MANIPULATING LIGHT: A THIN-FILM DEVICE PERSPECTIVE

Canek Fuentes-Hernandez

Center for Organic Photonics and Electronics, School of Electrical and Computer Engineering, Georgia Institute of Technology

canek@ece.gatech.edu

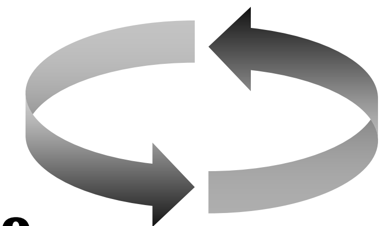
Outline

- An introduction to Printed electronics.
- Light and Thin film devices
  - Organic Solar Cells

The Dawn of the Information Age

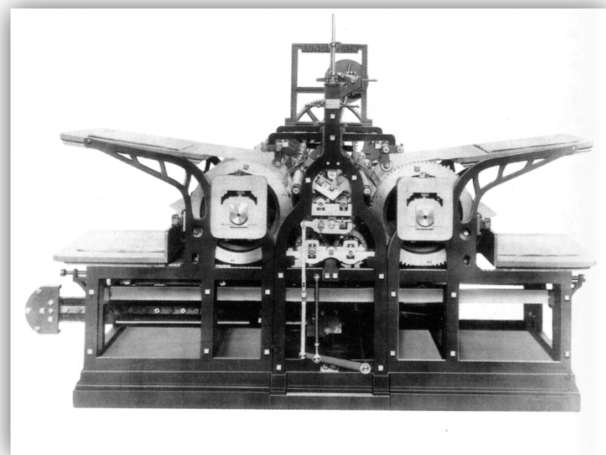
Printing

Ideas and information to text



Text to ideas and information

Gutenberg press (1450)

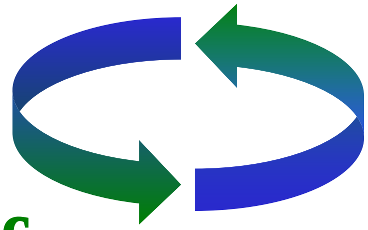


Koenig and Bauer steam powered press (1812)

20^{th} century industrial press

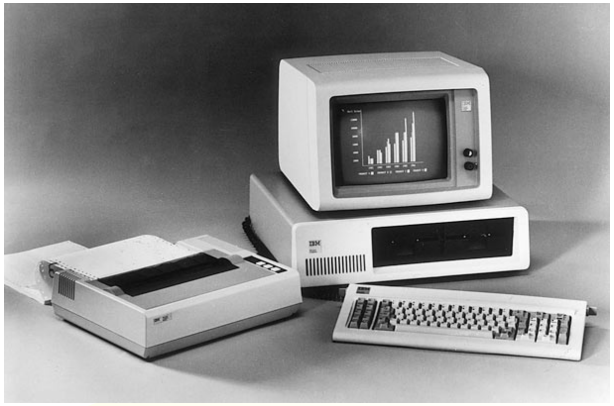
The Dawn of the Information Age

Computing



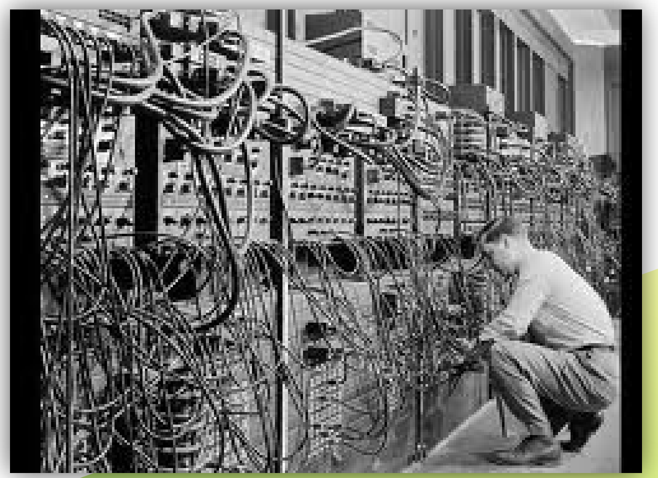
Logic and/or arithmetic's to electricity

Electricity to logic and/or arithmetic's



IBM PC, (1981)

Apple I, (1976)



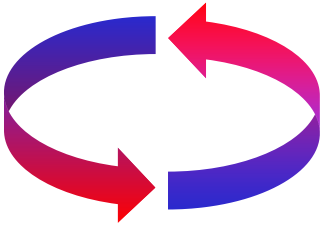
Electronic Numerical Integrator and Computer

ENIAC, U. Penn. (1946)

The Dawn of the Information Age

Optoelectronics

Electricity to light



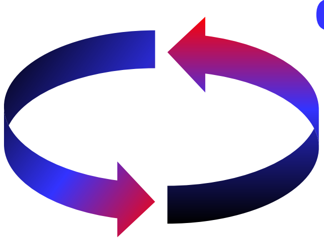
Light to electricity

Energy Generation

The Dawn of the Information Age

Telecommunications

Information to **electricity** or **light**



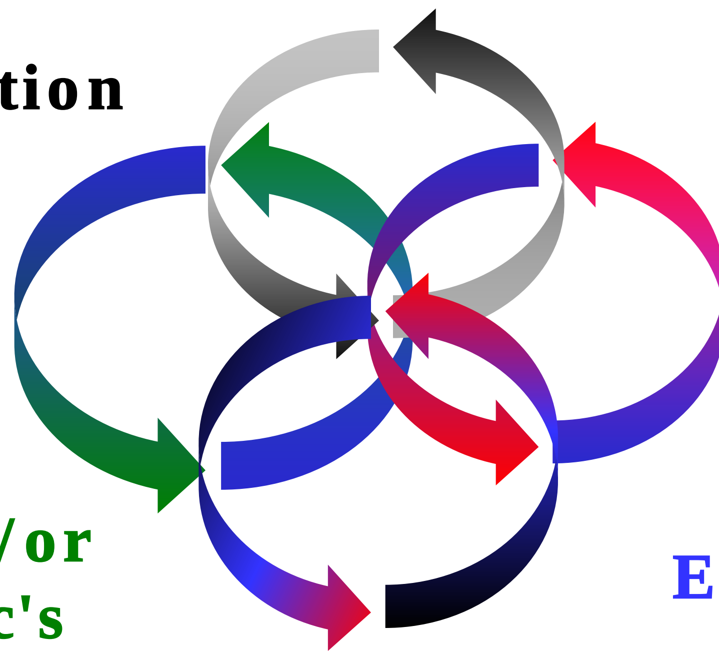
Electricity or **light** to Information

An information revolution

Printing

Printed ideas and information

Light (electro-magnetic waves)



Computing

Opto-electronics

Logic and/or arithmetic's

Electricity

Telecommunications

Printed Electronics: Ubiquitous information

Harry Potter

Avatar

Plastic Logic, 2013

© Plastic Logic

Samsung, 2013

Heliatek, 2013

A shift of paradigm in manufacturing

Inkjet printing

1. The Dimatix DMP-2800 printers can deposit a wide range of customer-supplied materials on the surface of almost any material.

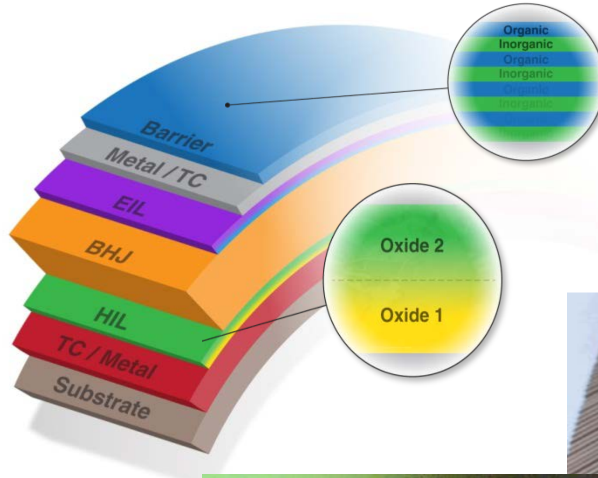
Roll-to-roll

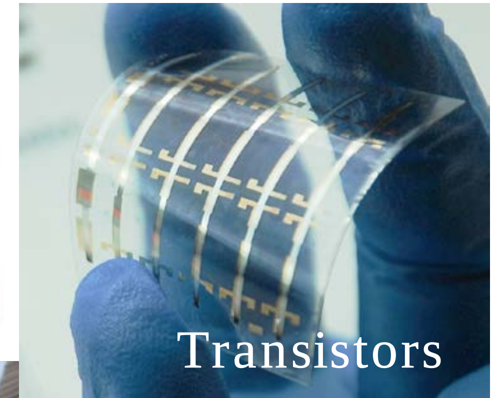
Printing electronics, 21th century

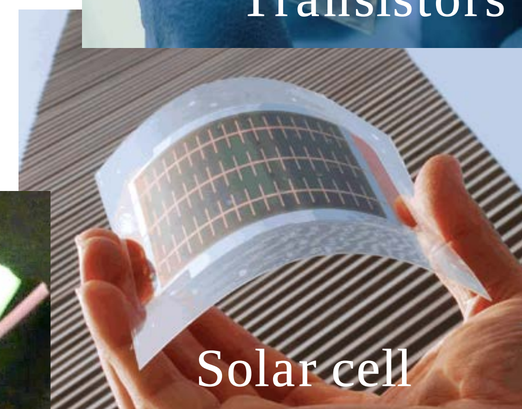
<u>Flexible or free form; Large area; Low-cost.</u>

Thin-film devices: The building blocks

- **Light emitting diodes**
- **Solar cells**
- Photodetectors
- Antenas
- Sensors
- Field-effect transistors
- Capacitors
- Batteries
- Memories
- Etc.



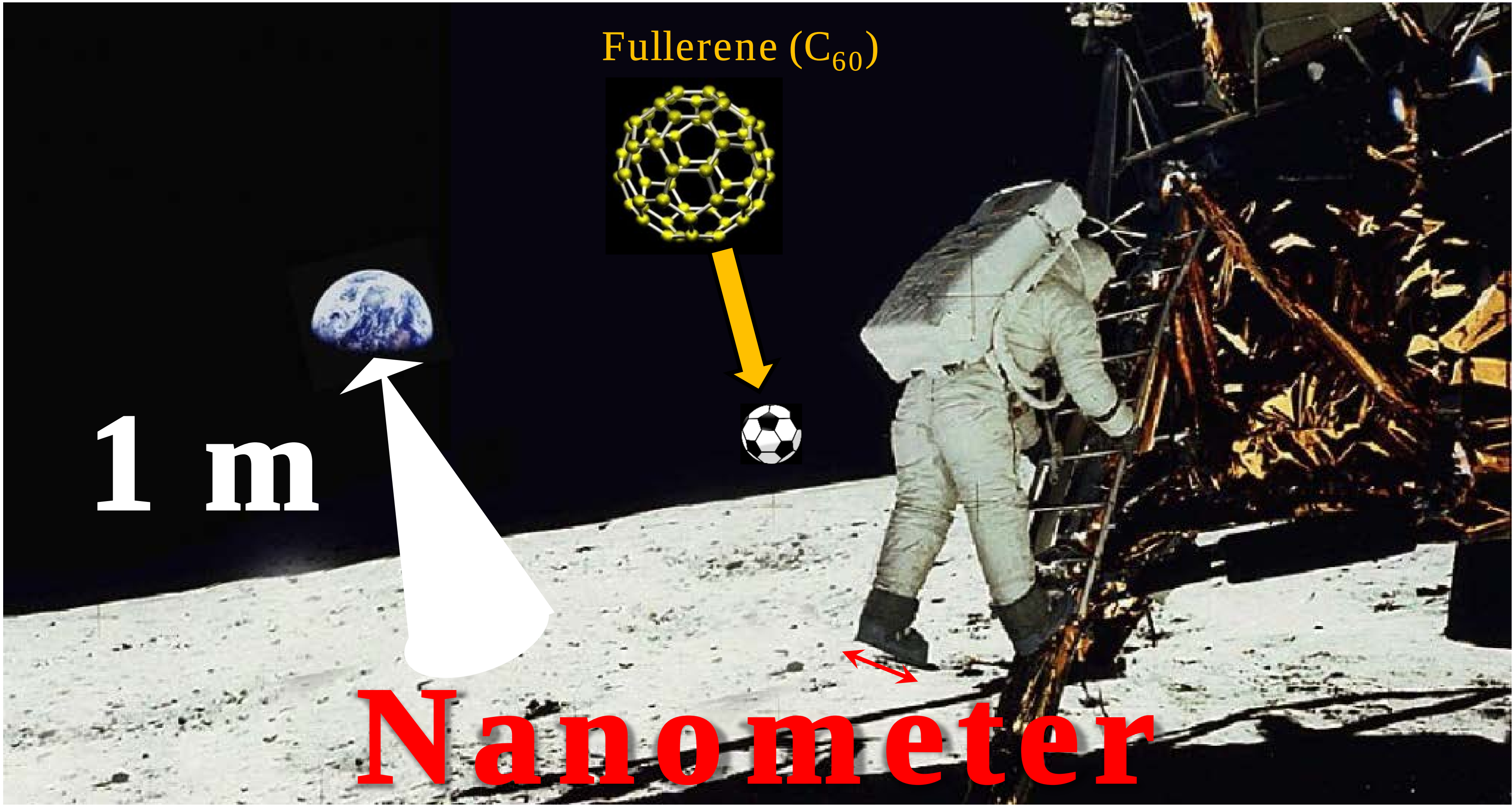




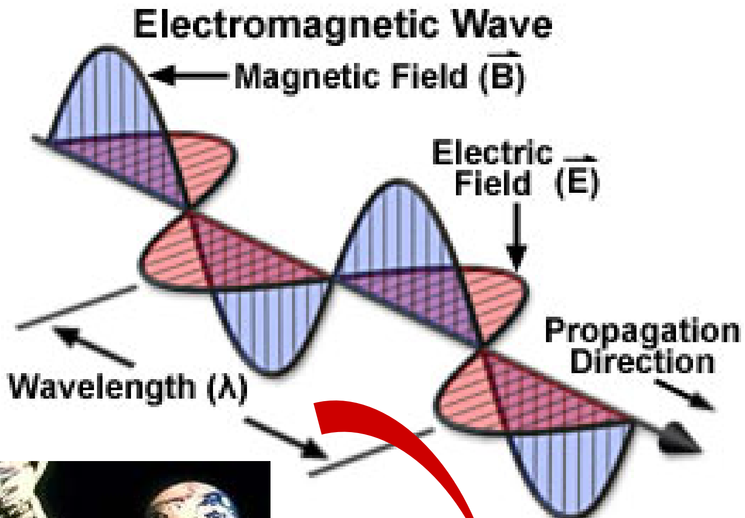
Georgia Tech

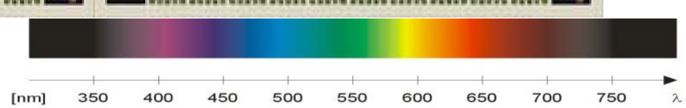
Functional structures with many layers of different materials with thicknesses ranging from **less than a nanometer to hundreds of nanometer**

A nanometer?



A big is a light wave?





Visible spectrum

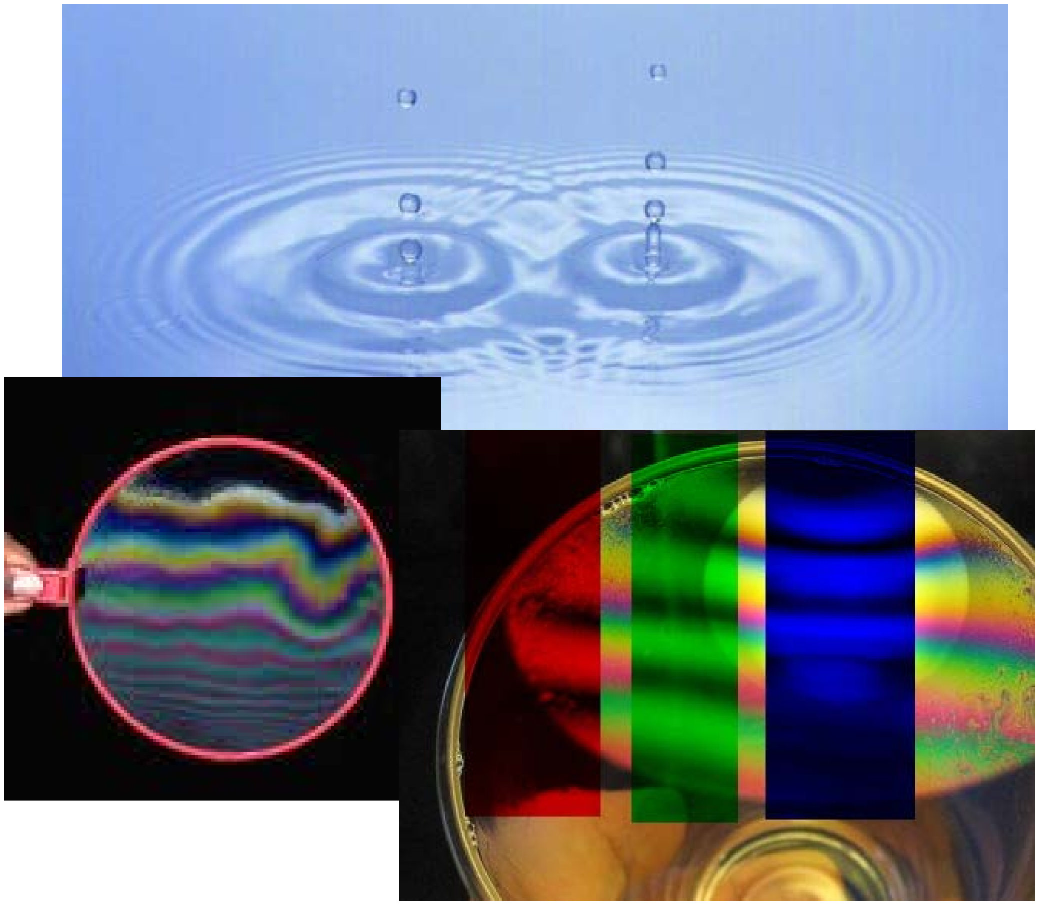
700 nm

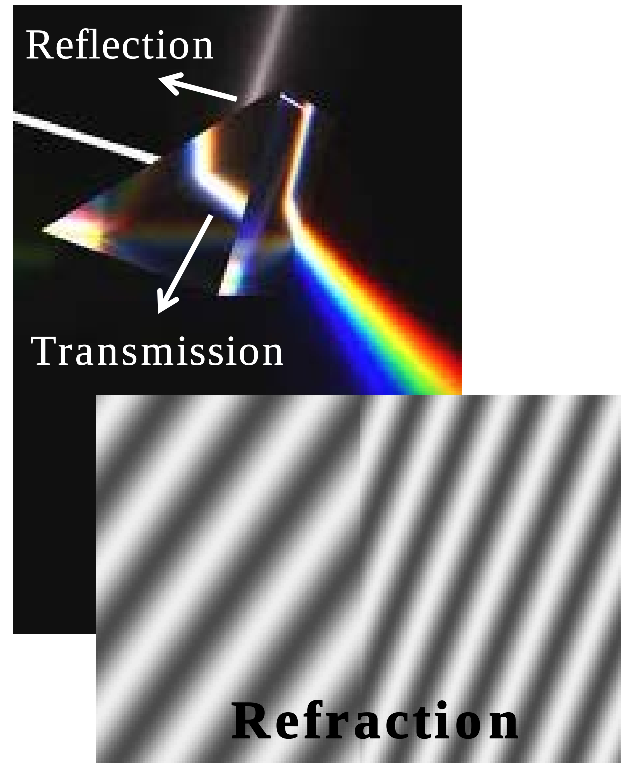
390 nm

Light waves interact :

with each other

with materials



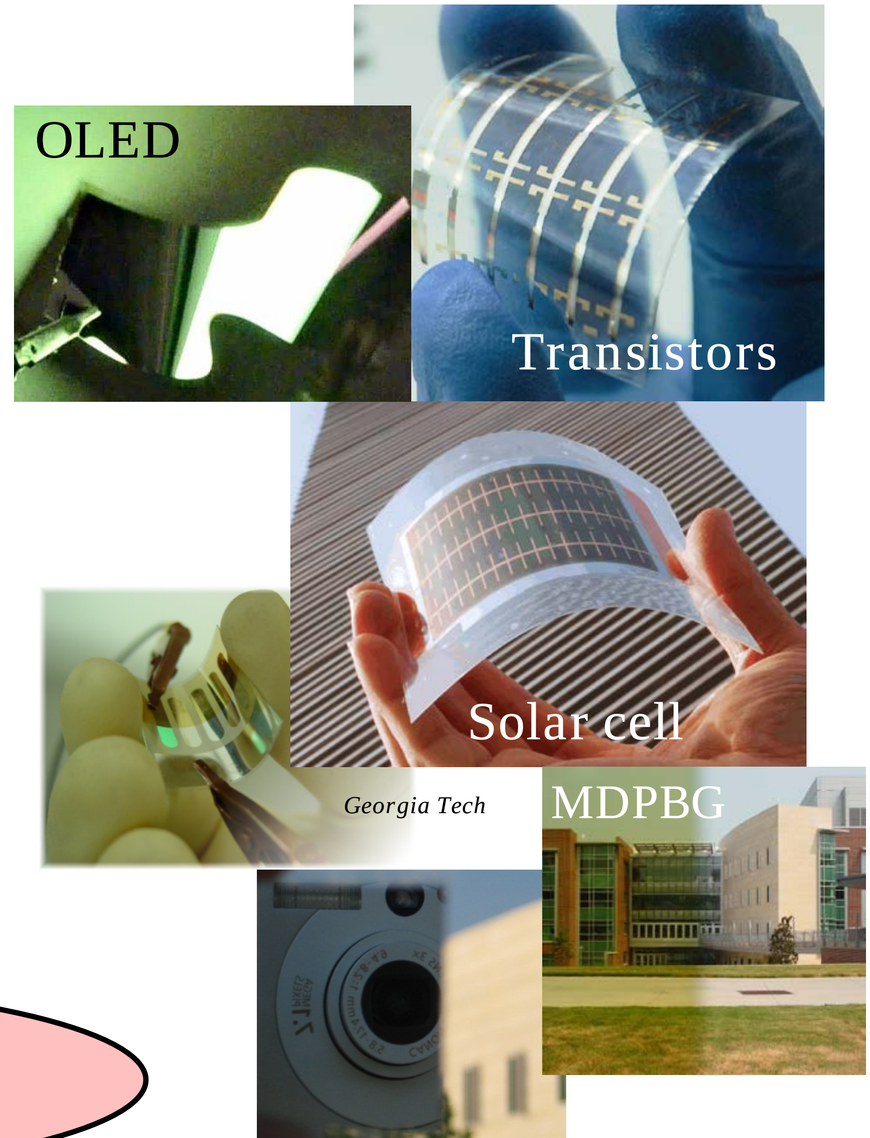


To control interference → **Control refractive index and thickness**

What do we do?

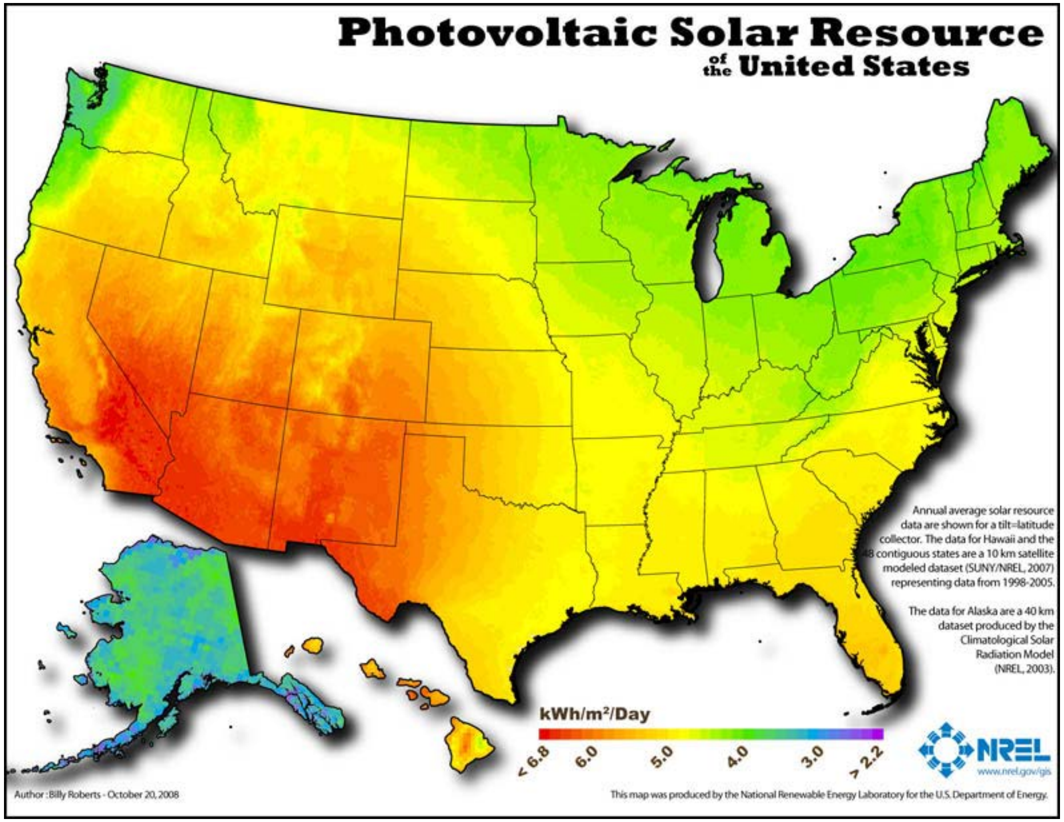
1. Select functionality. What kind of device we want.
2. Select materials and characterize their properties
3. When possible, simulate optical and electrical properties to design structures
4. Fabricate devices and analyze performance

Publish results



The need for solar power

- Abundant
- Affordable
- Reliable
- CLEAN



SURFACE AREA REQUIRED TO POWER THE WORLD

WITH ZERO CARBON EMISSIONS AND WITH SOLAR ALONE

www.landartgenerator.org

BOXES TO SCALE WITH MAP

1980 (based on actual use)
207,368 SQUARE KILOMETERS

2008 (based on actual use)
366,375 SQUARE KILOMETERS

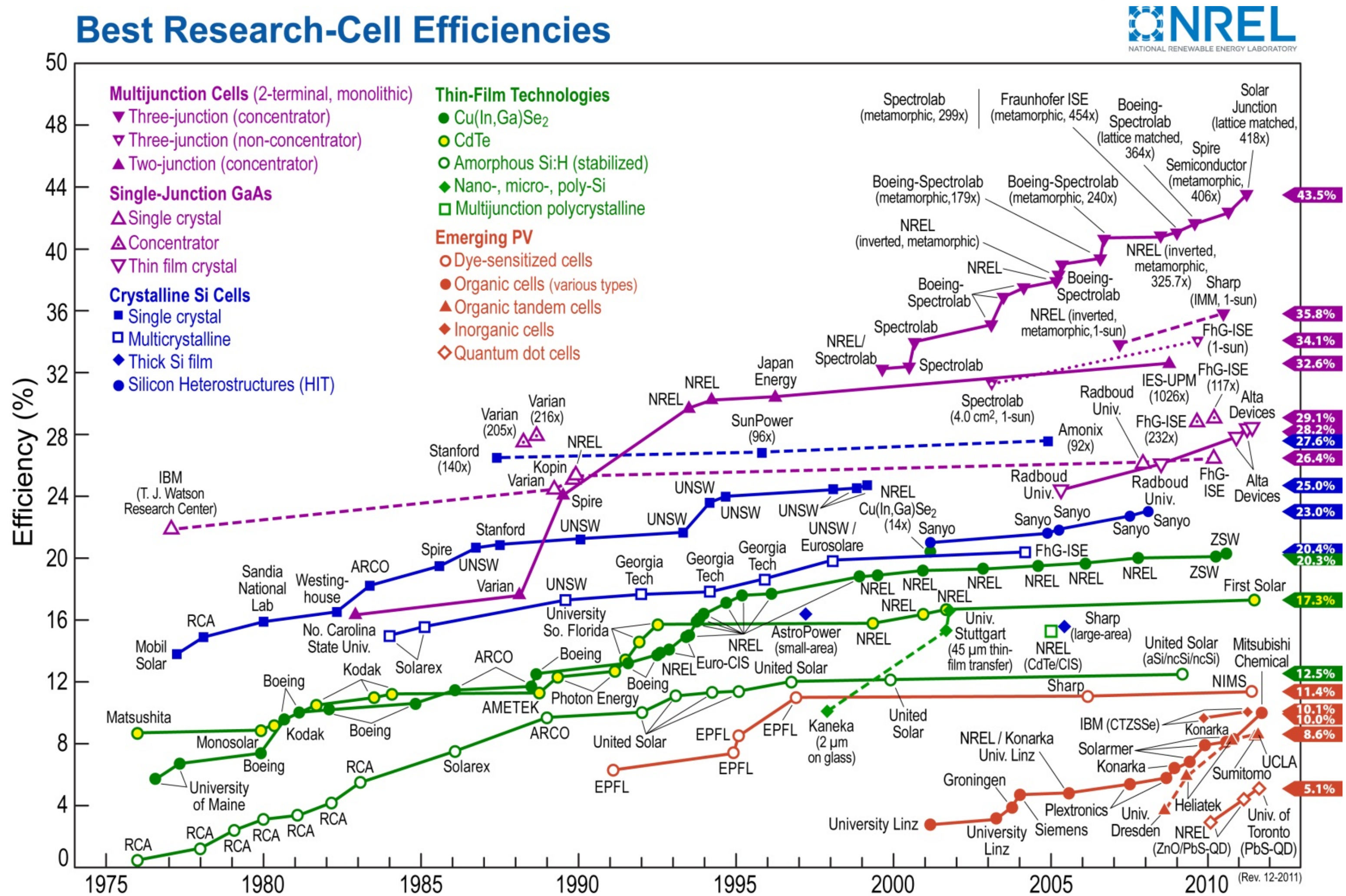
2030 (projection)
496,805 SQUARE KILOMETERS

Required area that would be needed in the year 2030 is shown as one large square in the key above and also as distributed around the world relative to use and available sunlight.

- Areas are calculated based on an assumption of 20% operating efficiency of collection devices and a 2000 hour per year natural solar input of 1000 watts per square meter striking the surface.
- These 19 areas distributed on the map show roughly what would be a reasonable responsibility for various parts of the world based on 2009 usage. They would be further divided many times, the more the better to reach a diversified infrastructure that localizes use as much as possible.
- The large square in the Saharan Desert (1/4 of the overall 2030 required area) would power all of Europe and North Africa. Though very large, it is 18 times less than the total area of that desert.
- The definition of "power" covers the fuel required to run all electrical consumption, all machinery, and all forms of transportation. It is based on the US Department of Energy statistics of worldwide Btu consumption and estimates the 2030 usage (678 quadrillion Btu) to be 44% greater than that of 2008.
- Area calculations do not include magenta border lines.

LAND ART GENERATOR INITIATIVE

Solar cell technologies



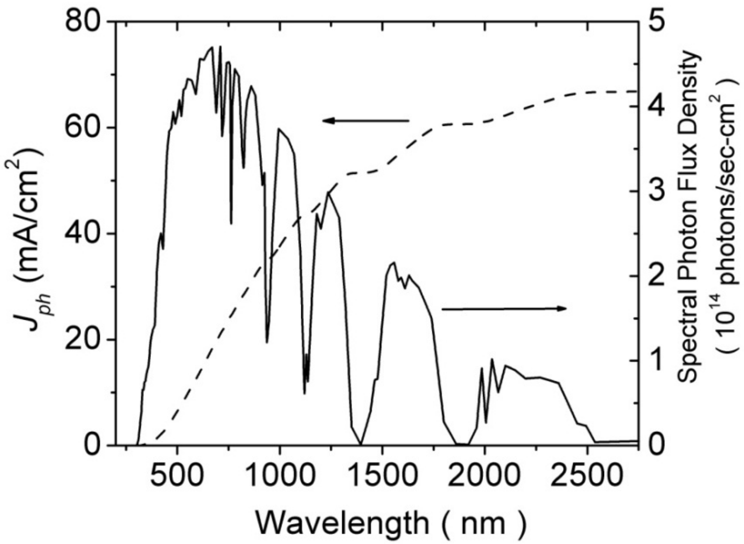
C.W. Tang, Appl. Phys. Lett, 48, 183 (1986)

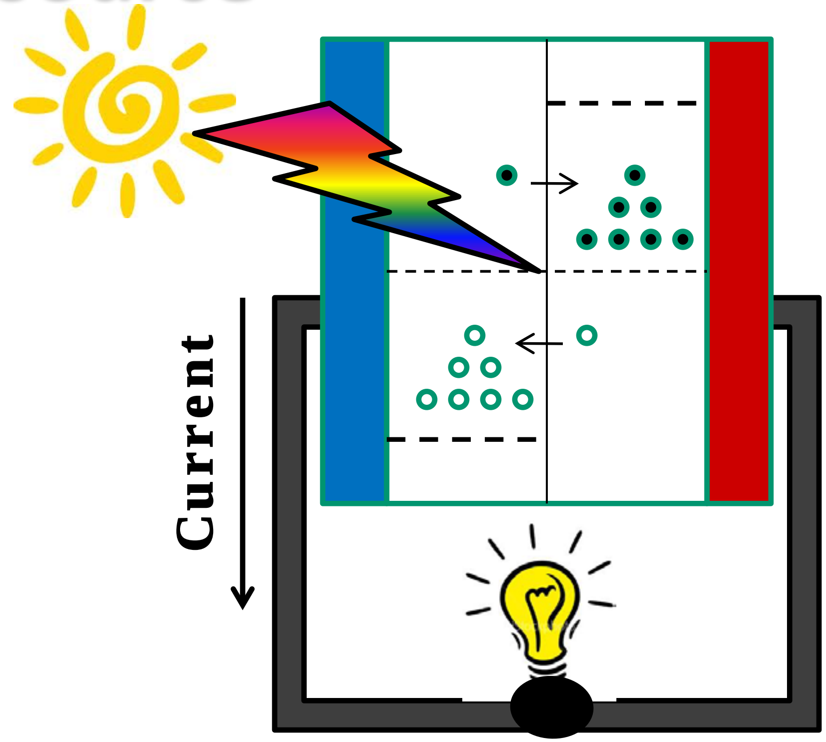
1%

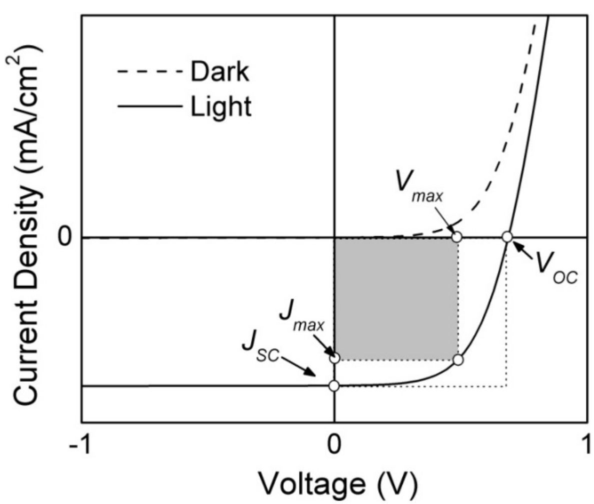
South China University of Technology: 9.2% (polymer) Aug. 2012

HeliaTek: 12% (small molecules) Jan 2013

Design the detector around the light source

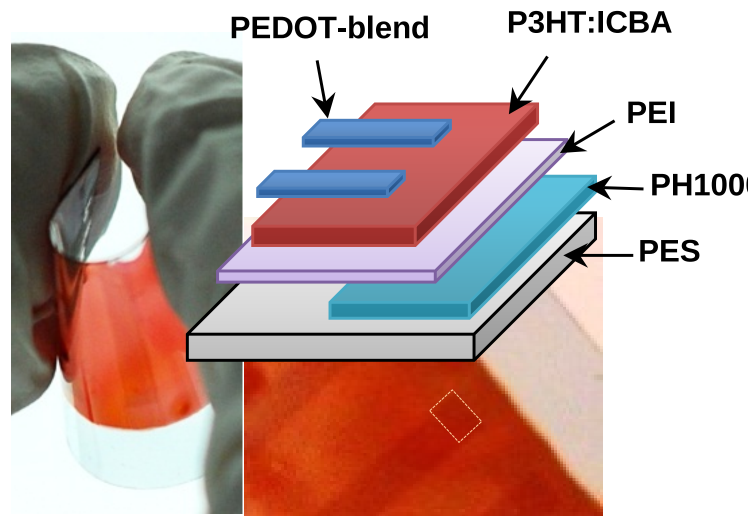






$$\eta = \frac{P_{\max}}{P_{solar}} = FF\frac{J_{SC}V_{OC}}{P_{solar}}$$

Example 1: semitransparent solar cells for smart windows



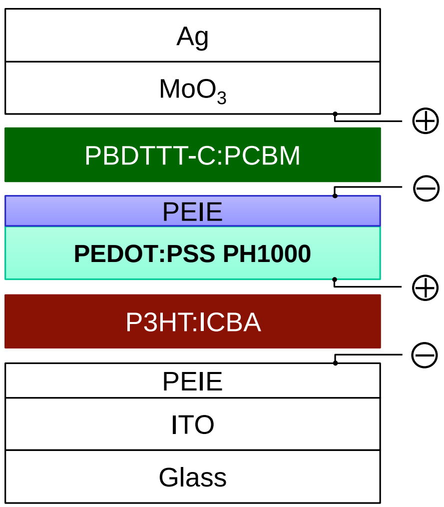
PCE = 1.8 %

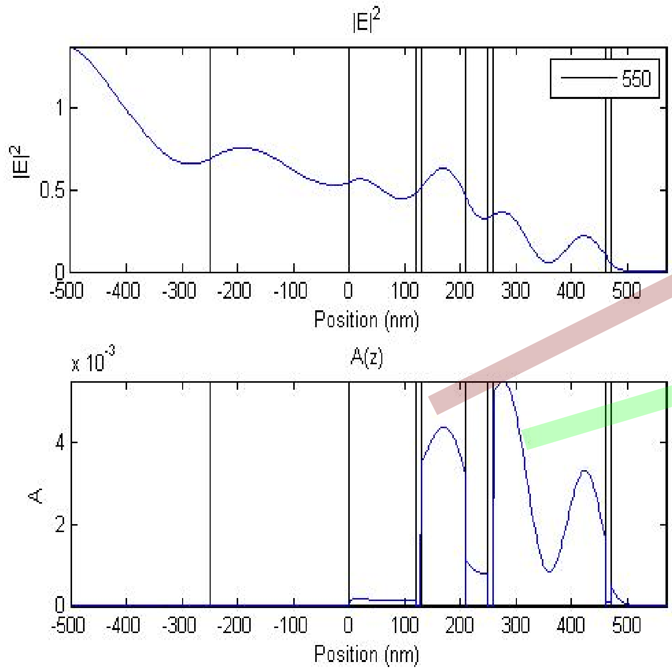
PCE = 3.3 %

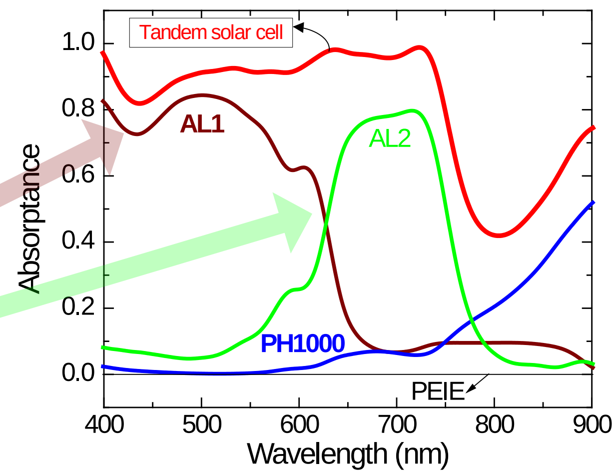
Metals like Ag are expensive, so do not use them.

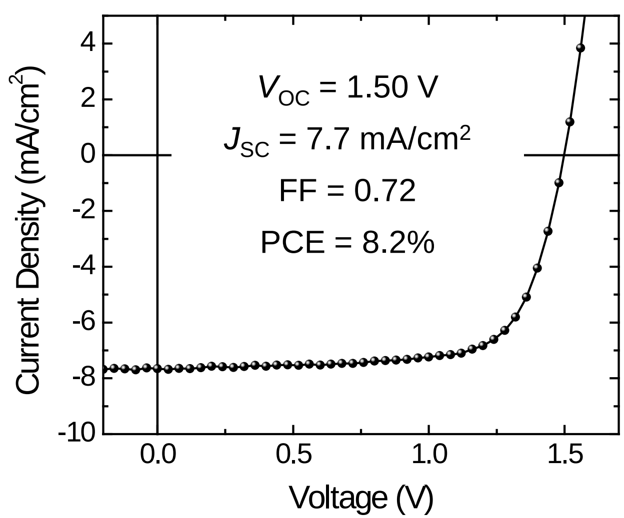
Zhou Y. et.al. Applied Physics Letters 97(15), 153304 Oct. (2010)
Zhou et al. Organic Electronics 12 (5) 827 (2011)
Zhou et al. Science, 336 (2012) 327-332.

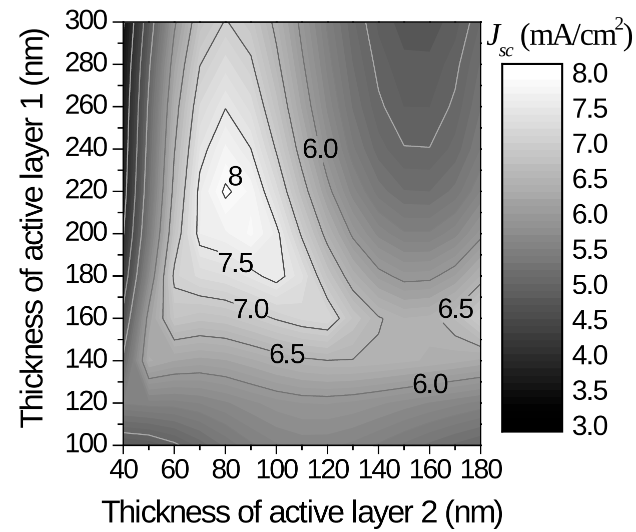
Tandem solar cells





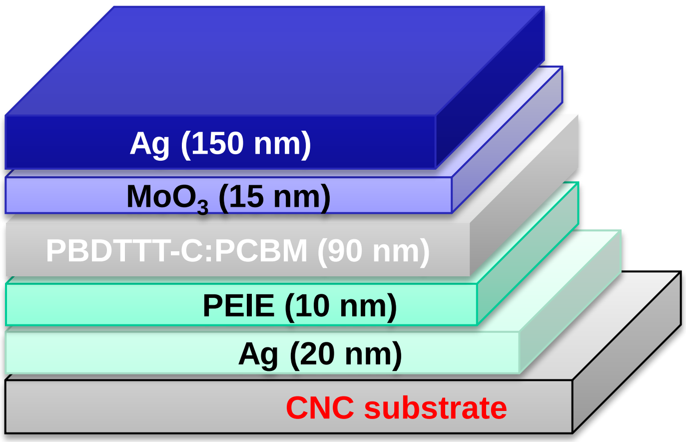


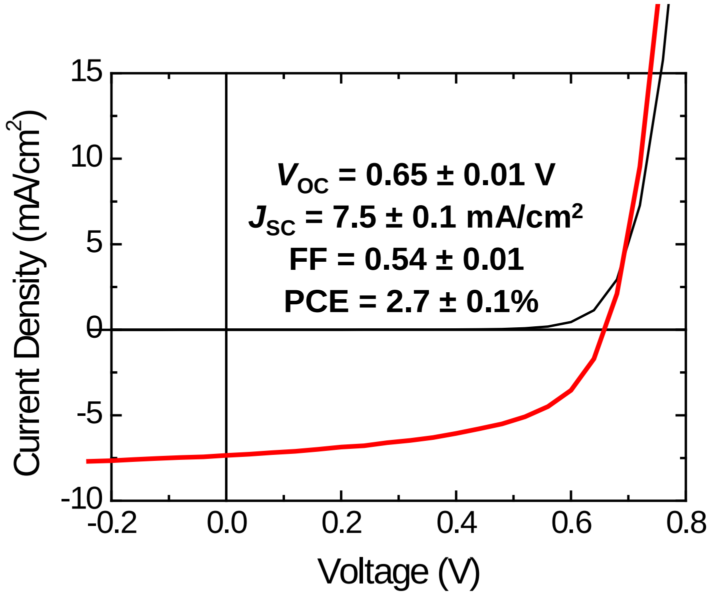


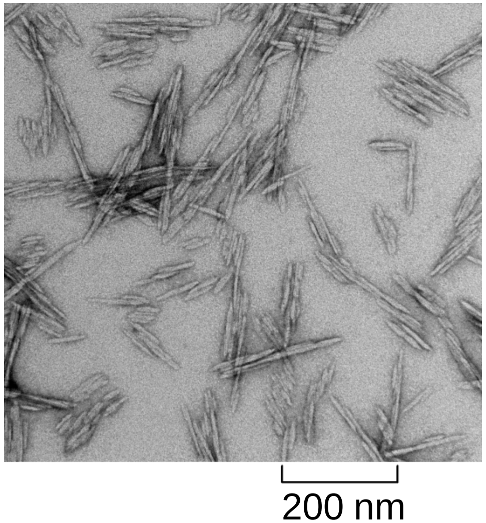


Zhou, et al. Energy & Environmental Science, 5 (2012) 9827-9832.

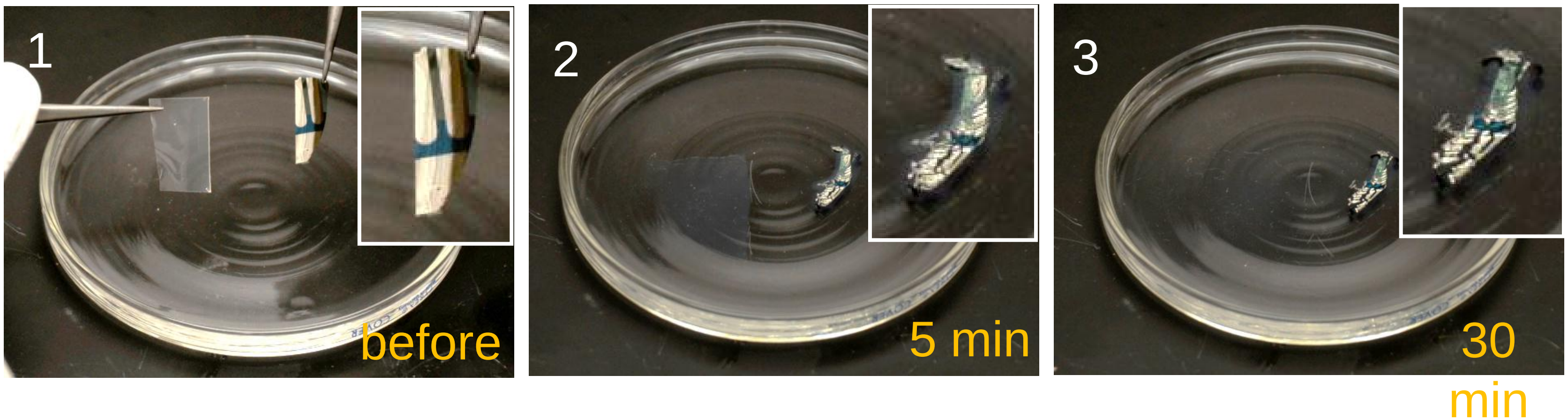
Recyclable solar cells

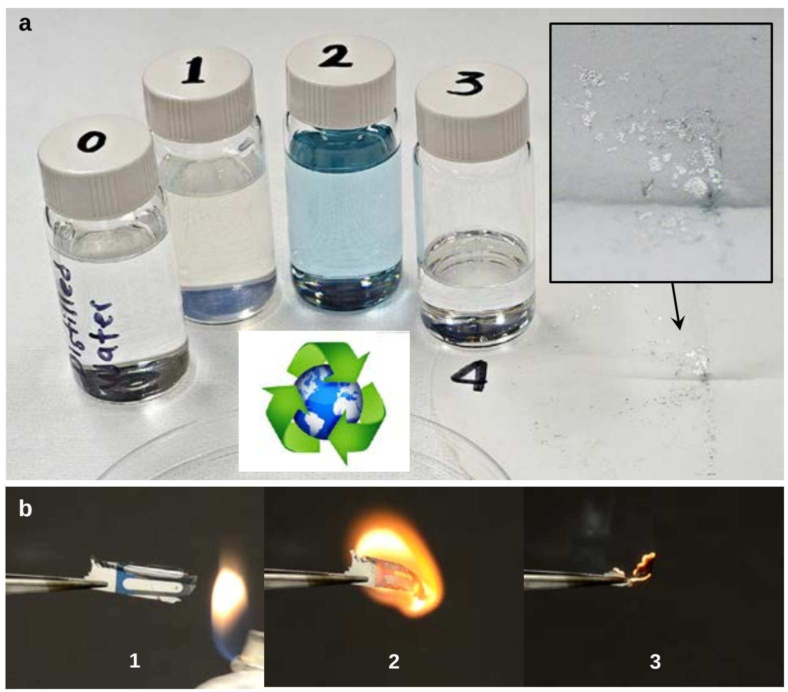






Recycling

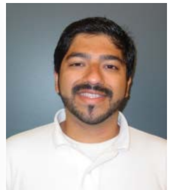




Acknowledgments

Bernard Kippelen

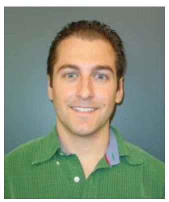
Yinhua Zhou



Talha Khan

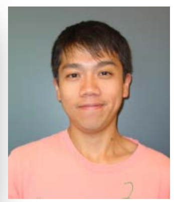
Jaewon Shim

Amir Dindar



Keith Knauer

Ehsan Najafabadi

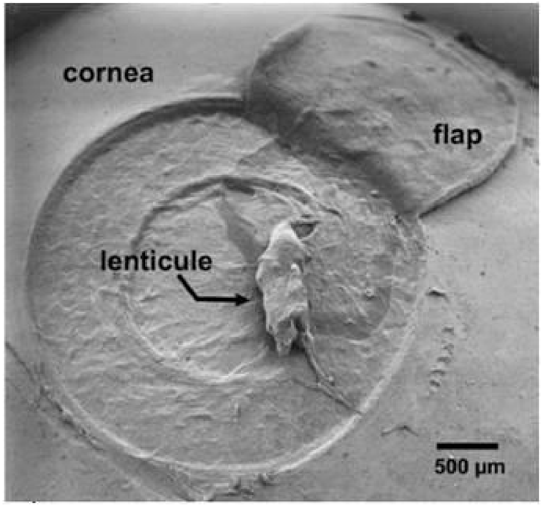


James Hsu

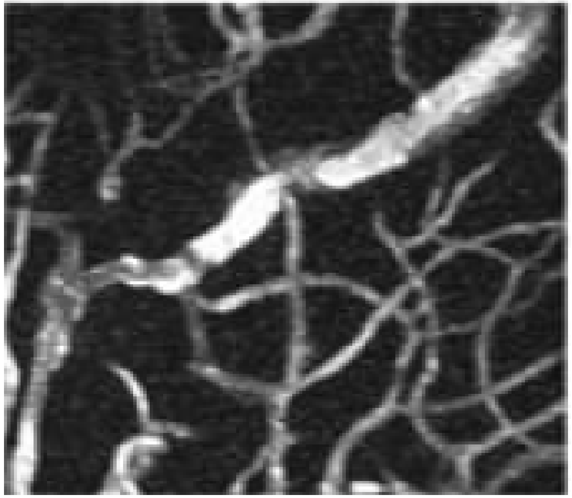
Albert Ernst

Asha Sharma

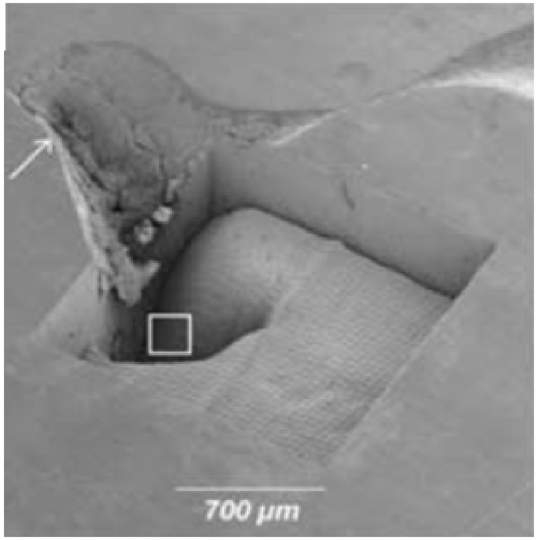
Light knifes



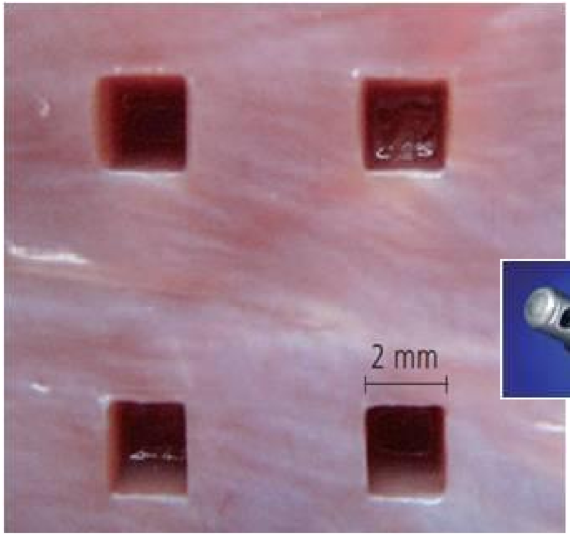
Eye



Blood vessels

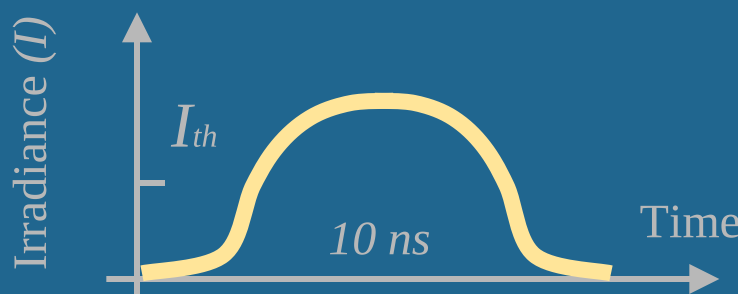


Dental



Neuroendoscope

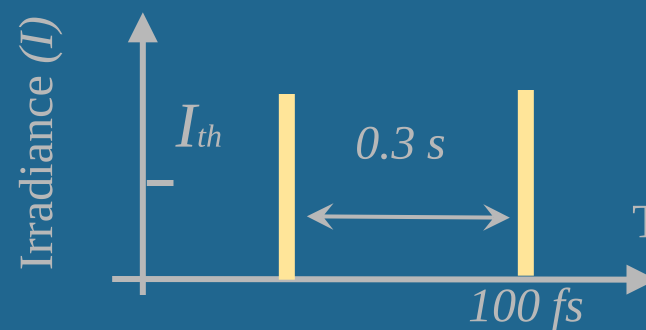
ns Laser



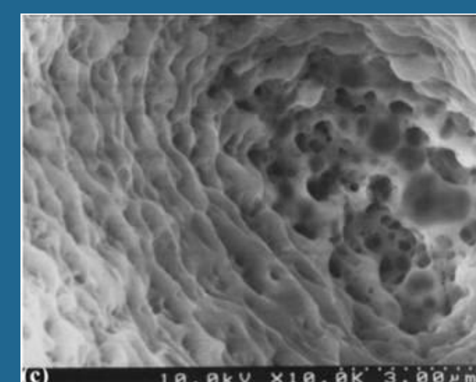
Evaporate
with Heat

Pain + $

fs Laser



Evaporate
w/o Heat



Our Innovation

Journal paper published

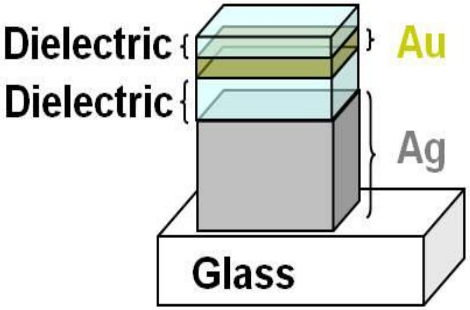
Provisional patent filed (GTRC 6221)

Dose Control System (Shutter) ~ $2*k*

(Compact and Ultrafast)

Ultrafast Mirror

(*R* changes)



SURFACE AREA REQUIRED TO POWER THE WORLD

WITH ZERO CARBON EMISSIONS AND WITH SOLAR ALONE

www.landartgenerator.org

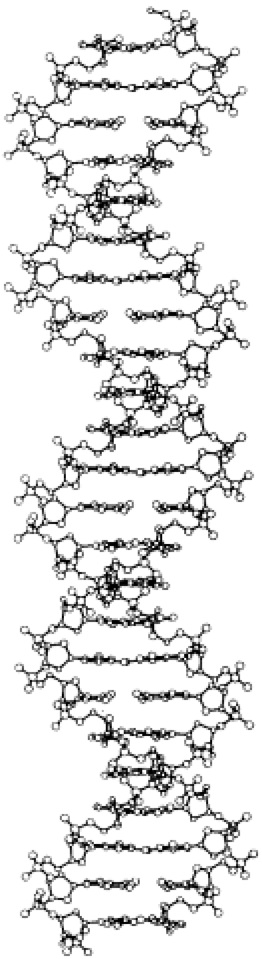
Required area that would be needed in the year 2030 is shown as one large square in the key above and also as distributed around the world relative to use and available sunlight.

- The large square in the Saharan Desert (1/4 of the overall 2030 required area) would power all of Europe and North Africa. Though very large, it is 18 times less than the total area of that desert.
- The definition of "power" covers the fuel required to run all electrical consumption, all machinery, and all forms of transportation. It is based on the US Department of Energy statistics of worldwide Btu consumption and estimates the 2030 usage (678 quadrillion Btu) to be 44% greater than that of 2008.
- Area calculations do not include magenta border lines.

LAND ART GENERATOR INITIATIVE

Organic molecules and polymers

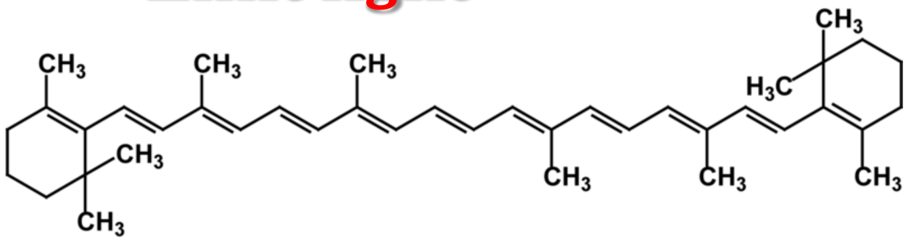
Synthetic **organic** compounds.

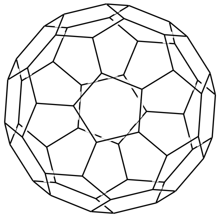


An important class of organic compounds:

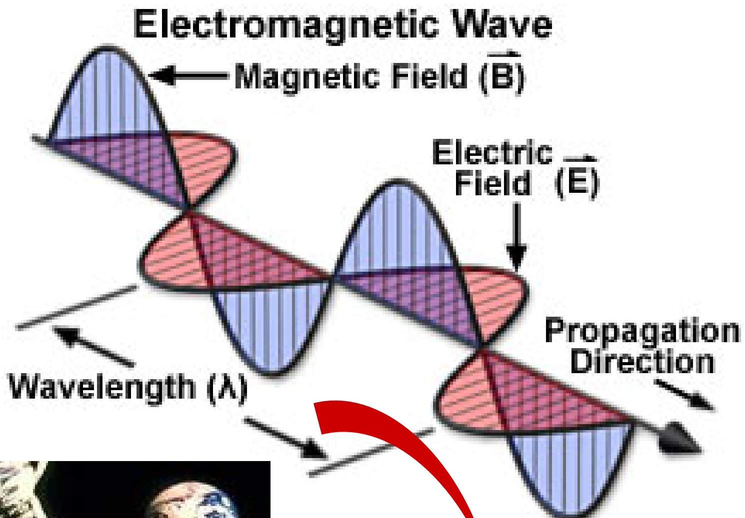
conjugated organic molecules and polymers

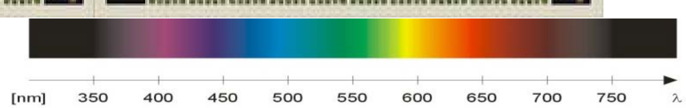
- **Conduct electricity**
- **Absorb**
- **Emit light**





Light waves





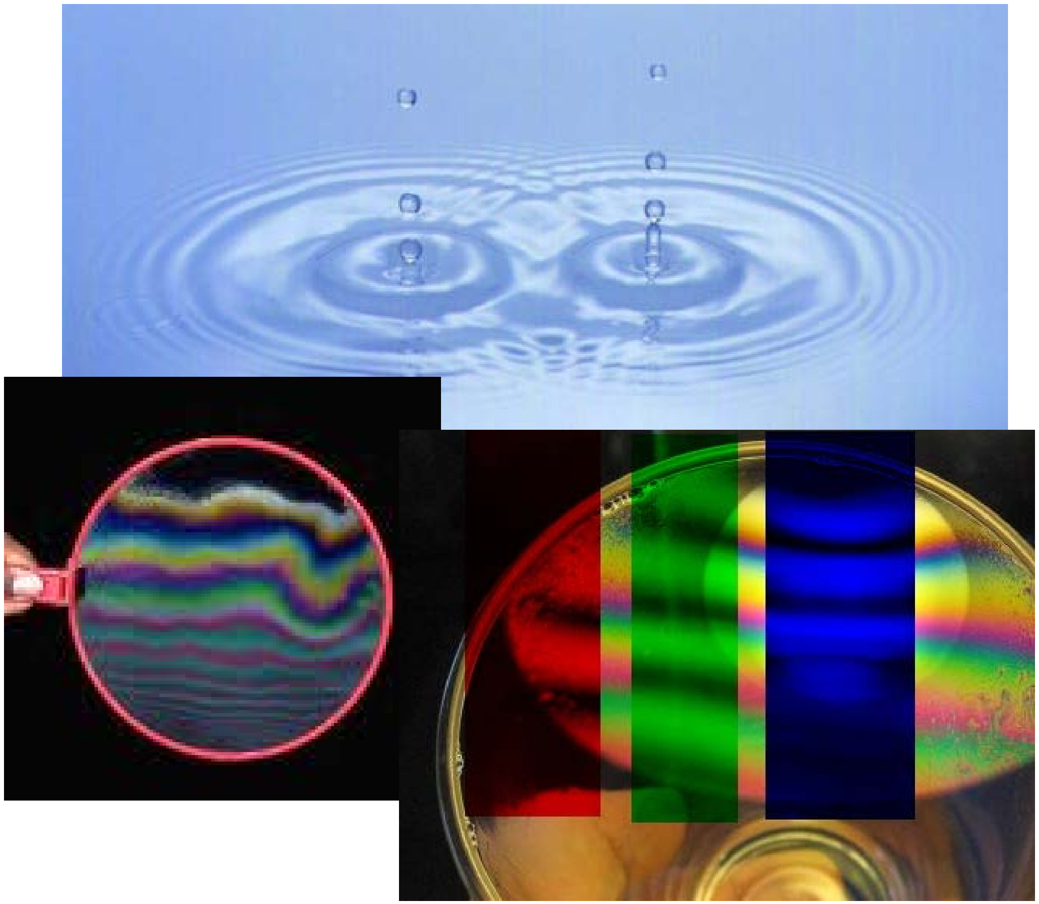
Visible spectrum

700 nm

390 nm

Light waves interact :

with each other



Interference

with materials