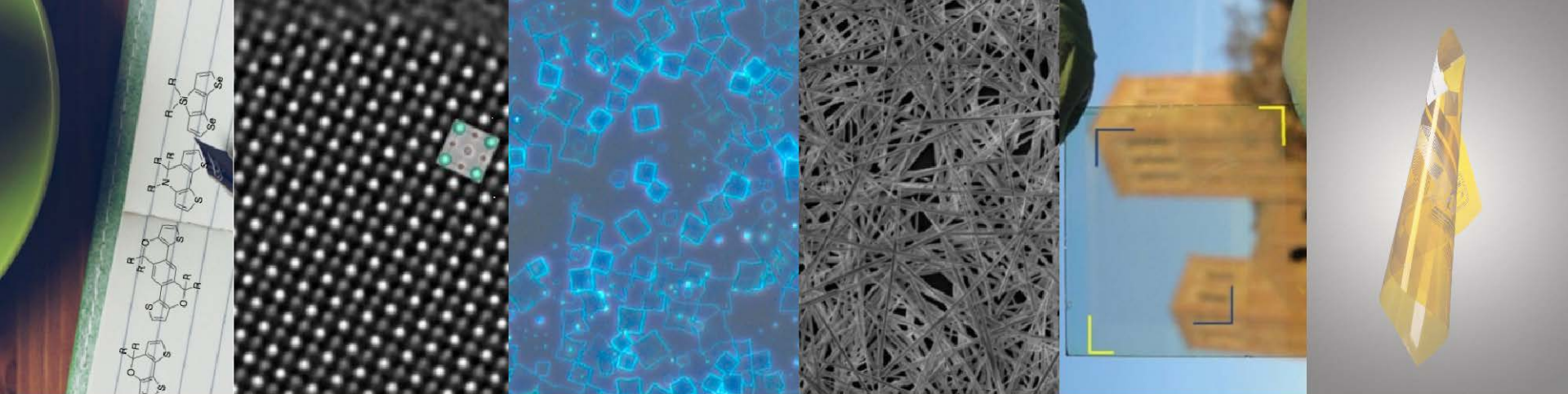




Safer Materials and Processing Design for Next-Generation Printed Electronics

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Next generation Semiconductors

Conventional semiconductors

Si: Czochralski method

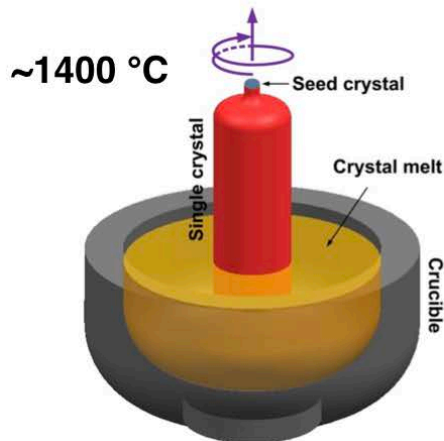
At 1900 °C $\text{SiO}_2 + 2 \text{C} \rightarrow \text{Si} + 2 \text{CO}$

At 300 °C $\text{Si} + 3 \text{HCl} \rightarrow \text{SiHCl}_3 (\text{g}) + \text{H}_2$

After purification: 99.9999999%

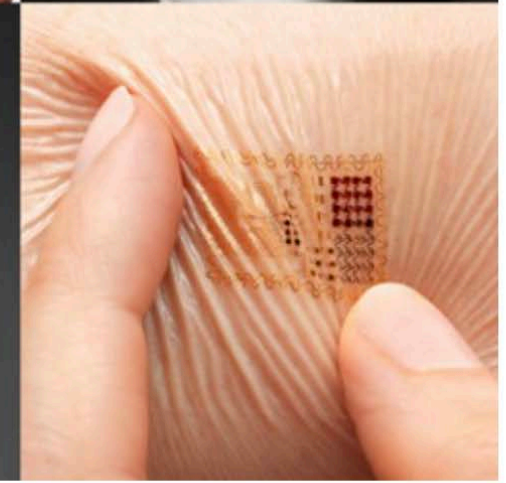
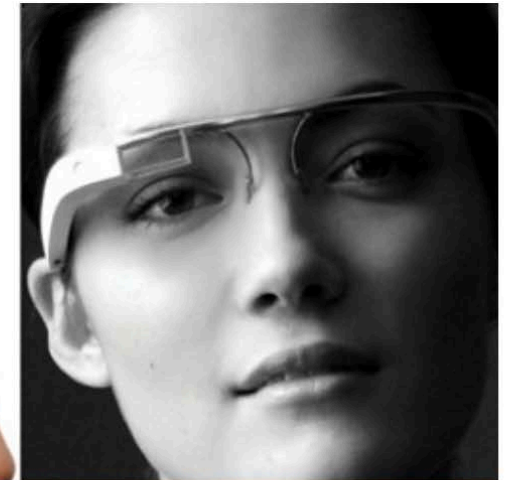
At 1100 °C $\text{SiHCl}_3 + \text{H}_2 \rightarrow \text{Si} + 3 \text{HCl}$

Electronic grade silicon: 99.9999999%



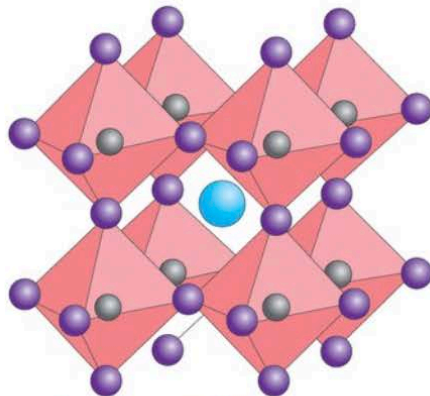
III-V (GaAs):
Metal Organic Chemical Vapor Deposition or
Molecular Beam Epitaxy

The future of electronics



Hybrid halide perovskite

— *Combining high performance and low-cost processing*



A : Cs^+ , R-NH_3^+ ...
B : Pb^{2+} , Sn^{2+} , Ge^{2+} ...
X : Cl, Br, I ...

Long carrier
diffusion length
($> 1 \mu\text{m}$)

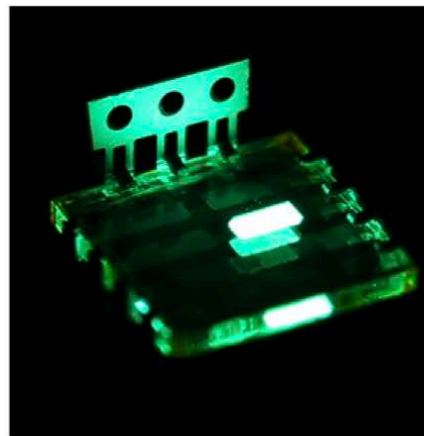
High absorption
coefficient
($> 10^5$)

High PL quantum
efficiency
($> 90\%$)

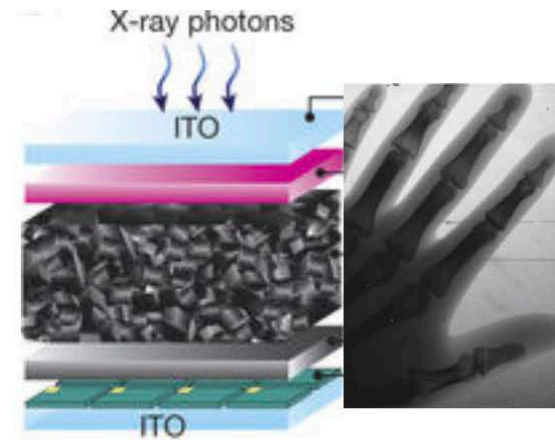
Defect tolerant



Miyasaka, *JACS*, 2009, 131, 6050
Snaith, *Science*, 2012, 338, 643



Friend, *Nature Nanotechnology*,
2014, 9, 687



Huang, *Nature Photonics*, 2016, 9, 679
Park, *Nature* 2017, 550, 87

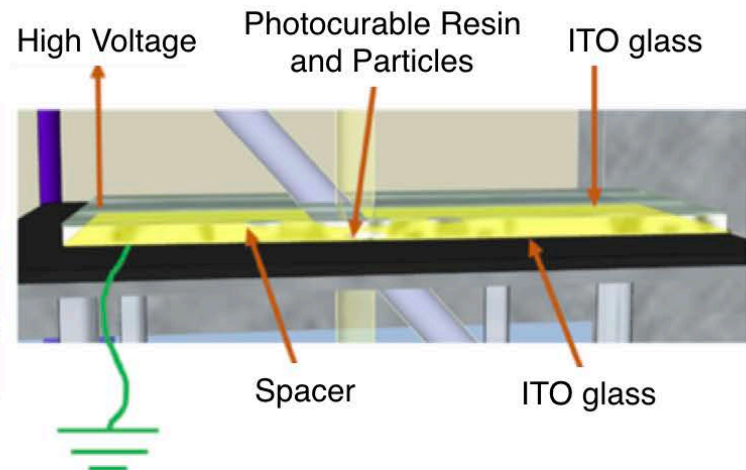
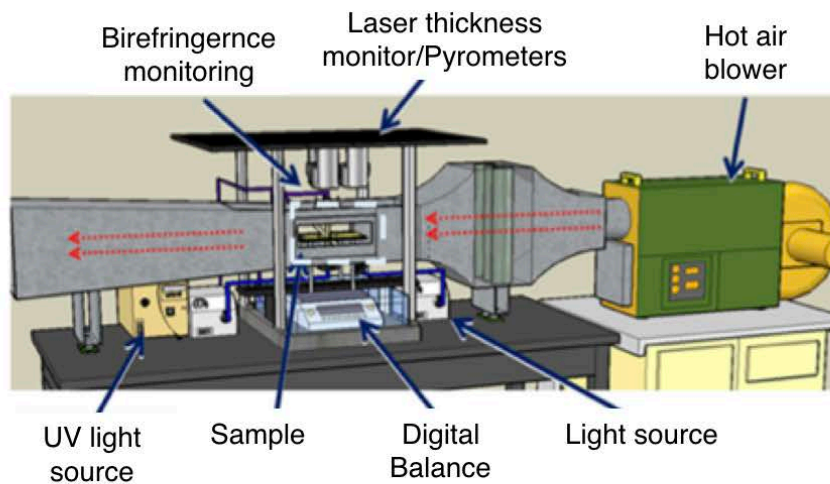
Scalable processing

Roll-to-roll coating:



Located in Birck Nanotechnology Center at Purdue

In-situ monitoring:



In collaboration with Miko Cakmak and Jianguo Mei

Project proposal

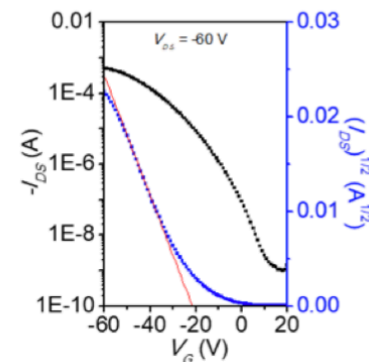
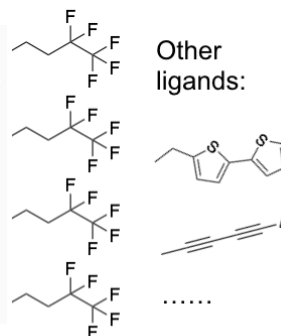
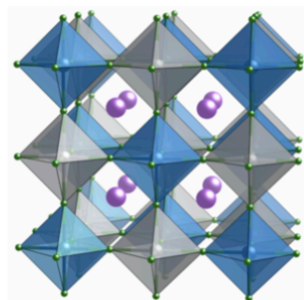
- **Lead-free perovskite materials (Year 1)**



* Double perovskite $\text{A}_2\text{B}'\text{B}''\text{X}_6$

$\text{B}' = \text{Cu}^+, \text{Ag}^+, \text{Au}^+,$

$\text{B}'' = \text{Bi}^{3+}, \text{Sb}^{3+}, \text{In}^{3+}$



Transistors with charge carrier mobility over 1 cm^2/Vs achieved

* Introducing organic functional building blocks

- **Aqueous phase solution-processing** to reduce organic solvent pollution and potential safety issues (Year 2)



- * Common solvents: DMF, chlorobenzene
- * Concentration $\sim 100 \text{ g/L}$ ($\sim 100 \text{ m}^2$ corresponds to 10L liquid solvent)
- * DMF, chlorobenzene $\rightarrow \text{H}_2\text{O}$ (or alcohol)
- * Additives: PEG, polyelectrolytes
- * Stabilizer: HI, H_3PO_2

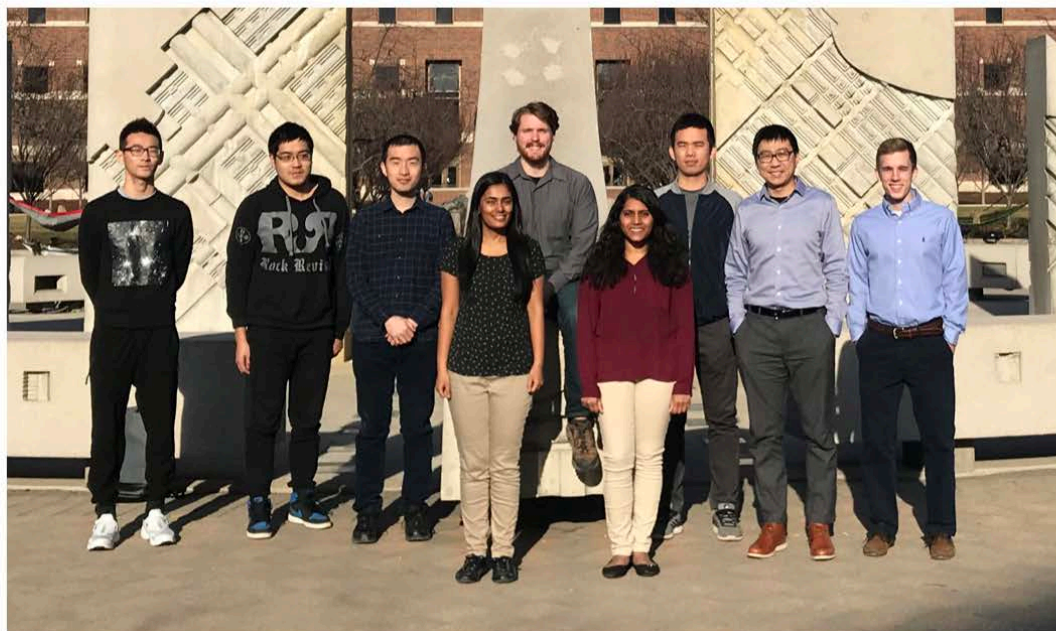
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- Dr. Enzheng Shi



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Thank you for your attention!