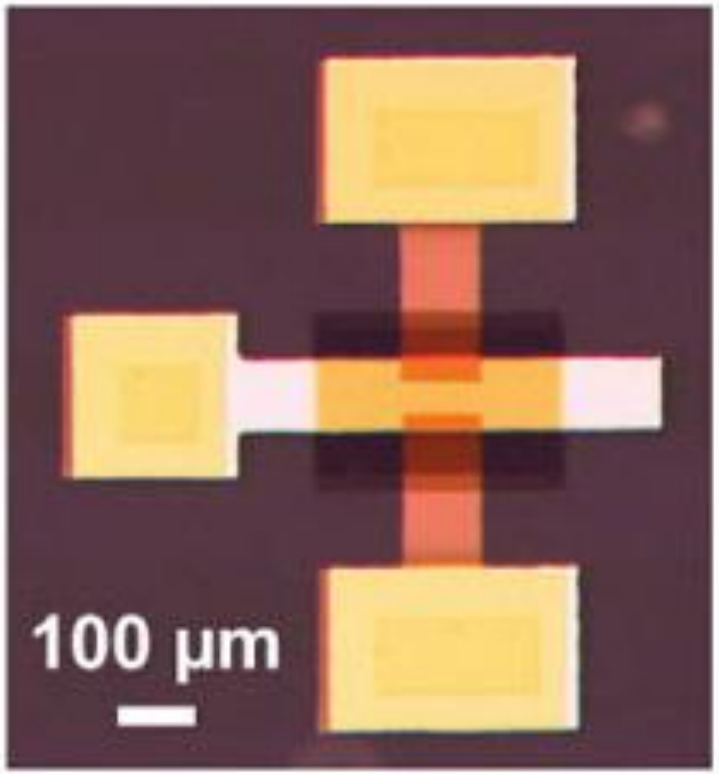
- **Challenges involved:**
  - Workarounds for complications with photo resists.
  - To find organic semiconductors with high enough mobilities and switching times.



Organic Thin film transistors(OTFTS) (2)

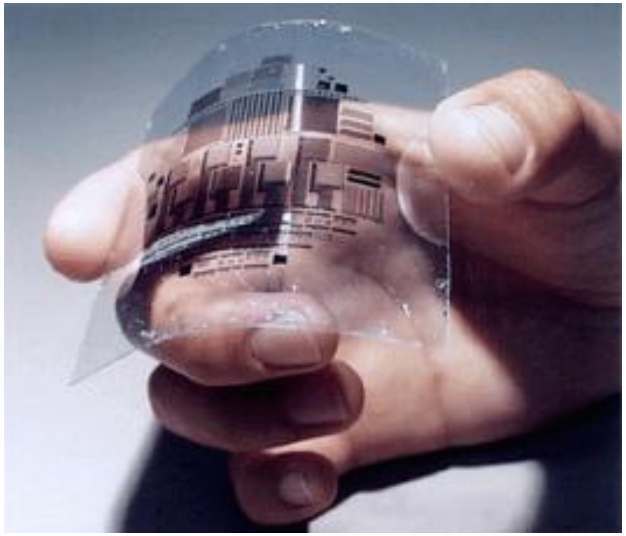






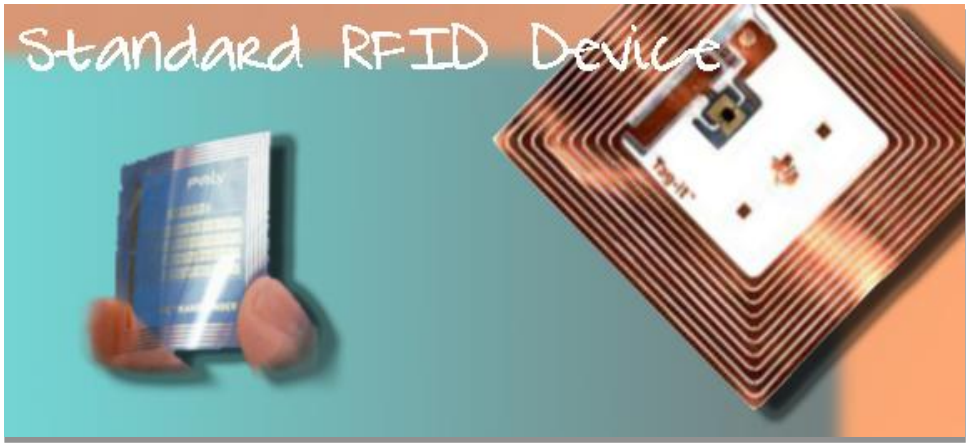
Picture of an OTFT made on a plastic substrate

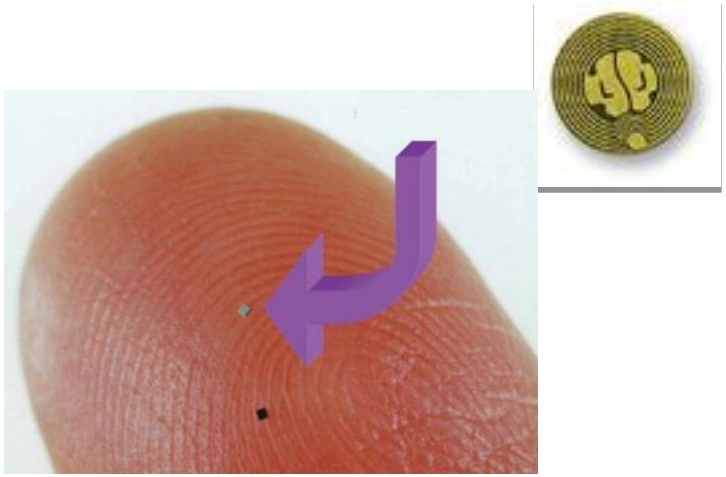
- **FUTURE**
  - OTFT technology's application is diverse.
    Organic thin-film transistor (OTFT) technology involves the use of organic semiconducting compounds in electronic components, notably computer displays. Such displays are bright, the colors are vivid, they provide fast response times (which need to be developed in OTFT), and they are easy to read in most ambient lighting environments.



  - Organic substrates allow for **displays to be fabricated on flexible surfaces**, rather than on rigid materials as is necessary in traditional TFT displays. A piece of flexible plastic might be coated with OTFT material and made into a display that can be handled like a paper document. Sets of such displays might be bundled, producing **magazines or newspapers whose page contents can be varied periodically, or even animated.** This has far-reaching ramifications. For example, **comic book characters might move around the pages and speak audible words.** More likely, such displays will find use in portable computers and communications systems.

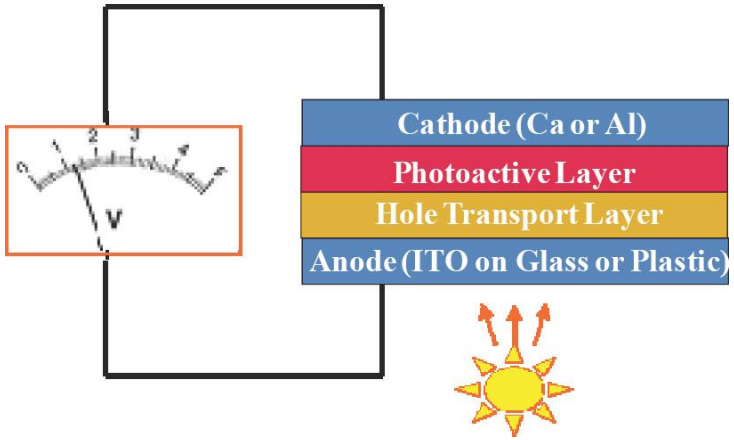
Organic Nano-Radio Frequency Identification Devices



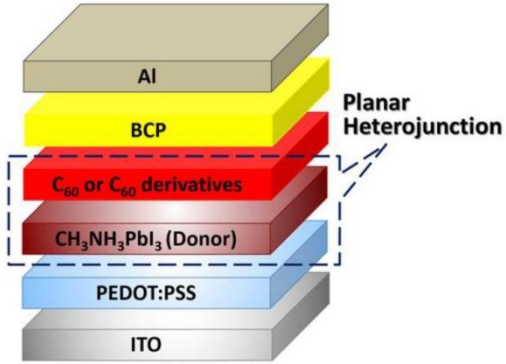


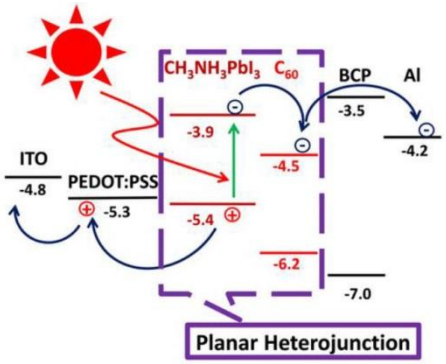
Solar Cell

Revers process of the OLED



Incident light push energy into electrons



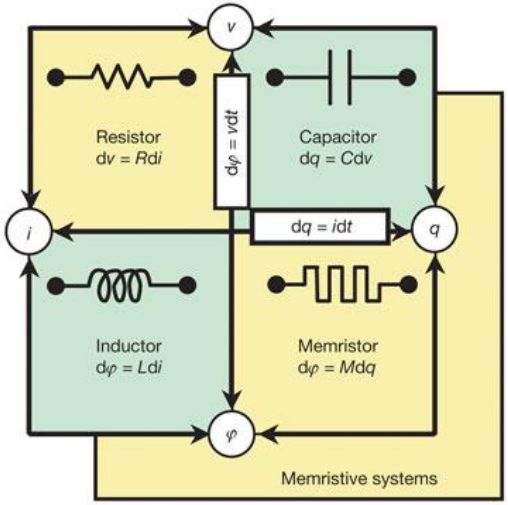


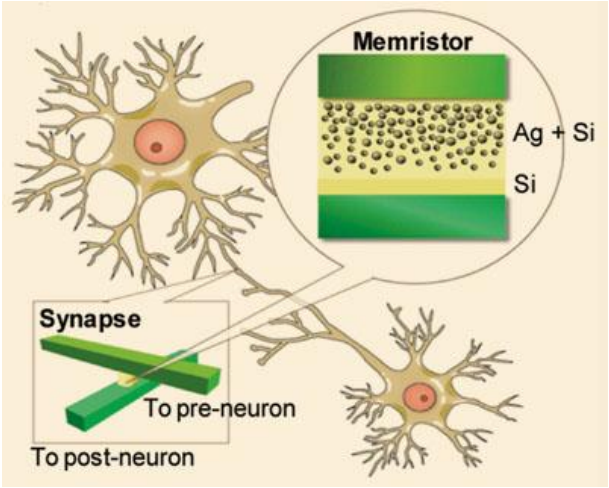
Efficiency is low <15%

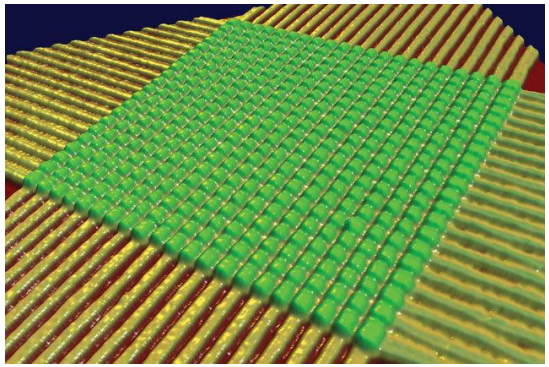
Needs improvement

Introduce holes and electron blocking layers

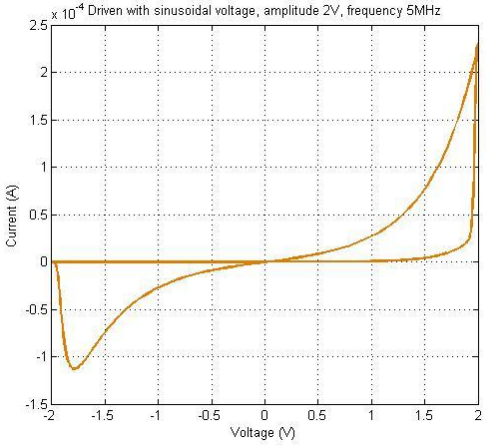
Memristor





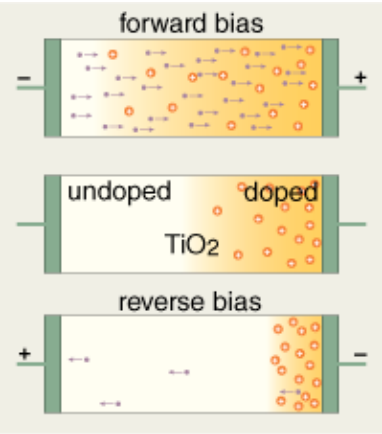


I-V curve



Working

Switch between HRS/LRS



LRS

HRS

Non-volatile memory

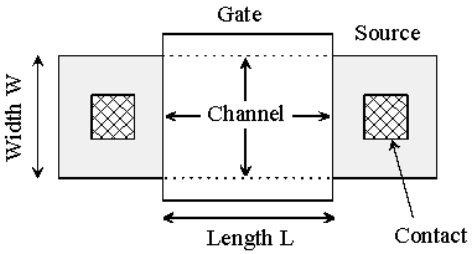
Retains data for years

1971 Chua Predicts this device.

Memristor

Silicon Tech.

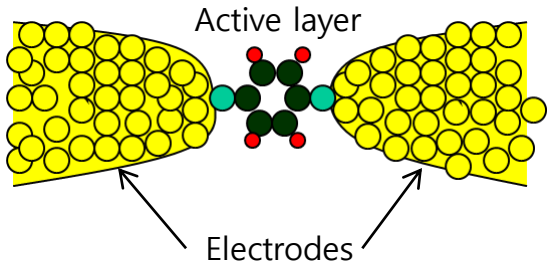
- Needs 6 transistors
- Feature size, reached its limit



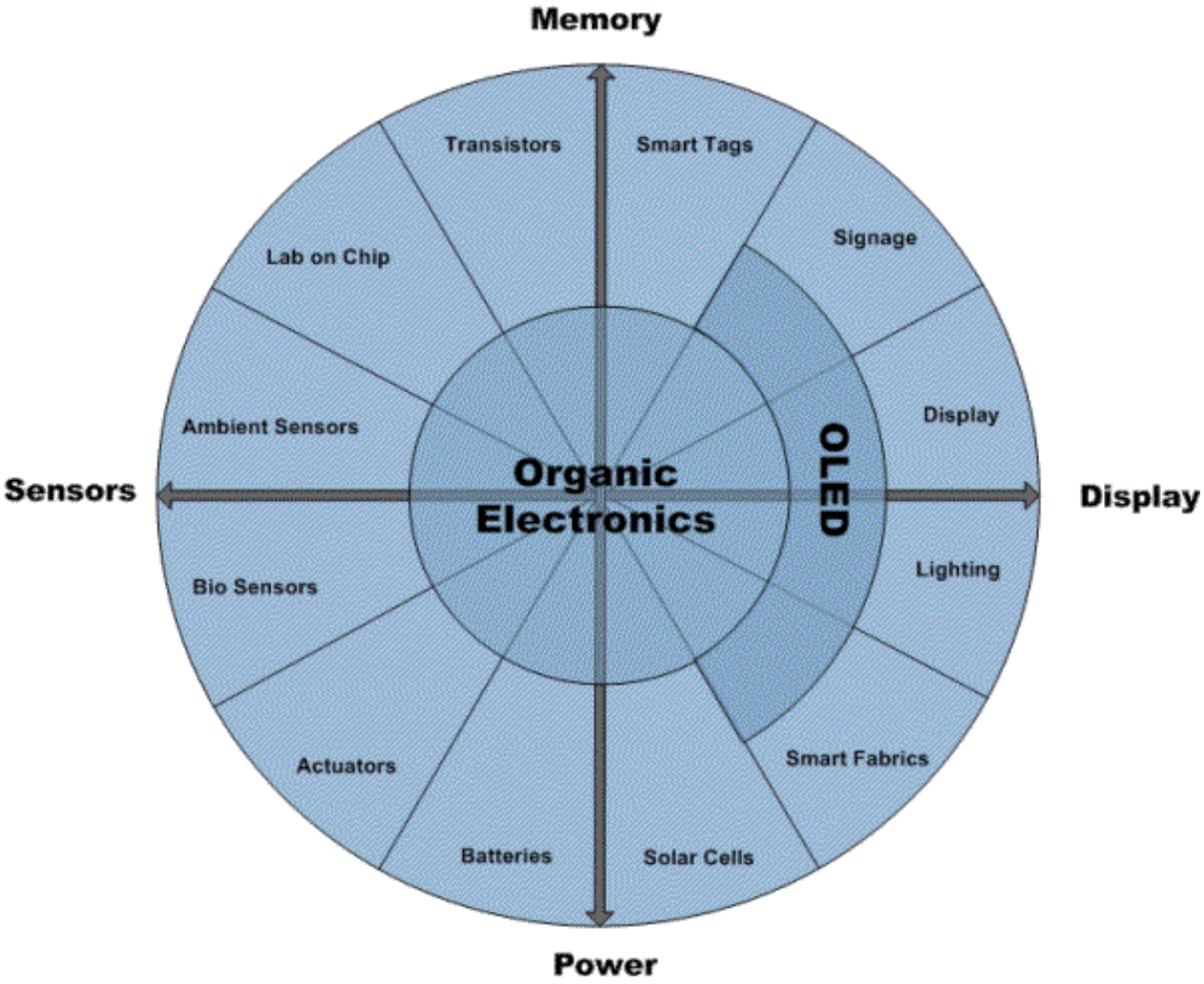
L=14 nm, **Intel** in 2015

Organic Elec.Tech.

- It is a transistor less memory cell
- Can be of a size of single molecule
  - Can be reduced to 1 atom



The Future of Organic Electronics



http://www.orgatronics.com/organic_electronics.html

Materials

Solution Processable Materials

Metal Inks	Resistor Inks	Non-Metallic Conductors
An Cuig (Pt)	Acheson (carbon)	Brewer Science (SWCNTs)
Applied Nanotech (Ag, Cu, Ni, and Al)	Asahi (carbon)	Heraeus (PEDOT:PSS)
Clariant (Ag)	DuPont (carbon and ruthenate)	NanoIntegris (SWCNTs / MWCNTs)
DuPont (Ag)	Lord (carbon)	SouthWest Nano (SWCNTs / MWCNTs)
Henkel (AG)	Methode Development (carbon)	**Semiconductors**
Intrinsiq (Cu)	**Dielectrics and Adhesives**	Aldrich (organic semiconductors)
Novacentrix (Ag, Cu)	Aldrich (polyimide)	Alfa (organic semiconductors)
Paru (Ag)	BASF (PVP)	Merck (organic semiconductors)
Resin Designs (AgE)	DuPont (Teon AF)	NanoIntegris (SWCNTs)
Sun Chemical (Ag)	Henkel (adhesives)	**Reactive Chemistries**
UTDots (Ag, Au, Pt)	Loctite (adhesives)	Rohm & Hass (Enlight)
Xerox (Ag)	Norland (UV adhesives)	Shipley (photo and etch resists)

Move for E-printing Technologies

https://www.youtube.com/watch?v=QqyW9vdS0x0

Jinho Bae

Ocean System Engineering

Ocean Information System Group

강의자료 출처: 선형대수학 Express. 김대수 저

EHD system

https://www.youtube.com/watch?v=r6TGvG7RUyo

Micro Piezo technology explanation and animation

https://www.youtube.com/watch?v=mJMOCmVPv8A

Roll to Roll

https://www.youtube.com/watch?v=7zA7tckExH4

https://www.youtube.com/watch?v=qe1l3kRMeeU

https://www.youtube.com/watch?v=qo5D8o0Pu8s

Screen printing

https://www.youtube.com/watch?v=cODVhMdcXfw

https://www.youtube.com/watch?v=2qg5BXH1mPs

https://www.youtube.com/watch?v=ZesXSJ0inBg

Our project

- Find new organic devices
- Find new type organic materials and blended materials
- Find new printed technologies: EHD, Piezo head, Aerosol etc.

References

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- http://www.chem.uky.edu/research/anthony/tft.html
- http://en.wikipedia.org/wiki/OLED
- www.tagsysrfid.com
- Yole developpement, Semicon West 2013
- Georgia Tech, Manufacturing Institute
- PARC A Xerox Company