Interface-Engineered Materials For High-Efficiency All-Organics Solar Cells

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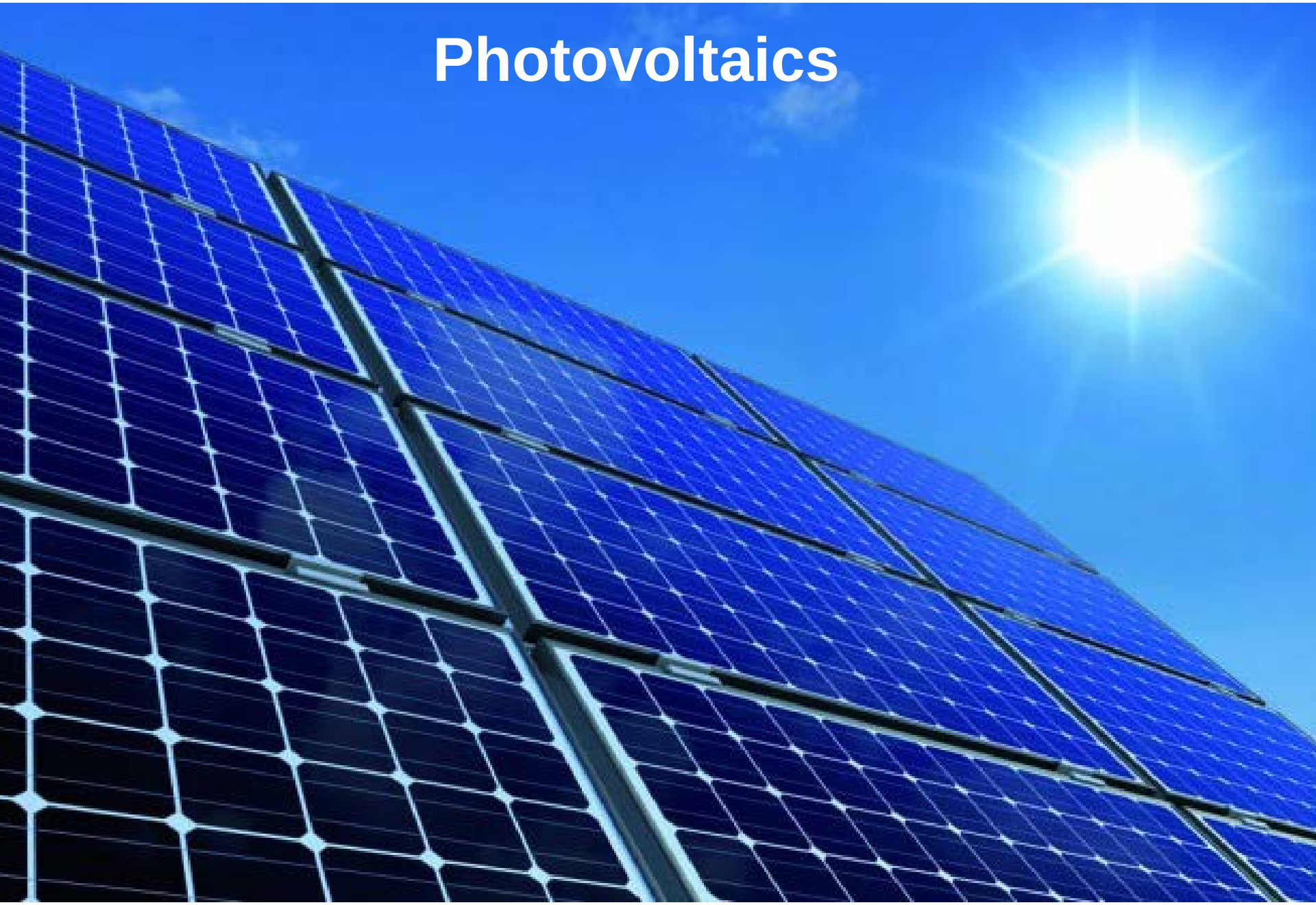
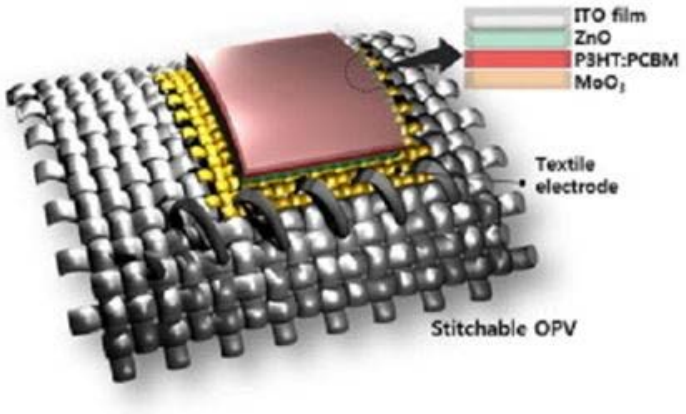
Photovoltaics

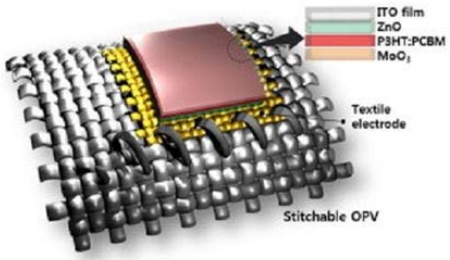


Photovoltaics from Organics



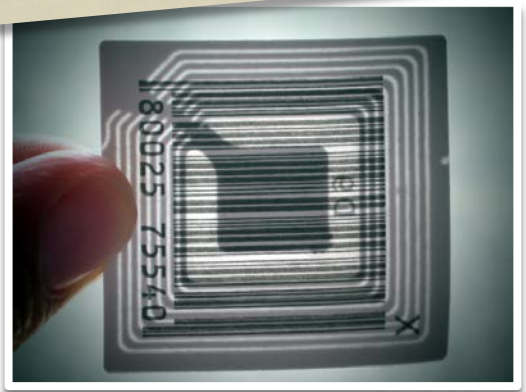
Organics are in principle cheap, flexible, bendable, and amenable to a variety of high throughput production methods

Organic / molecular electronics is the future!



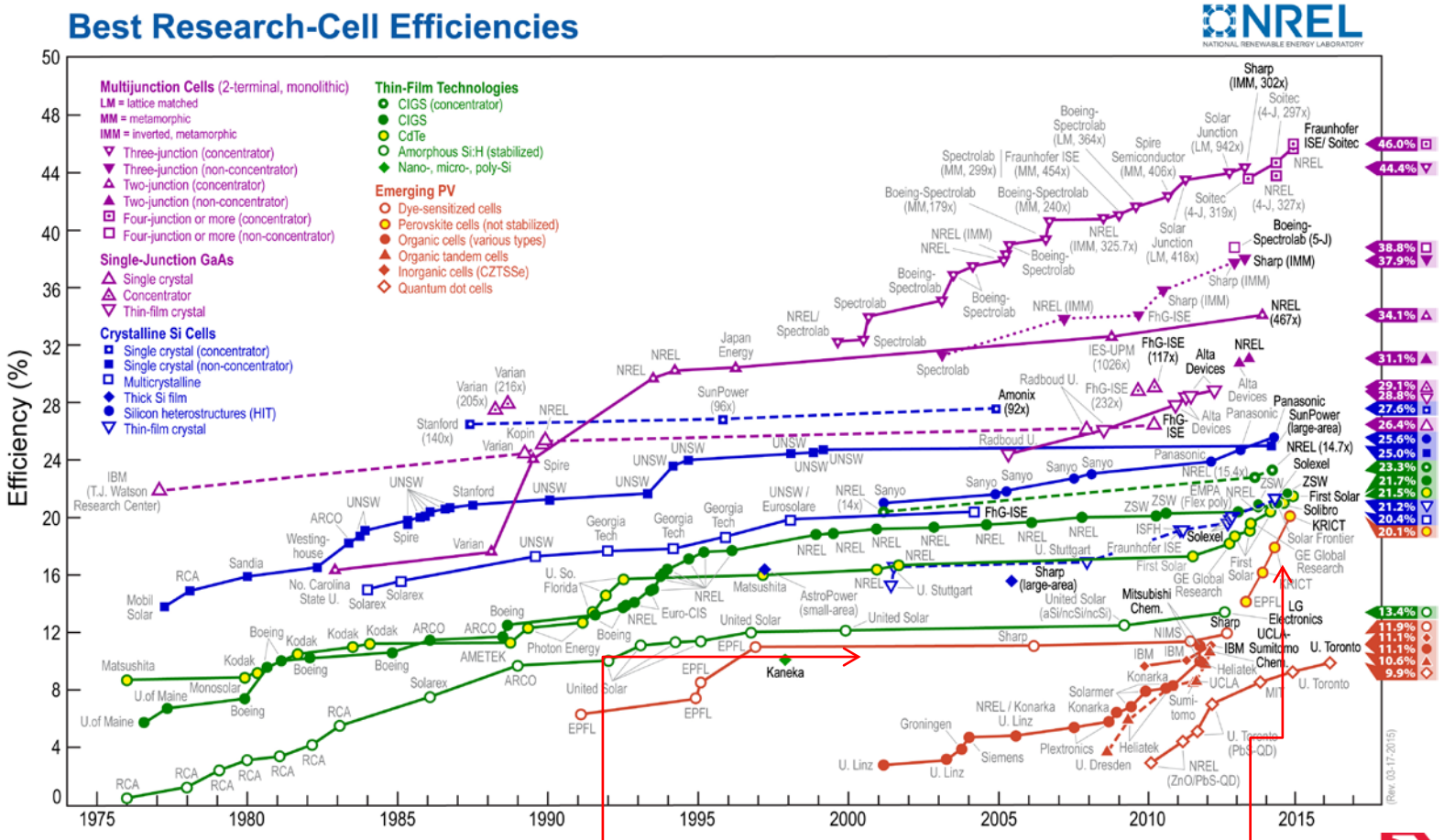
Organic Photovoltaics

Non-volatile Memory



RFID Tags

Organic Photovoltaics are emerging and promising, with some



Red are the organic solar cells

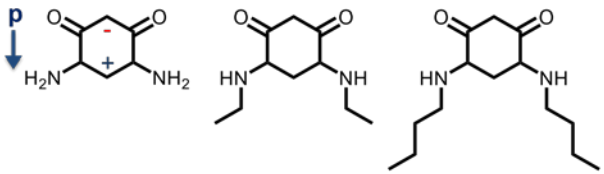
And these are not very stable

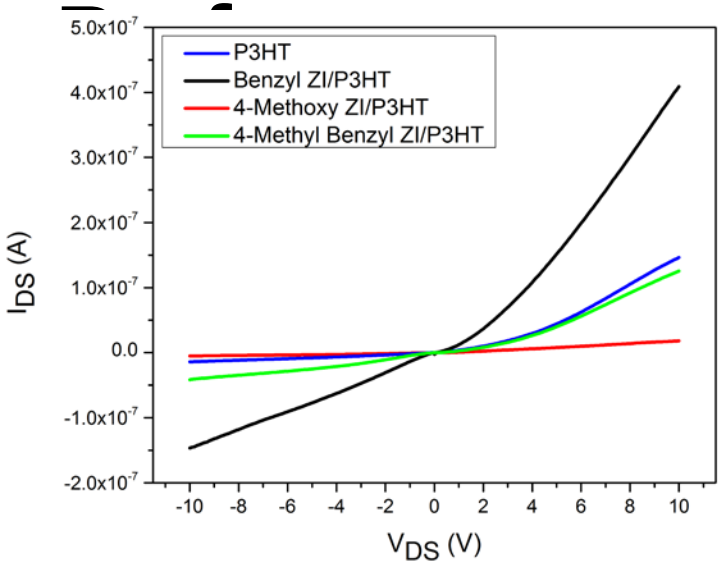
Problems with Organic Photovoltaics

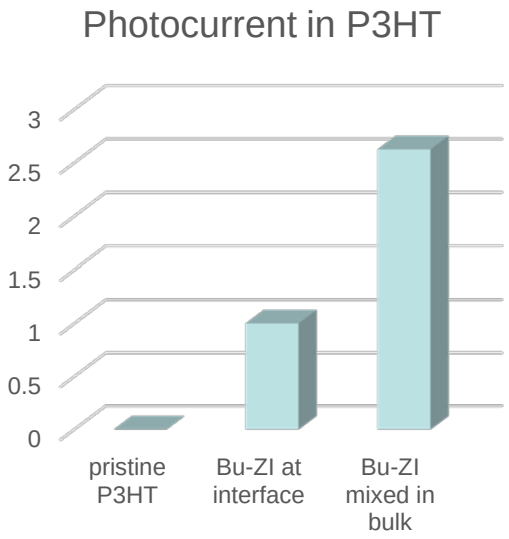
- Organic solar cells need to stable! They have to work for a long, long time and survive in harsh conditions.
  - solution: need additives to stabilize the organics
- They need to be made more efficient! Now efficiency is low (about 5%) or high (23%) but in materials not very stable. (high efficiency materials that degrade in sunlight)
  - solution: need additives to stabilize the organics – these will be dipolar molecules, and graded multilayers could improve efficiency a lot
- The organic solar cells need to be scalable! Can the materials be manufactured cheaply on a large scale?
  - Solution: Deposition from solution

Demonstration of Additives on PV

Addition of dipolar molecular additives (zwitterions) to a semiconductor organic polymer, P3HT, changes I-V characteristics in a broad range, from insulating to semiconducting to metallic

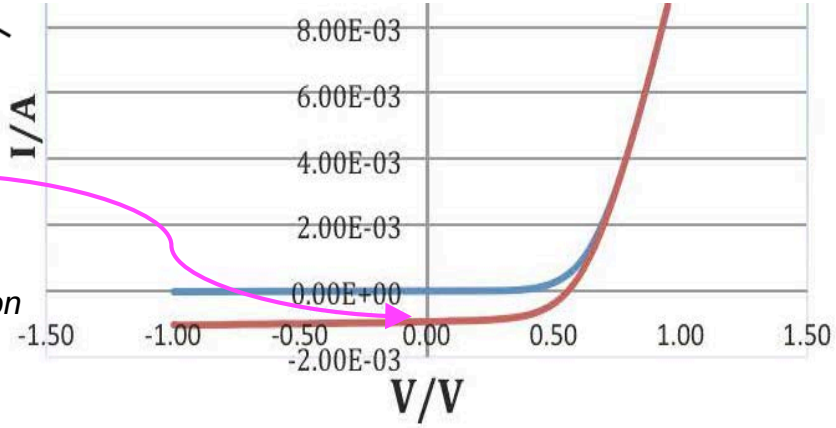






The signature of a successful organic solar cell combination: current at zero applied volts.

Enders, Dowben, and Doudin; unpublished data for dipolar zwitterion molecule (where R = C_4H_9) in combination with the organic semiconductor PEDOT (Poly(3,4-ethylenedioxythiophene).



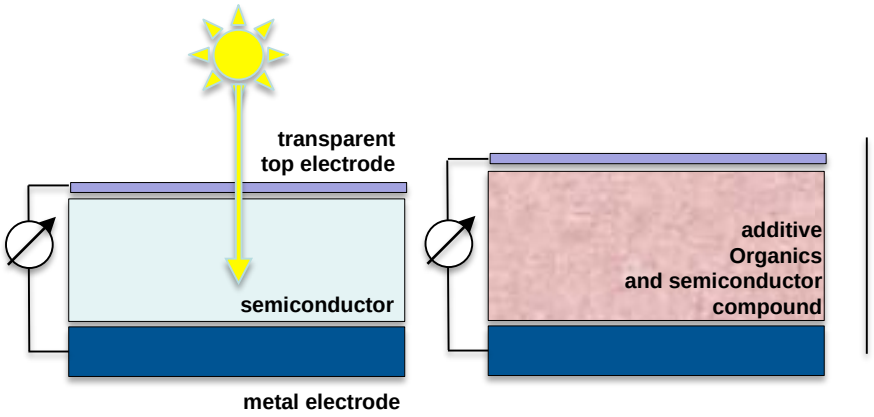
The additives enhance photo current generation!

But:

We still need to increase this current generation!

Dipolar molecules produce an intrinsic electric field that enhances the electron-hole separation in the semiconductor. This is new science!

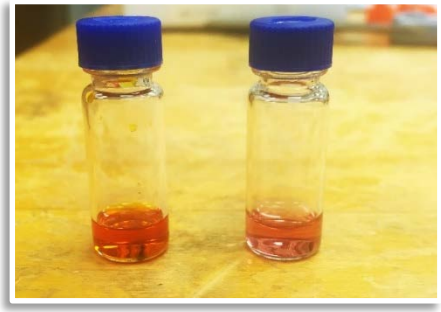
Materials and Device Fabrication



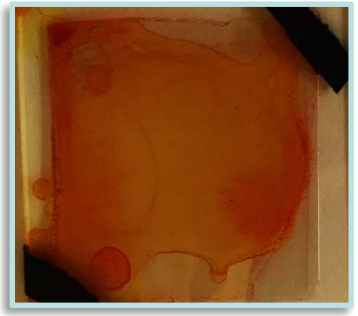
Standard PV
device structure

NEW PV
device structure

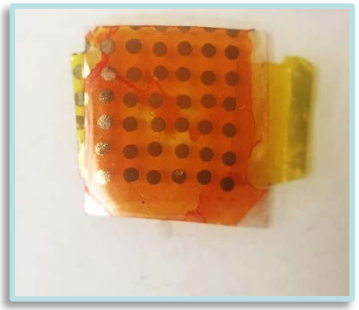
P3HT and BZI in
Dicholoromethan



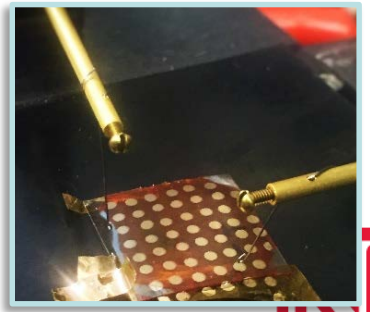
thin film deposition
on ITO bottom
electrode
by spin coating



evaporation
of a top electrode

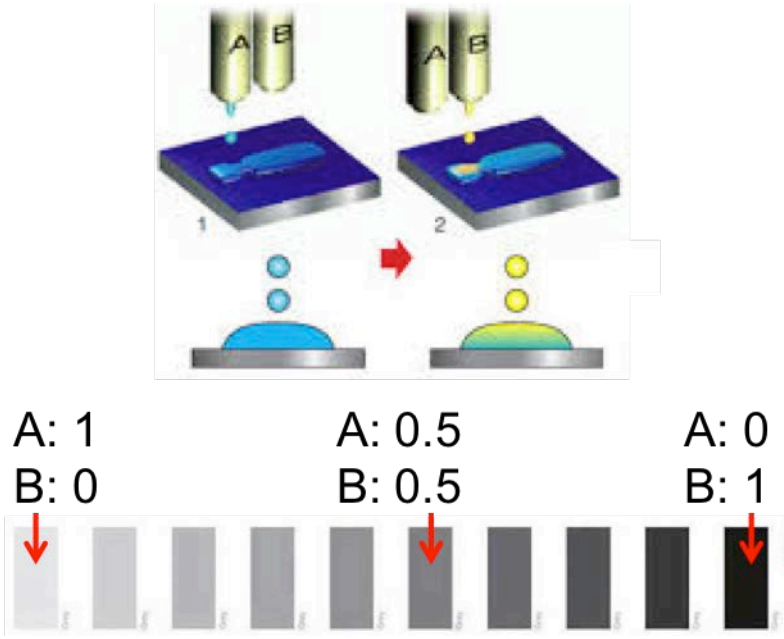


device
characterization

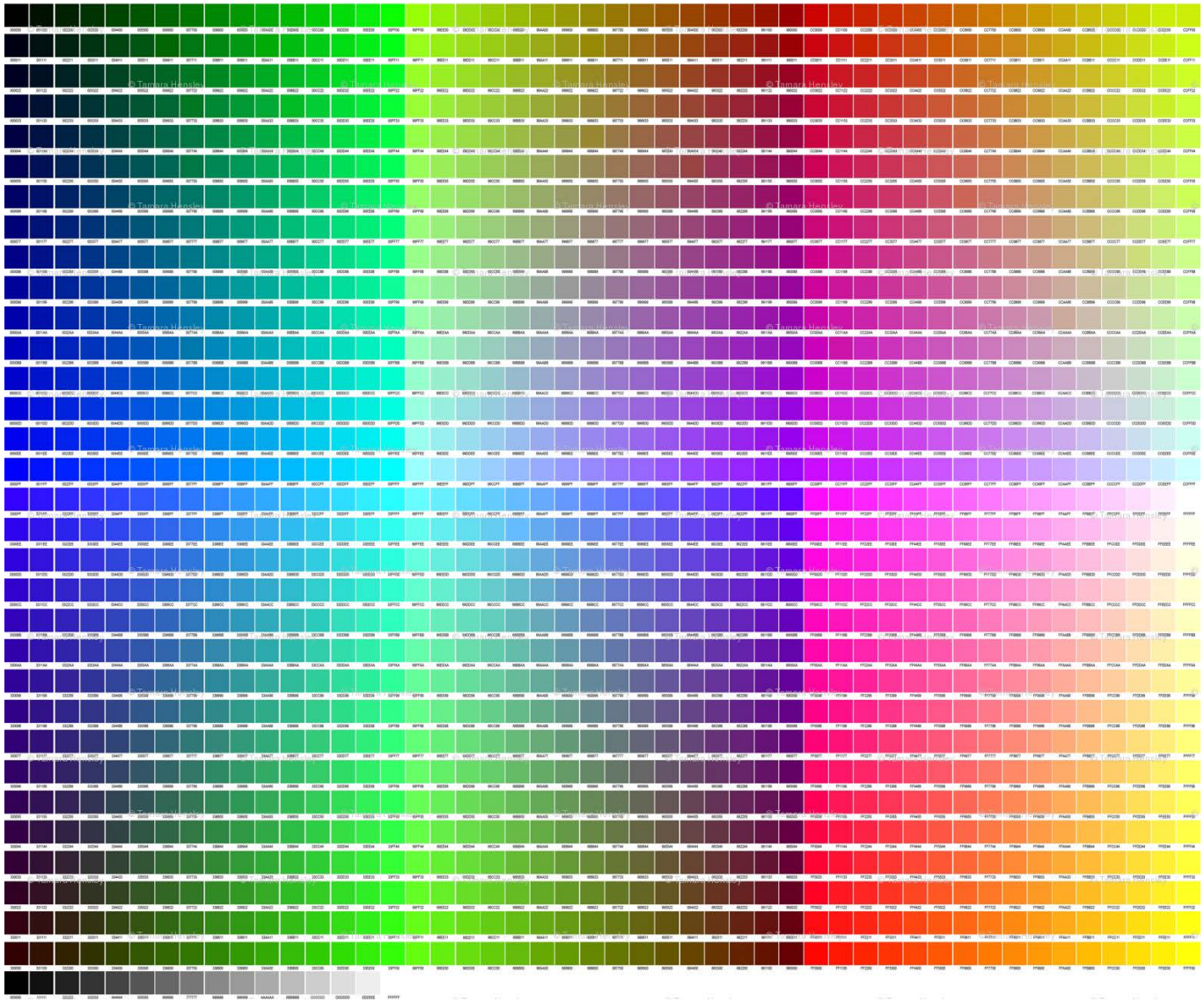


Inkjet Printing of Organics

Rapid prototyping with inkjet printer technology using a modified inkjet printer



Rapid Prototyping of Materials Combinations



Thin-Films of Inkjet-printed Perovskites

Protesescu, Loredana, et al. "Nanocrystals of cesium lead halide perovskites (CsPbX3, X= Cl, Br, and I): novel optoelectronic materials showing bright emission with wide color gamut." *Nano letters* 15.6 (2015): 3692-3696.

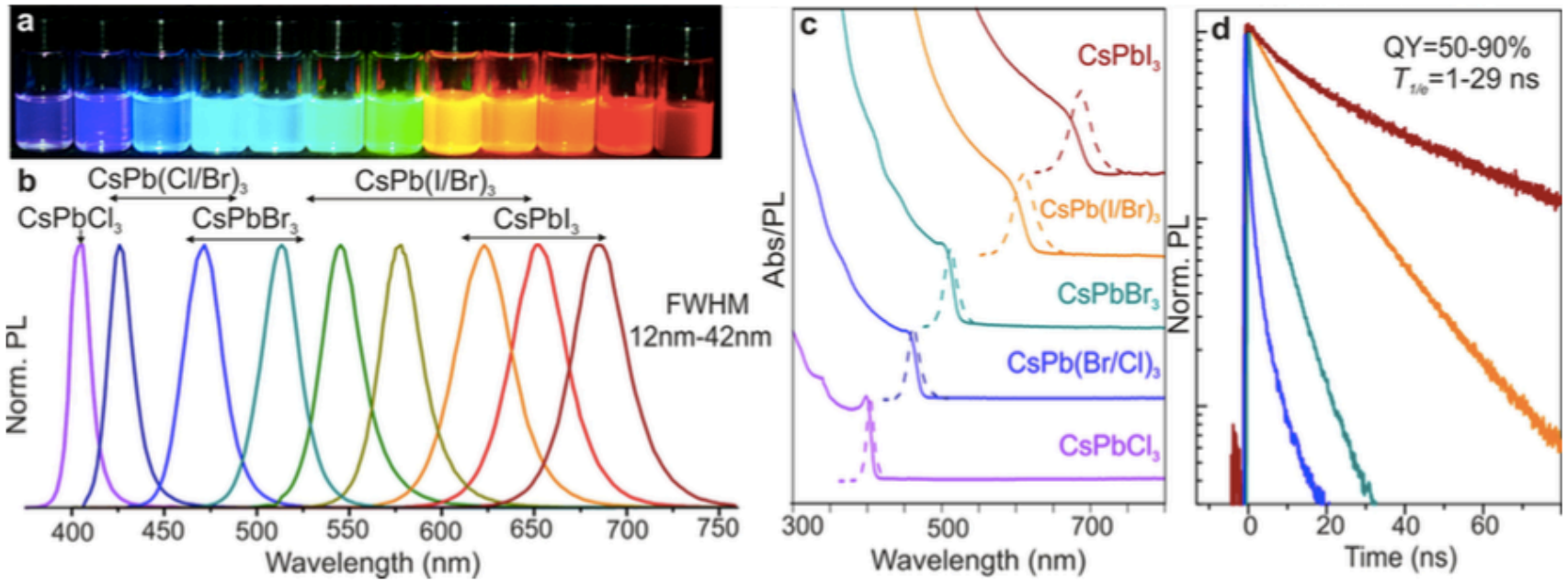
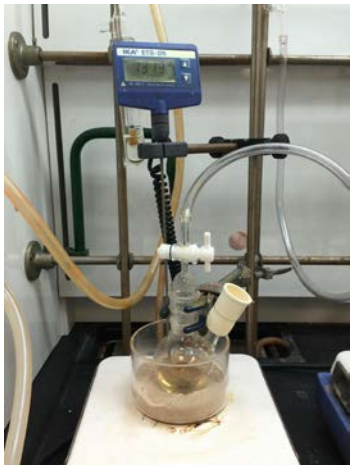


Figure 2. Colloidal perovskite $CsPbX_3$ NCs (X = Cl, Br, I) exhibit size- and composition-tunable bandgap energies covering the entire visible spectral region with narrow and bright emission: (a) colloidal solutions in toluene under UV lamp (λ = 365 nm); (b) representative PL spectra (λ_{exc} = 400 nm for all but 350 nm for $CsPbCl_3$ samples); (c) typical optical absorption and PL spectra; (d) time-resolved PL decays for all samples shown in (c) except $CsPbCl_3$.

Perovskite Synthesis

Example: $CsPbBr_3$



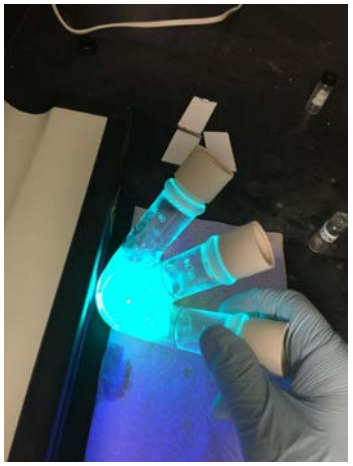
Synthesis of Cesium Oleate

+

Synthesis of $PbBr_2$ Solution

=

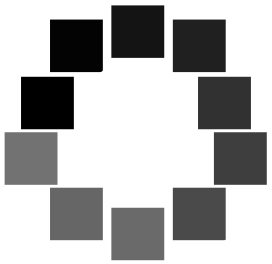
Synthesis of $CsPbBr_3$ Quantum Dots (QD)



QDs under UV

Inkjet-printing of Perovskite

Ink



Template design for CD/DVD tray of printer

Grayscale ink printing (10 samples)

$CsPbBr_3$ in Hexane

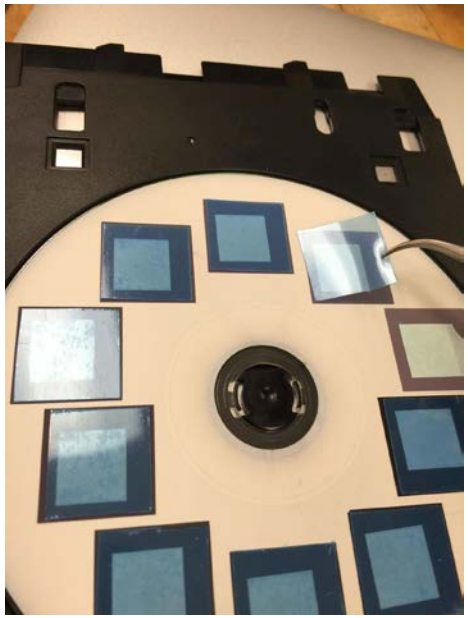
Easy-fill cartridges

Filling with $CsPbBr_3$ + Hexane

Replacing ink cartridges with sample cartridges

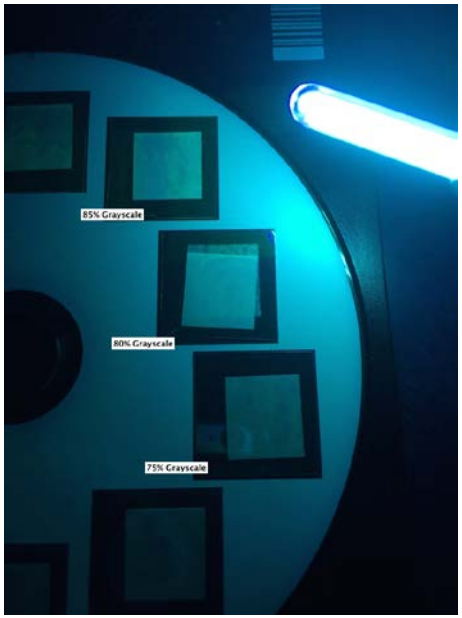
Controlling $CsPbBr_3$ Perovskite Coverage Through Grayscale Printing

Optical Microscope under UV



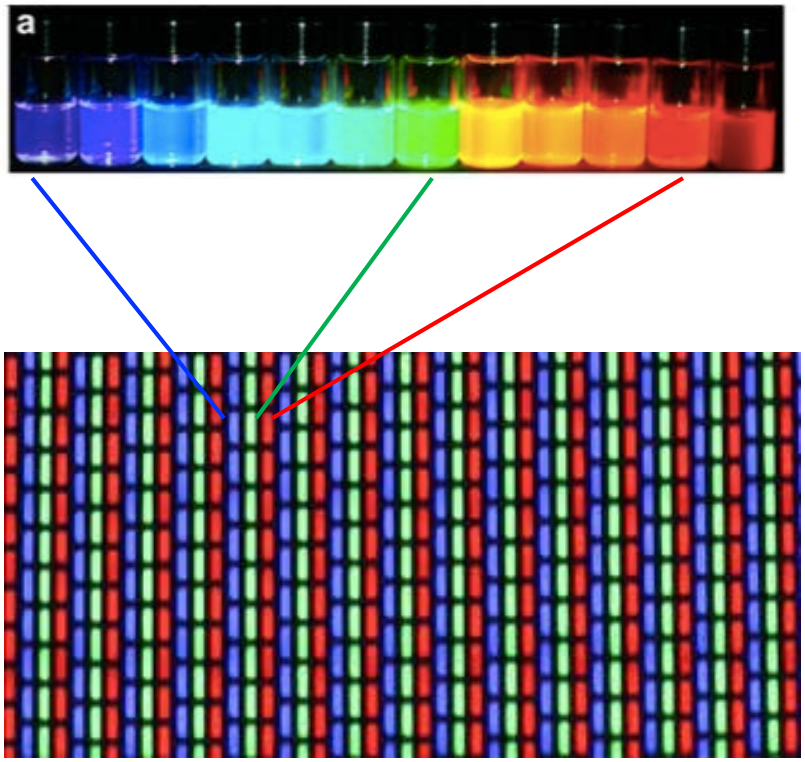
Placing ITO-PET on CD/DVD Tray

Finished Disc with 10 sample areas



Photoluminescence of perovskite on 0% grayscale (black) to 20% grayscale (dark gray).

Imagine we could …



… print highly resolved patterns of this material!
We might then be able to print flatscreens on pretty much anything!