Georgia Tech Institute for Electronics and Nanotechnology

# LOW-COST SOLAR CELL TECHNOLOGY FOR HETEROGENEOUSLY INTEGRATED SYSTEMS

## A Literature Study

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SENIC Southeastern Nanotechnology Infrastructure Corridor

National Nanotechnology Coordinated Infrastructure

NSF

# Purpose

Exploring feasibility of perovskite solar cell technology integration in optoelectronic devices

- Can be used in the study of photonics
- Future of quantum computing

# Why are Perovskites used?

- Increased power efficiency in the past decade: 3.8% to 19.6%
- Lightweight material
- Low production costs
- Flexible

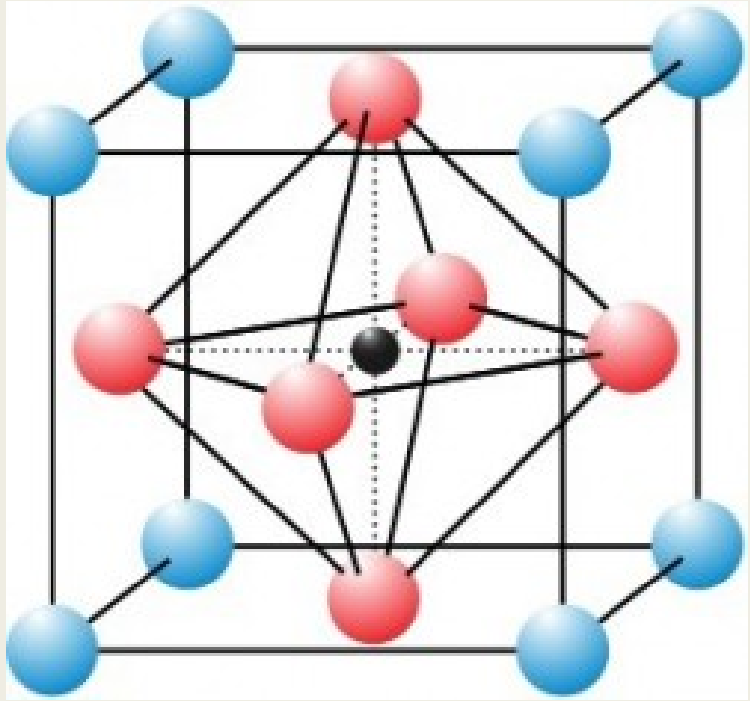
## So why optimize material?

- Function
- Different materials determine different levels of efficiency
  - Power conversion efficiencies
  - Lifetime
- Can affect outcome

Tai, Qidong; and Feng Yan. “Emerging Semitransparent.” *Advanced Materials*. 2017.
Clean Energy Institute. “Perovskite Solar Cell.” *University of Washington*. 2019.

# Perovskite Solar Cells (PSCs)

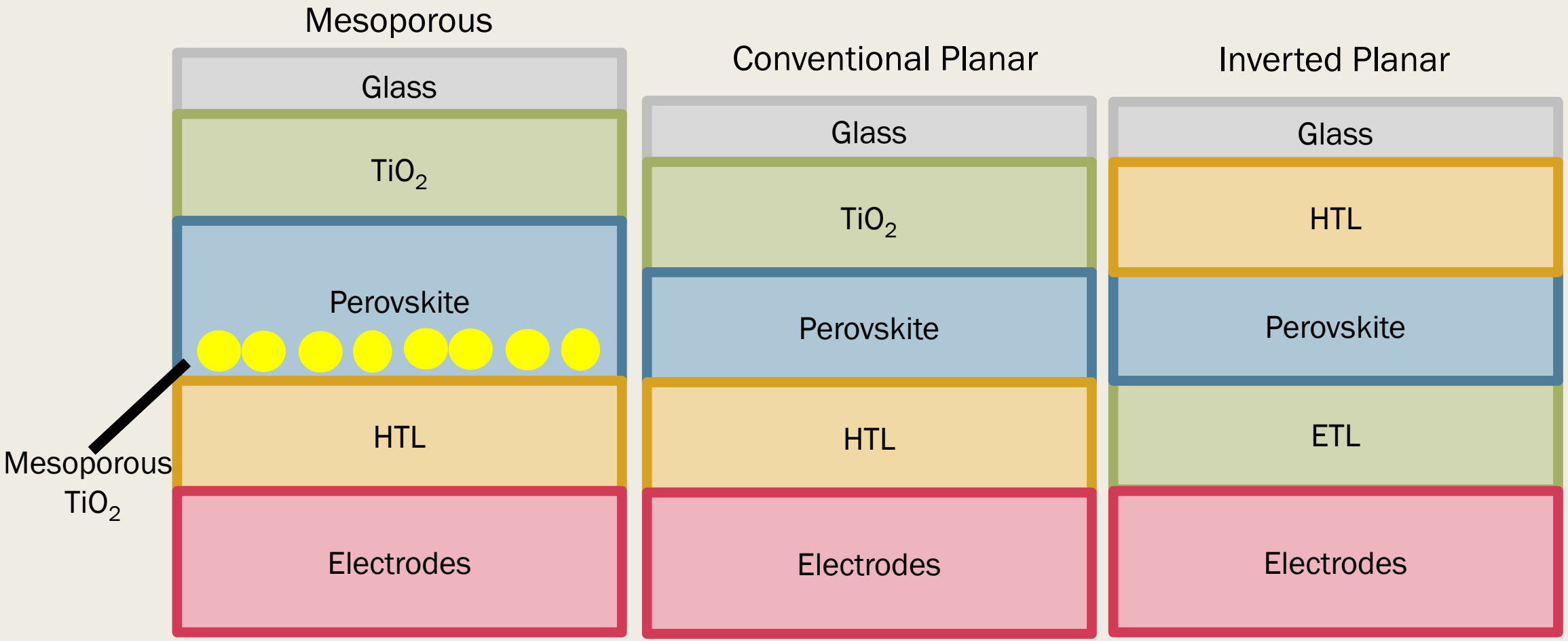
- A solar cell produced using material with specific Perovskite crystalline structure
- General Formula: $ABX_3$
  - *A & B = cations of different sizes (A > B)*
  - *X = anion bonded to both*
- Typically is a hybrid of organic-inorganic lead and/or tin halide material
- Differs in halide type, organic component



Above: Schematic of Perovskite structure
Korjus [CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0)]

Clean Energy Institute. “Perovskite Solar Cell”. *University of Washington*. 2019.
Snaith, Henry J. “Perovskites: The Emergence”. *The Journal of Physical Chemistry Letters.* 2013.

# Device Structure





Chilvery, Ashwith, et al. “A Perspective on the recent”. *Science and Technology of Advanced Materials.* 2016.
Chen, Wei, et al. “A comparative study”. *ScienceDirect.* 2018.
Mahmood, Khalid, et al. “Current status of”. *Royal Society of Chemistry.* 2017.

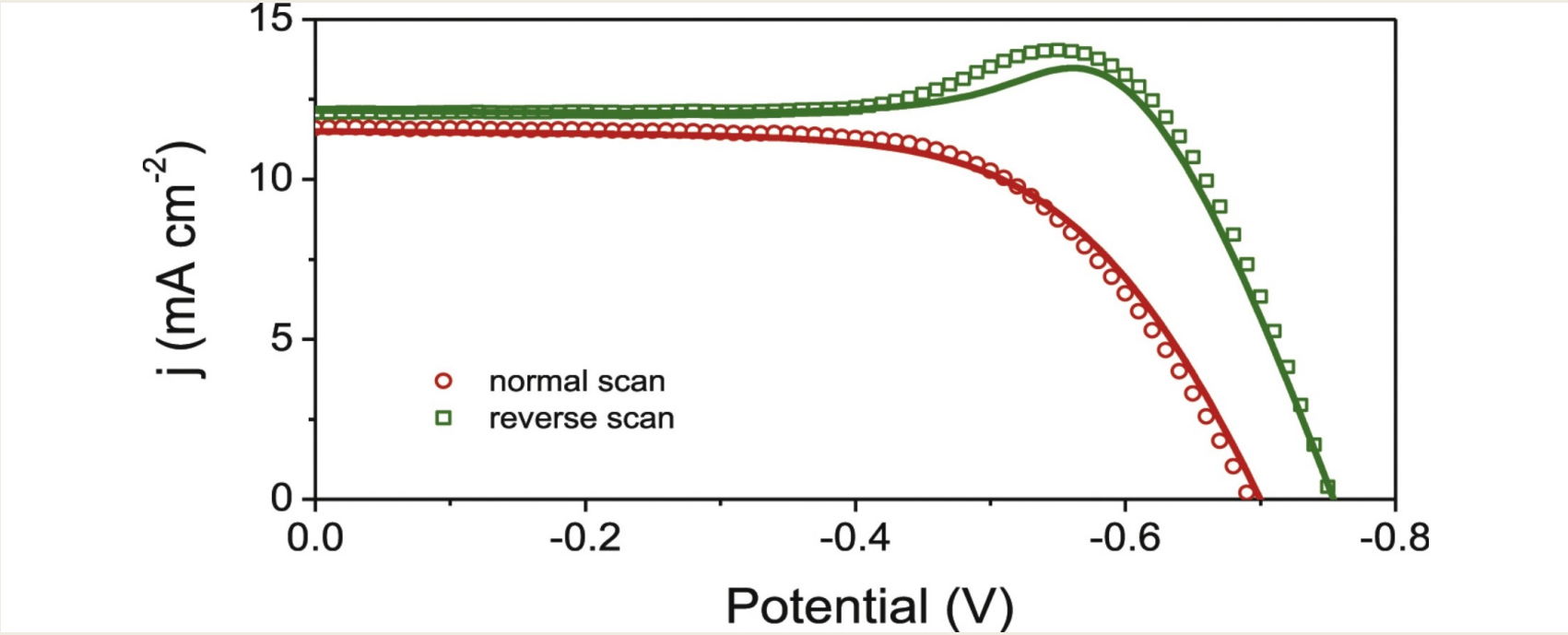
# How Perovskite Solar Cells are Made:

- Low-cost
- Spin coating
- Order of Synthesis:
  - *Spin coat b-$TiO_2$ onto surface of FTO substrate (500° C for 30 min.)*
  - *Thin film n-$TiO_2$ paste onto FTO/b-$TiO_2$ substrate (500° C for 30 min.)*
  - *Once cooled – prepared perovskite material spin coated onto surface (400° C for 30 min.)*
  - *HTM layer coated onto electrodes via two-step casting method*
  - *Electrodes layer and perovskite/glass/ETM layers stacked together*

Mahmood, Khalid, et al. “Current status of”. *Royal Society of Chemistry.* 2017.
Namatame, Miki, et al. “Direct observation of”. *Applied Physics Letters.* 2017.
Shi, Zhenggi and A. H. Jayatissa. “Perovskites-based solar cells”. *Materials (Basel).* 2018.

# Challenges

## Current Density-Voltage Hysteresis




Above: Graph depicting discrepancy due to j-V hysteresis.

Kang, Dong-Ho and Nam-Gyu Park. “On the current-voltage”. *Advanced Materials.* 2019.
Sarker, Subrata, et al. “On the hysteresis of”. *Elsevier*. 2015.

# Challenges

## Device Instability

- Due to several different factors (material, structure, environment, purpose)
- Can be solved if context is considered (environment and purpose) and different materials/structures are tested in experimental settings
  - *If degradation occurs in electrode*
  - *Device structure: Mesoporous vs. conventional/inverted planar*

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# STEP ONE

Research

# Checklist of Ideal Perovskite Material

- ✓ Hybrid organic-inorganic halide
- ✓ Decreased current density-voltage hysteresis activity
- ✓ Chemical and thermal stability
- ✓ Low production cost(s)
- X Degradation of Electrodes
- X Lead (if possible)
- X Inability to operate in harsh conditions (extreme temperatures, etc)

# $CH_3NH_3SnCl_3$
# methylammonium tin tri-chloride

- ✓ Does not contain lead
- ✓ Increased efficiency of PSCs
- ✓ Chemical and thermal stability
- ✓ Can operate in harsh conditions
- ✓ No degradation of electrodes occurs

- X No conclusive data on current density-voltage hysteresis

Rahul, et al. “New class of lead free”. *Elsevier.* 2017.

# STEP TWO

Plan

# Preliminary process of producing: methylammonium tin tri-chloride

1. $CH_3NH_3Cl$ (s) → dissolved in Ethanol
   i. *Heated at 60 °C for four hours*
   ii. *Frozen for 3 days*

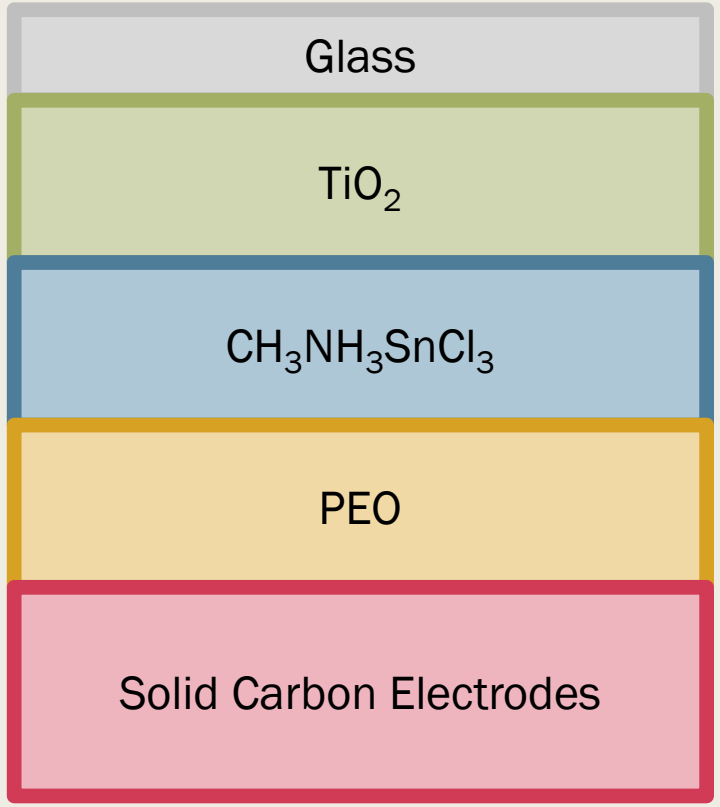
2. Recrystallization occurs naturally
   i. *Product filtered out*
   ii. *Vacuum at 80ºC for 2 days*

3. Add $SnCl_2$ to $CH_3NH_3Cl$ in DMF

# Preliminary design of device

**Conventional Planar structure:**

- **First layer:** Conductive glass
- **Second layer:** $TiO_2$ [ETL[1]]
- **Third layer:** $CH_3NH_3SnCl_3$
- **Fourth layer:** Polyoxyethylene (PEO) [HTL[2]]
- **Electrodes:** Solid Carbon




Produced using Spin Coating Method

1– Electron Transport Layer
2 – Hole Transport Layer

# STEP THREE

Simulate

# TCAD Sentaurus Software

- Used to create and simulate 2D mesh devices – to study electron and hole carrier transport (via electric field)
- Different simulations run on different widths of microelectronic circuits (self-powered microsystems)
- Evaluates potential and feasibility of integration with other semiconductor platform(s)
- Can incorporate perovskite material into software

# References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