



부산대학교
PUSAN NATIONAL UNIVERSITY

Towards Next-Generation Power Sources

: Stability of perovskite solar cells

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Principal Investigator

김민철 (Kim Min-cheol, Ph.D.)

기계관 Rm 514 (Tel: 2315)

Education & Research Experience

Seoul National University (B.S. 2009 – 2013, Ph.D. 2013 – 2018)

University of California, San Diego (Postdoc 2019 – 2021)

Samsung Electronics (Senior researcher 2021.3 – 2021.8)

Pusan National University (Assistant Professor 2021.9 –)



Research overview

Renewable Energy Devices

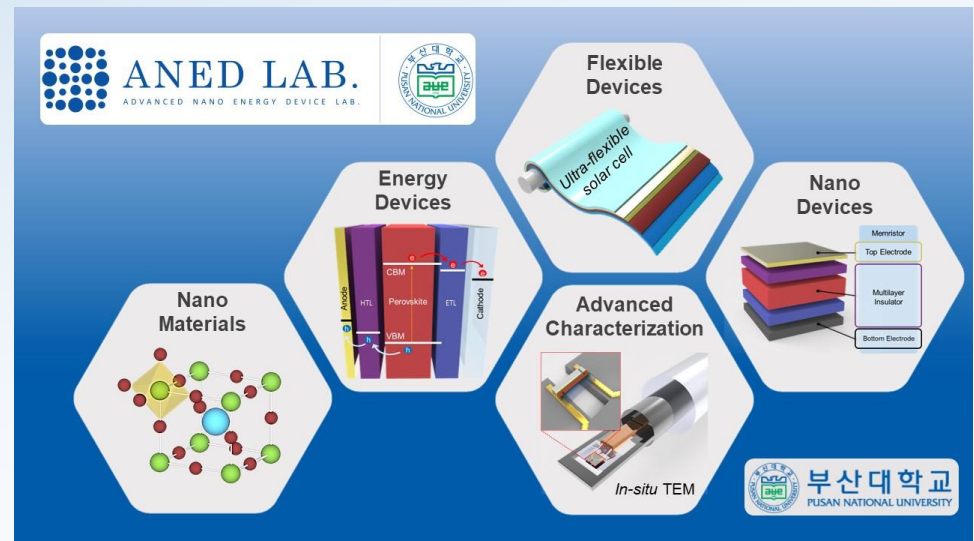
Development of energy conversion and storage devices including perovskite solar cells and lithium ion batteries

Flexible Nano Devices

Development of ultra-flexible electronic devices and investigation on the mechanical degradation mechanism of flexible nano devices

Advanced Nano Characterization

Study on the physical electronic properties of nano materials *via* advanced characterization tools such as an atomic resolution TEM



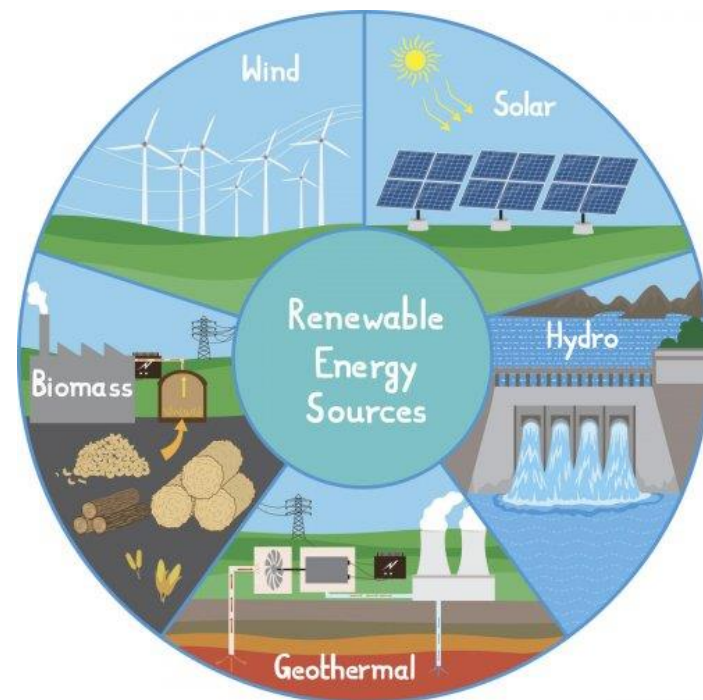
Introduction : Motivation



Depletion of Fossil Fuel Air Pollution Global Warming



Green vehicles (EV / FCEV)



Future Electronic Devices

- High energy density (Requires high power)
- Portability (Light-weight)
- Flexible and stretchable
- Human-centered (Health application)



Credit: Aptera

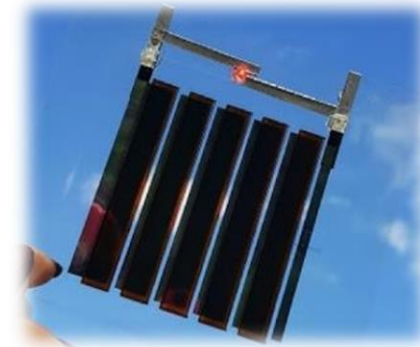
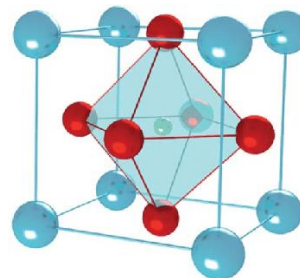


Credit: savvycomsoftware



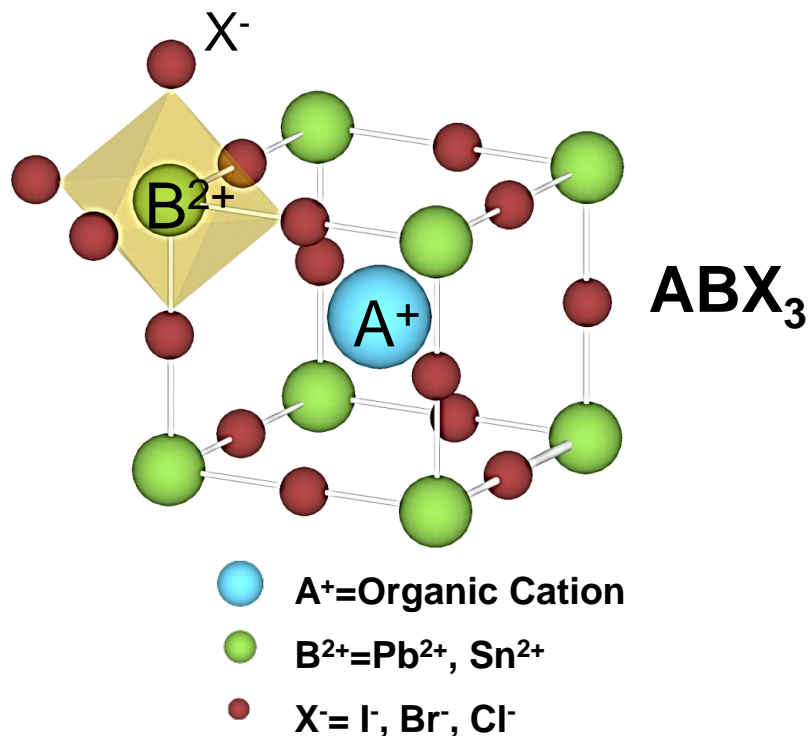
Credit: DuPont

Perovskite Solar Cells



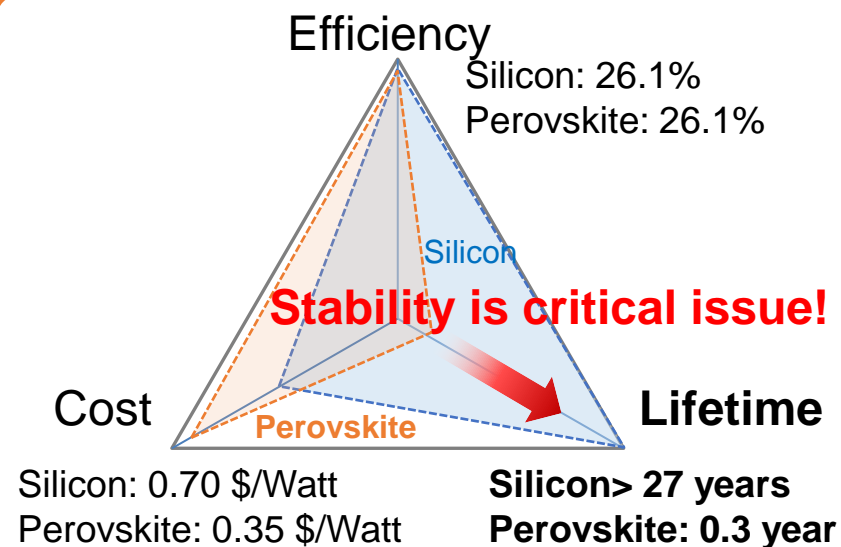
Credit: RSC Advances / Saule Technologies

Introduction : Perovskite solar cells

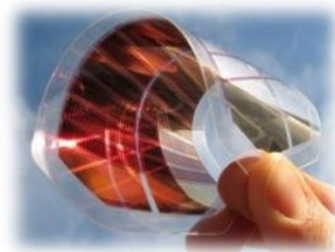


- ✓ High absorption
 - ✓ Low binding energy
- 26.1%**
High performance
- ✓ Ionic bonding
 - ✓ Soft and polarizable
- Low stability
& High flexibility

Golden triangle analysis



Flexible / Light-weight Devices



Ultra-flexibility

Credit: NREL

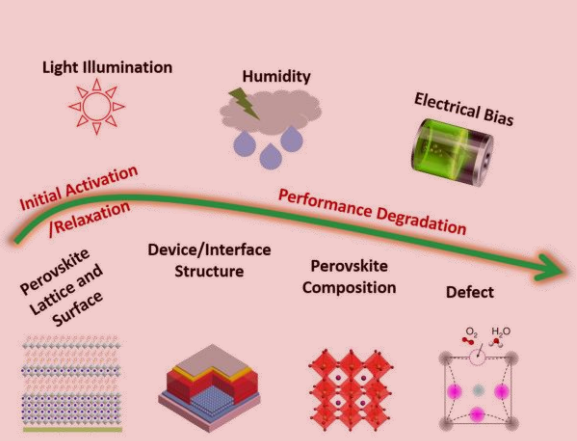


Portability

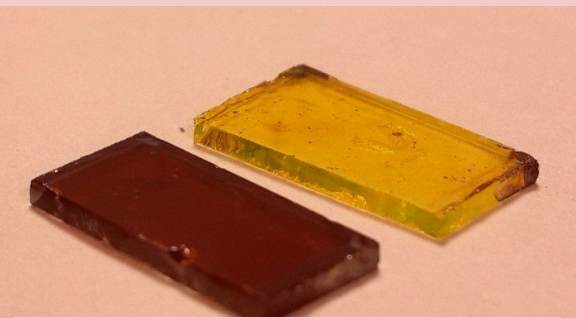
Credit: Lightyear

Introduction : Perovskite solar cells

Stability Issues



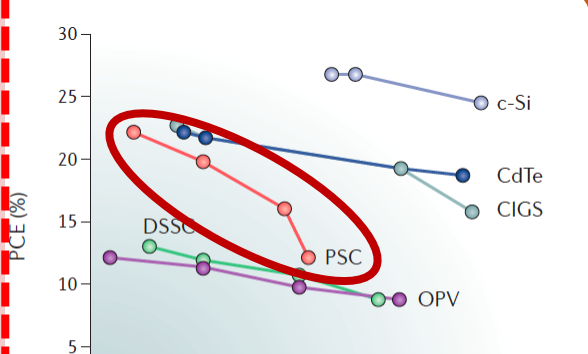
Credit: @Science China Press
<https://www.eurekalert.org/multimedia/pub/198000.php>



A fresh perovskite solar film (L) and a degraded film exposed to air and light for just six days (R)

<https://www.imperial.ac.uk/news/165809/scientists-discover-next-gen-solar-cells-break/>

Scalability Issues



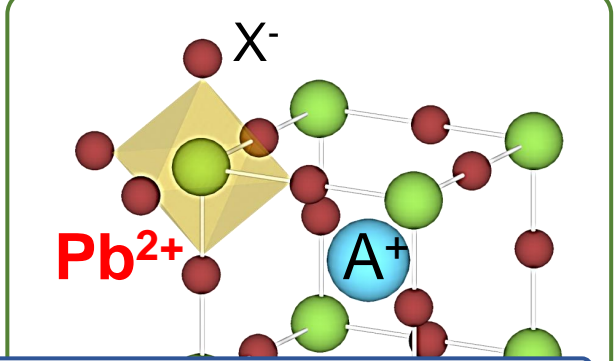
Long-term Stability
Ultra-flexible Devices

➔

- Material Stability**
 - Chemical stability
 - Structural stability
- Mechanical Stability**



Environmental Issues

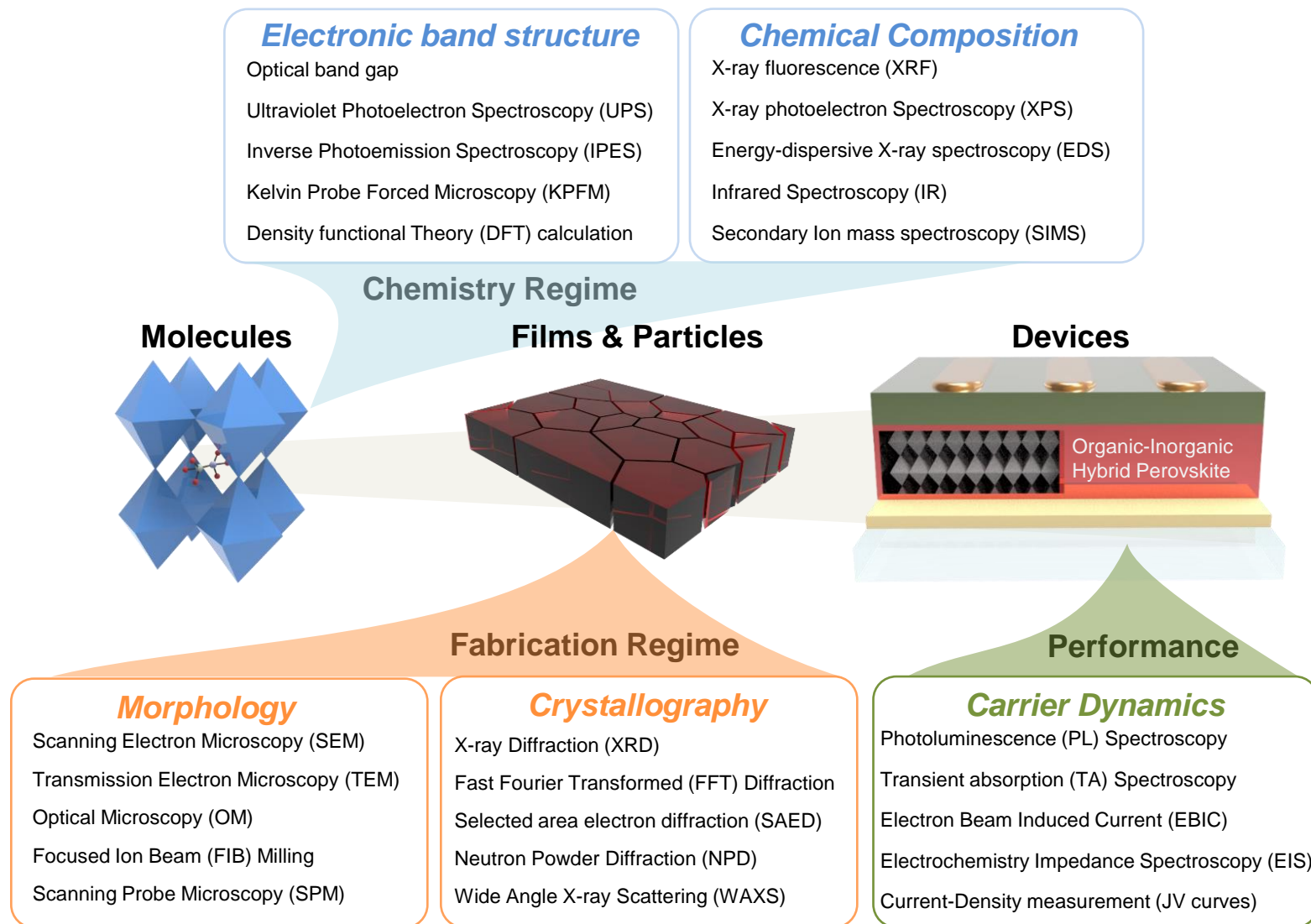


HEALTH ISSUES:

- SPEECH, LANGUAGE & BEHAVIOUR PROBLEMS
- ANAEMIA
- REDUCED GROWTH
- REPRODUCTIVE PROBLEMS (ADULTS)
- HEARING PROBLEMS
- HIGH BLOOD PRESSURE
- KIDNEY DAMAGE
- DIGESTIVE PROBLEMS
- LEARNING DIFFICULTIES

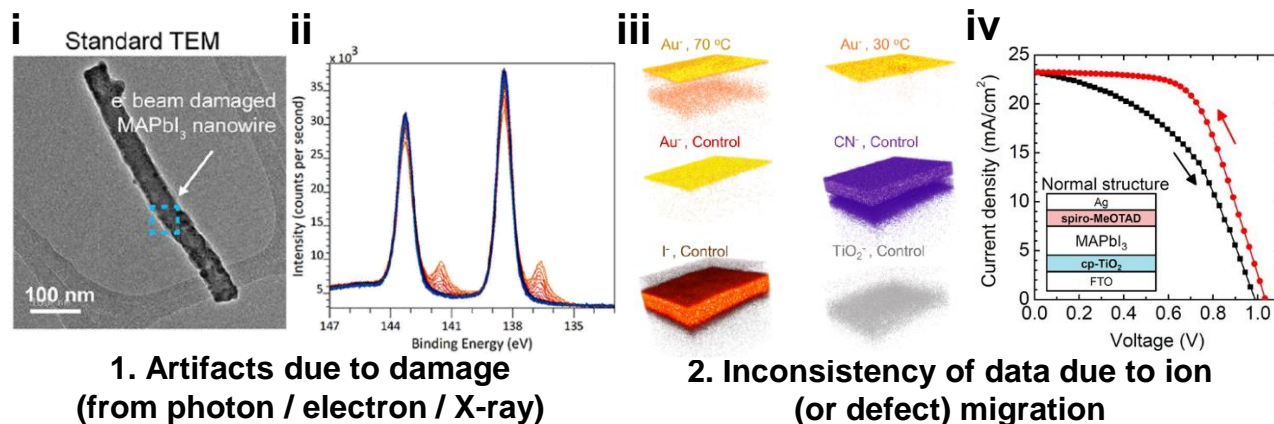
World Health Organization

Introduction : Nano-characterization

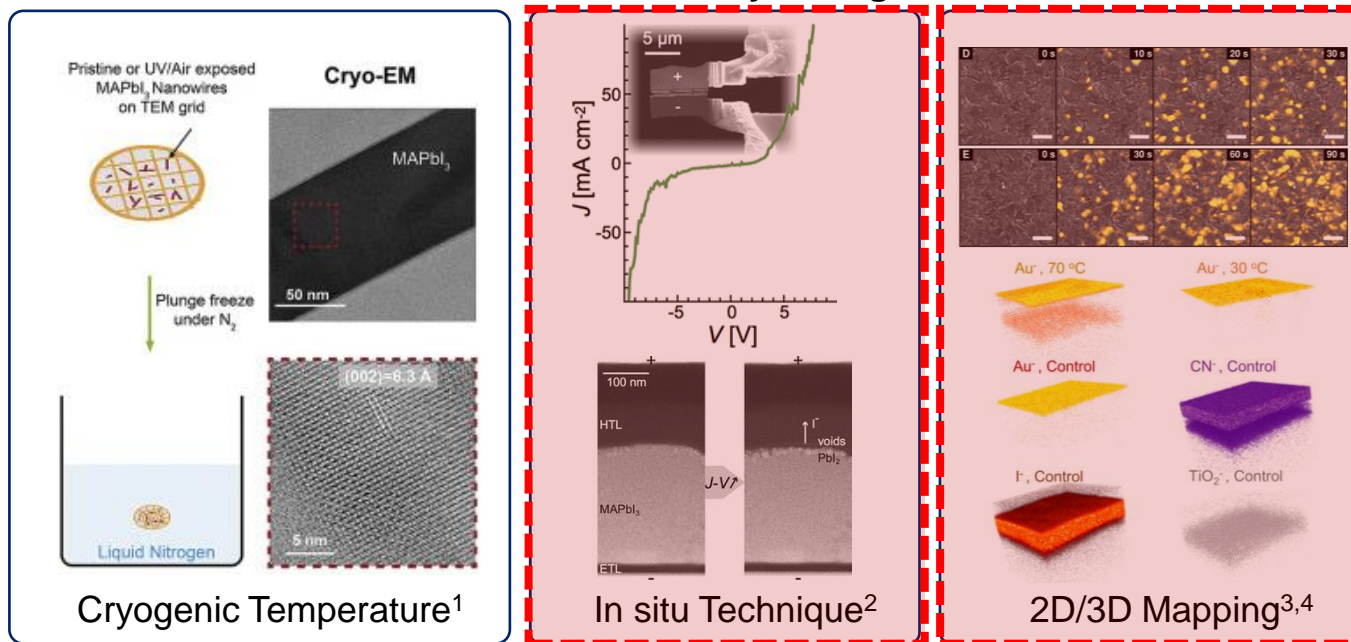


Introduction : Nano-characterization

Challenges for Characterizing Perovskite Materials



Solutions for artifacts and inconsistency during the characterization



1. Joule, **3**, 11, 2854-2866, 2019
2. Nano Lett., **16**, 11, 7013-7018, 2016

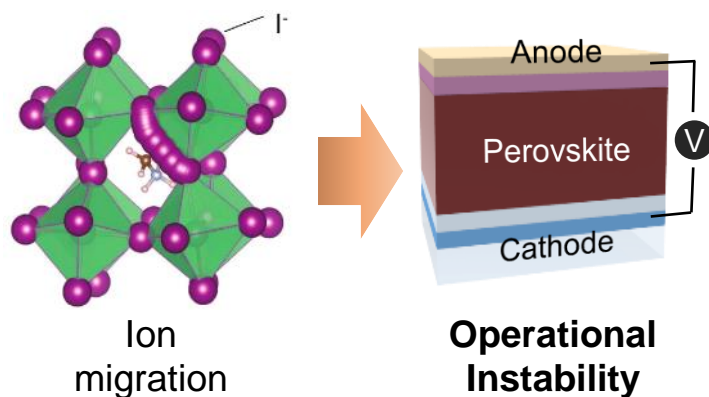
3. Nano Lett., **17**, 2, 1028-1033, 2017
4. ACS Nano, **10**, 6, 6306-6314, 2016

Advanced Characterization

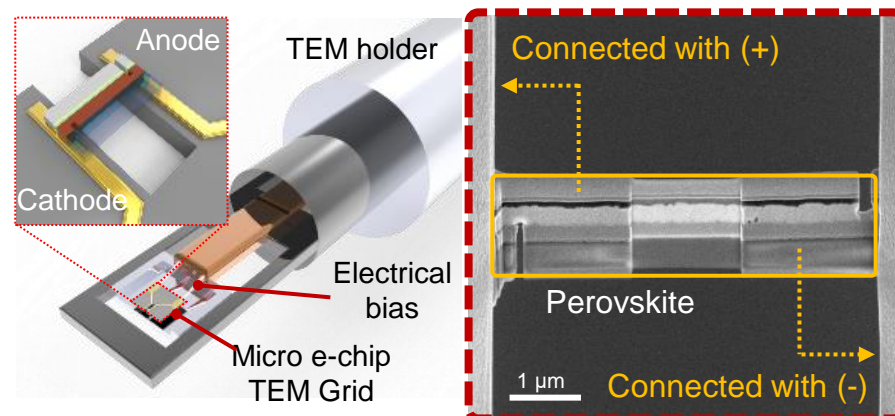
Operational instability of perovskite materials

ACS Energy Letters (2021) (First Author)

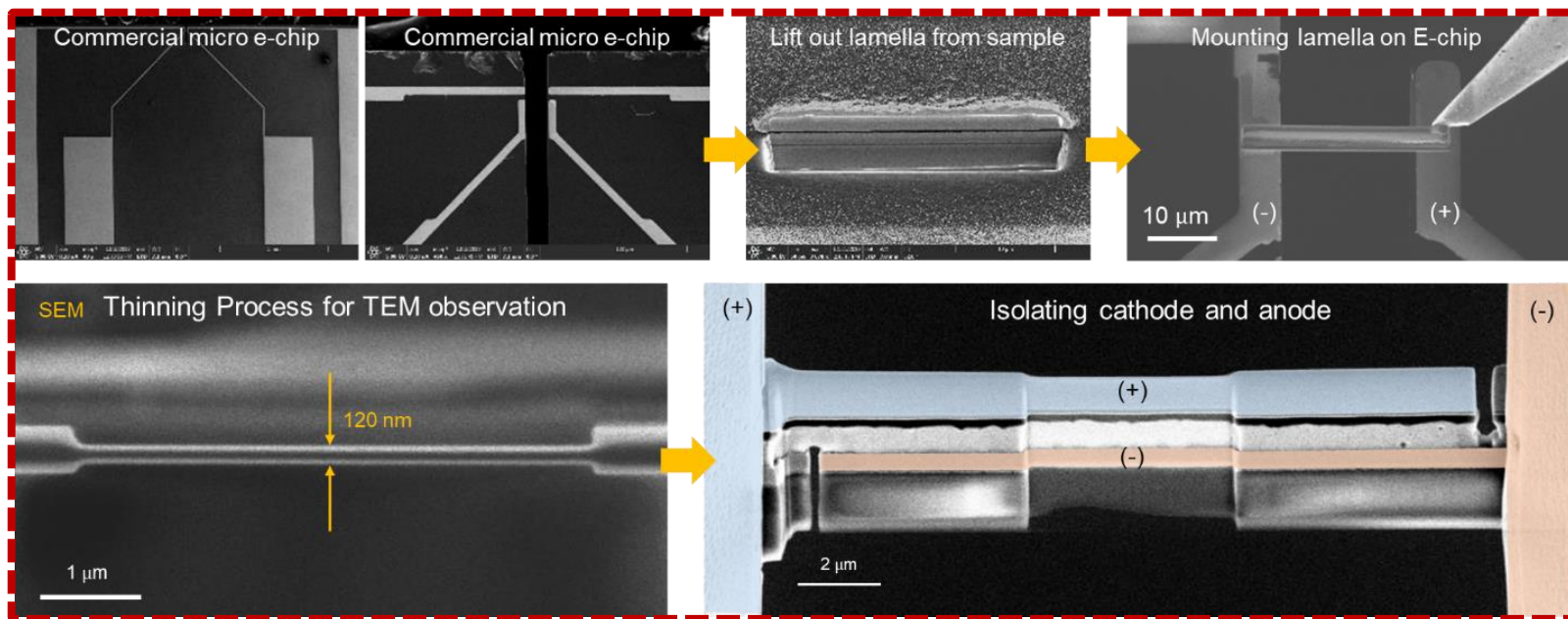
Operational Instability



In-situ TEM configuration



Detailed procedure

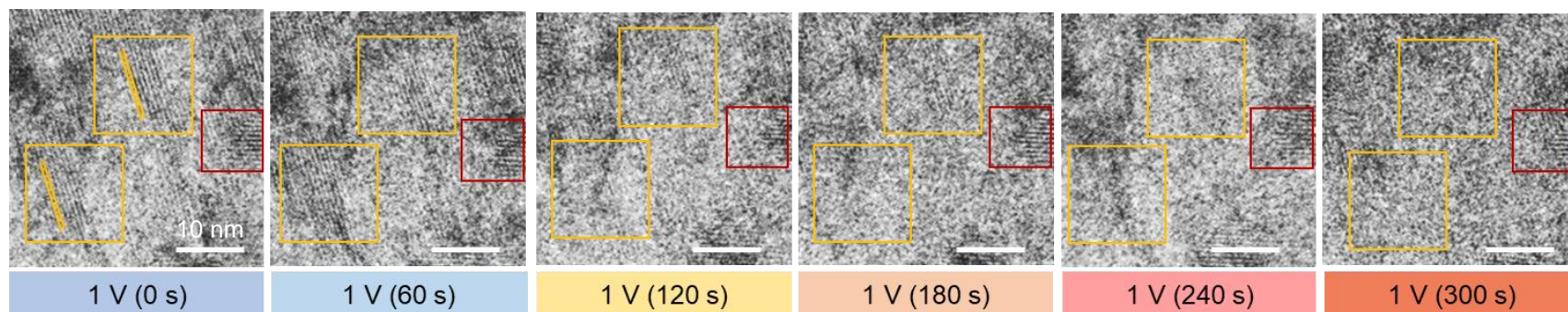


In-situ TEM techniques

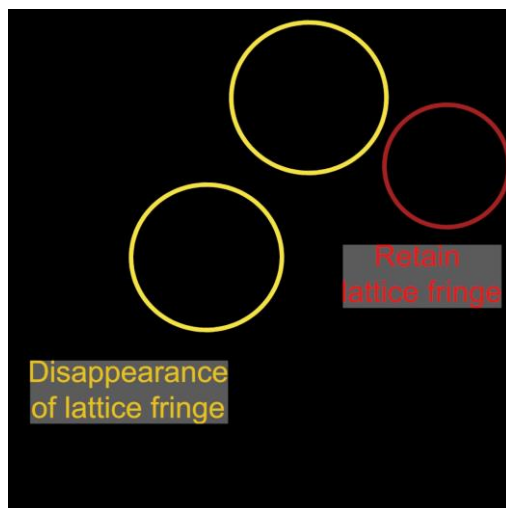
Operational instability of perovskite materials

ACS Energy Letters (2021) (First Author)

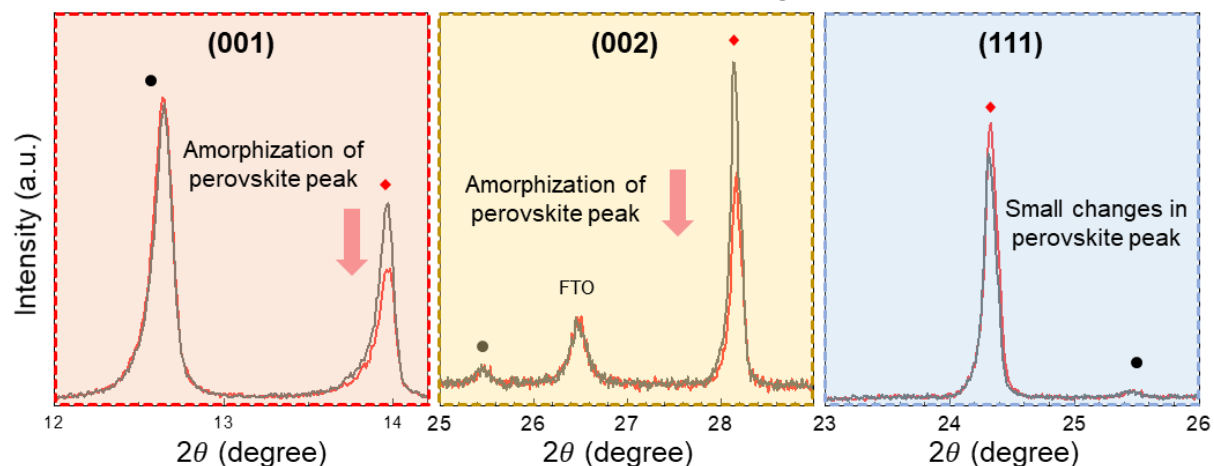
In-situ TEM observation under electrical bias



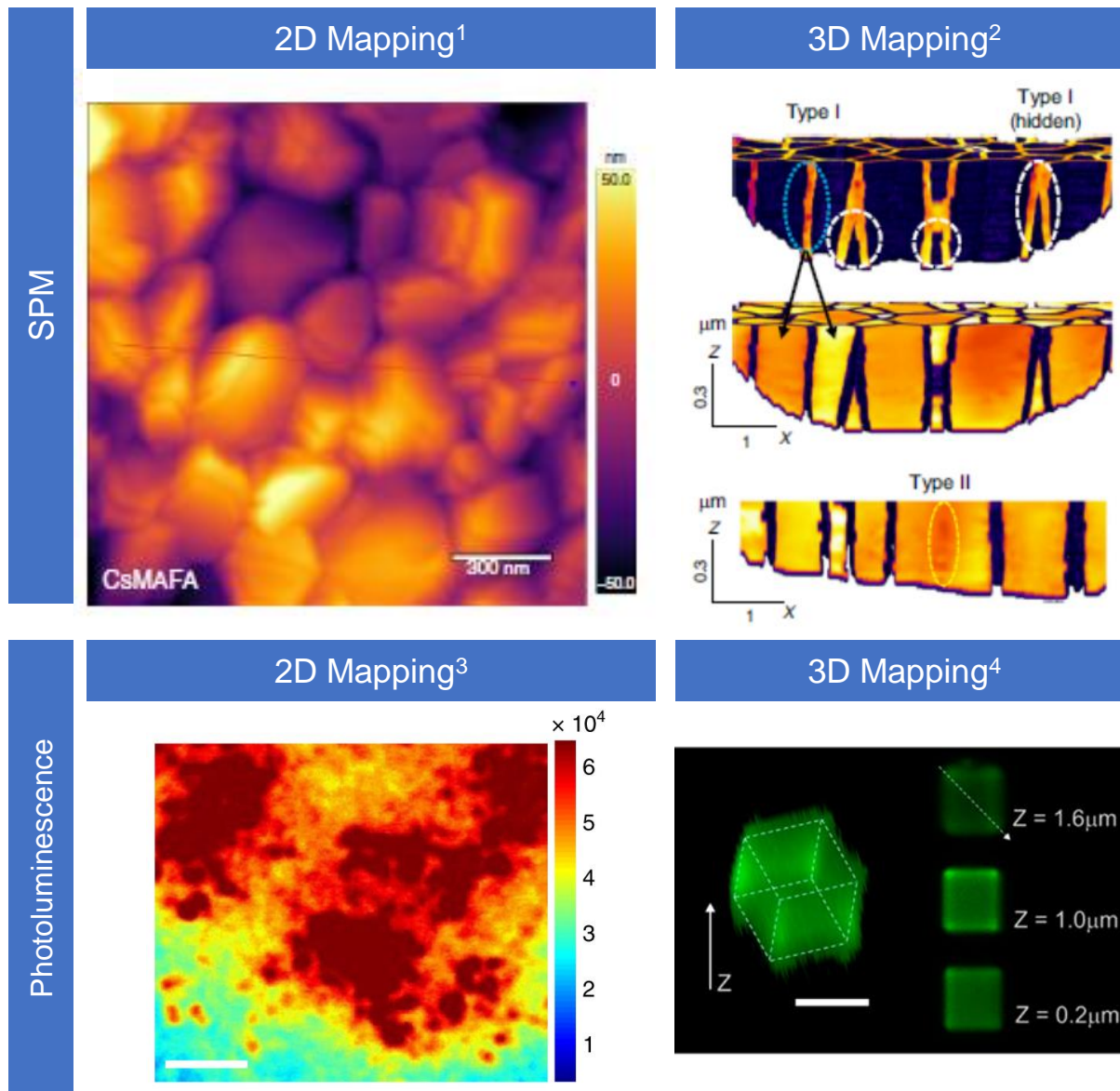
Lattice fringes are disappearing over time



In-situ XRD (e-biasing)¹



2D/3D Mapping techniques



1. Nat. Mat. **19**, 412–418, 2020

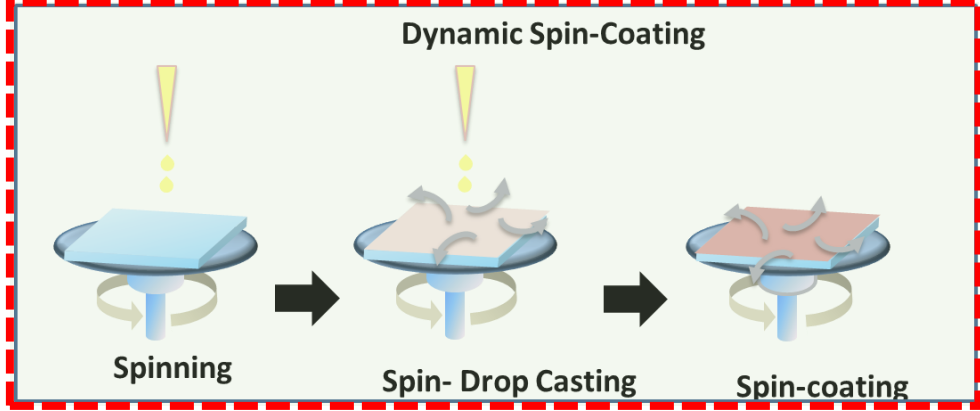
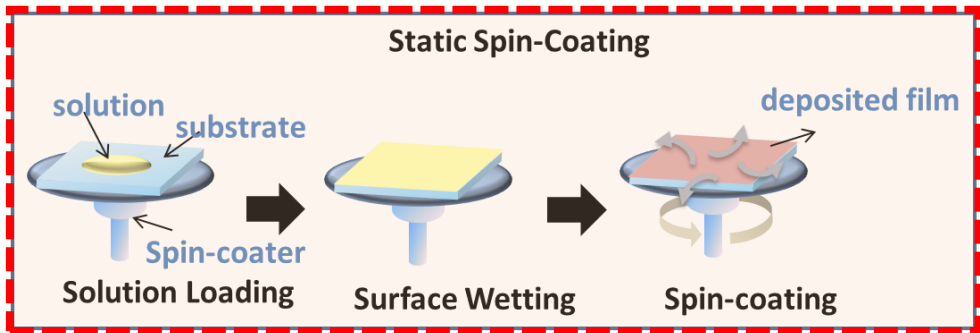
2. Nat. Comm. **11**, 3308, 2020

3. Nat. Mat. **19**, 412–418, 2020

4. J. Phys. Chem. Lett. **7**, 24, 5227–5234, 2016

2D/3D Mapping techniques

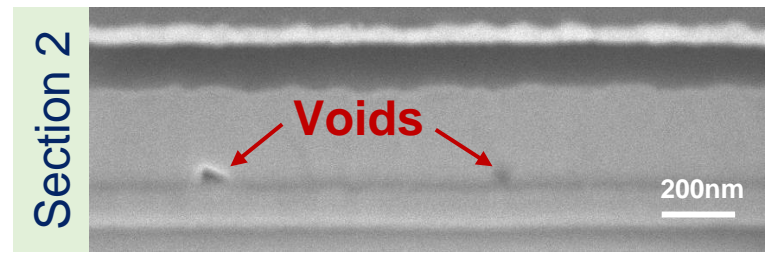
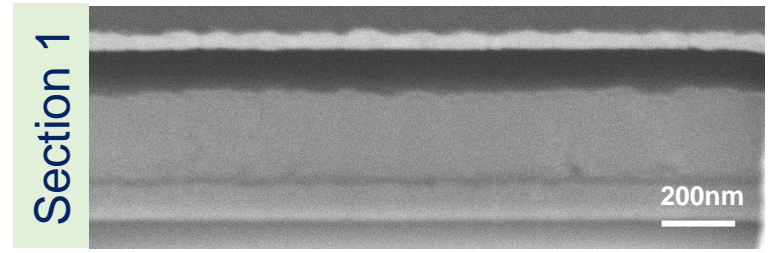
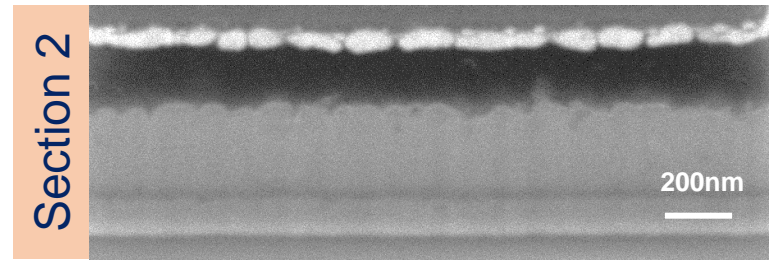
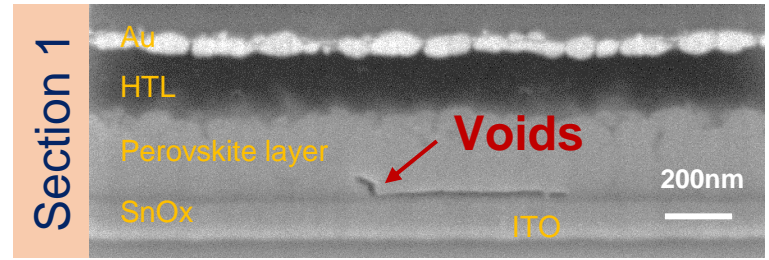
Spiro-MeOTAD Spin-coating method



2D cross-sectional image is not a representative information

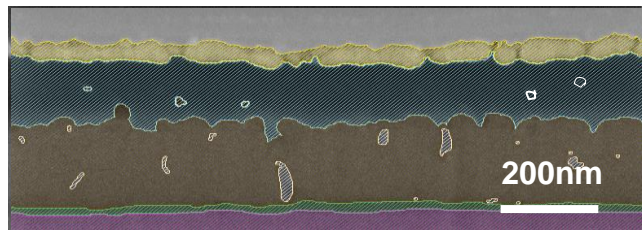
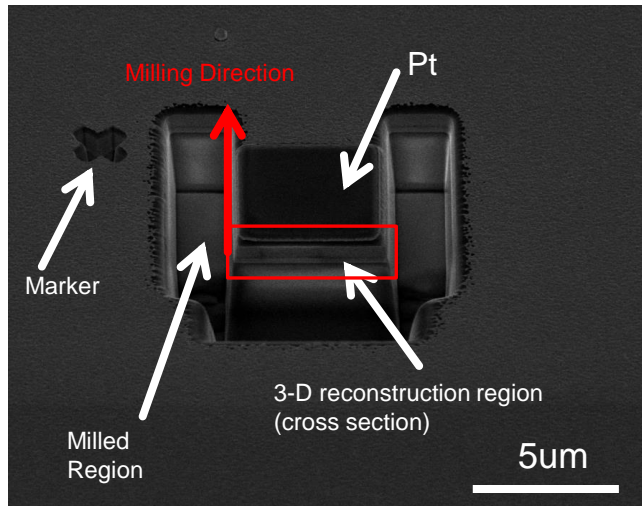


3D reconstruction image needed!

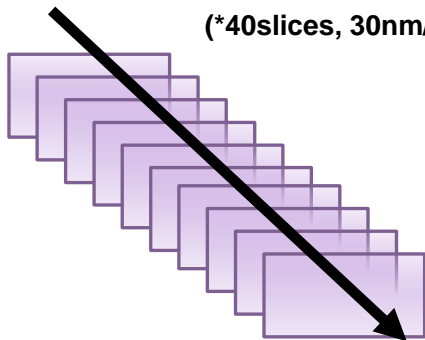


2D/3D Mapping techniques

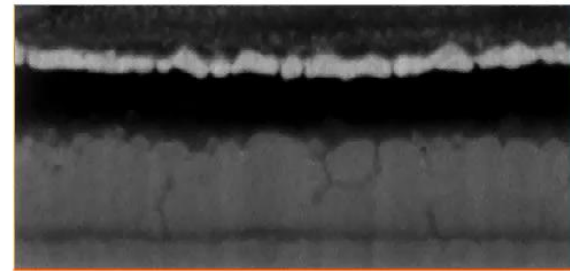
FIB-SEM (3D Reconstruction)



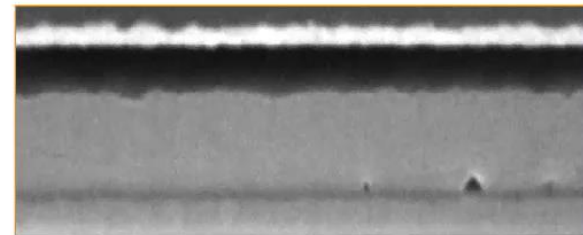
(*40slices, 30nm/slice)



Static Spin-coating



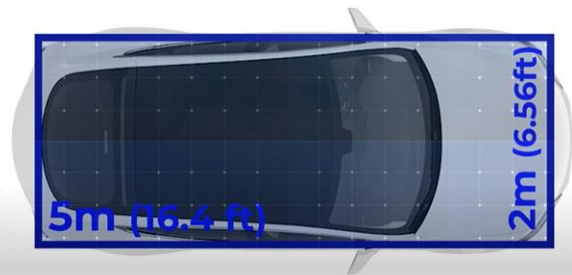
Dynamic Spin-coating



Research Interest (1): Ultra-flexible Energy Harvesting Devices

Future Plans

❖ Foldable Solar Cell Module for Automobiles

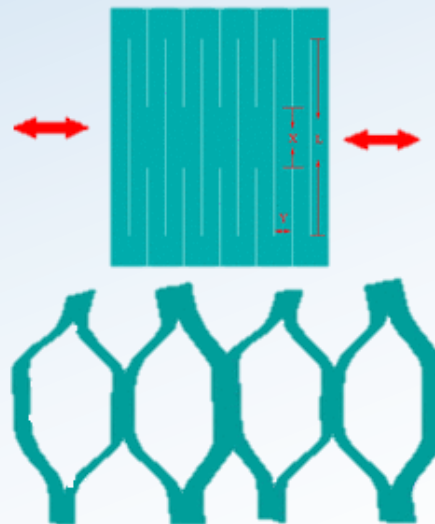
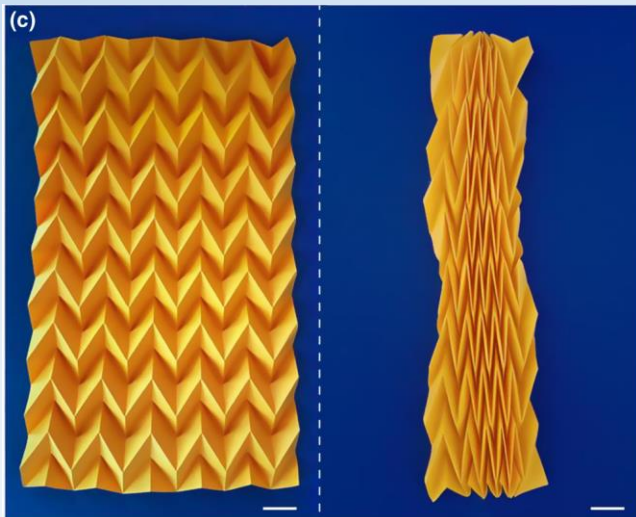


Daily Average

$$10 \text{ [m}^2\text{]} \times 1459 \text{ [kwh m}^{-2}\text{]} / 365 \text{ [days]} \times 20 \% = 8 \text{ kWh} \sim \mathbf{77 \text{ km}}$$

(Efficiency: 104 Wh/km, Lightyear One)

Origami & Kirigami Approaches



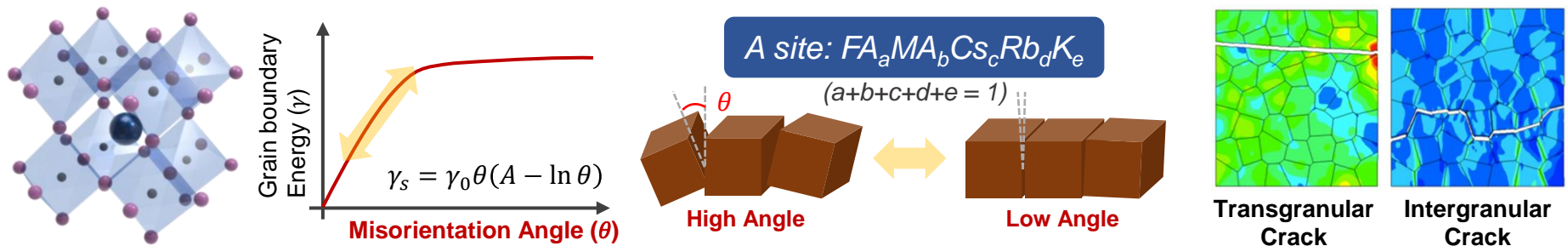
In preparation



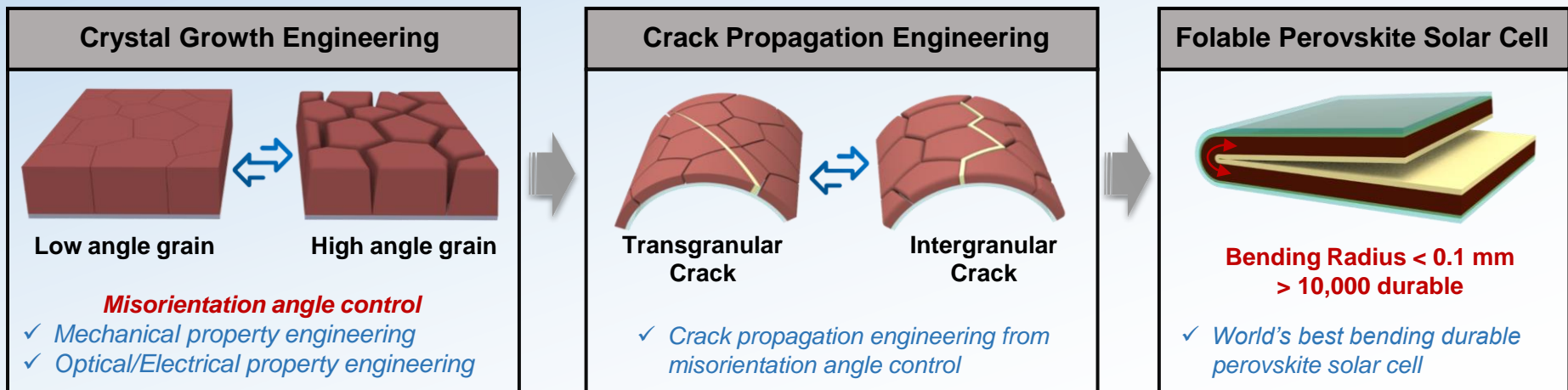
**Foldable
Solar Roof / Solar Vehicles**

Future Plans

- ❖ Investigation on the Mechanical Property of Perovskite Thin Film
: Toward Foldable Solar Cell



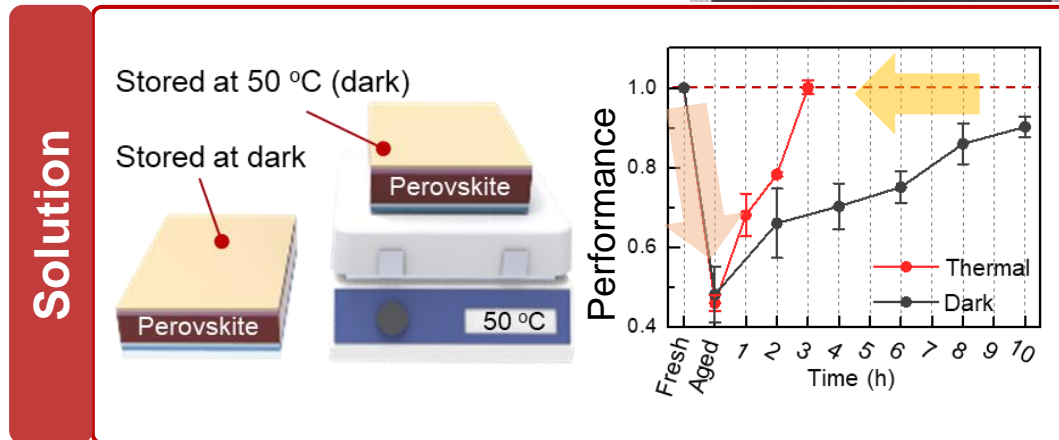
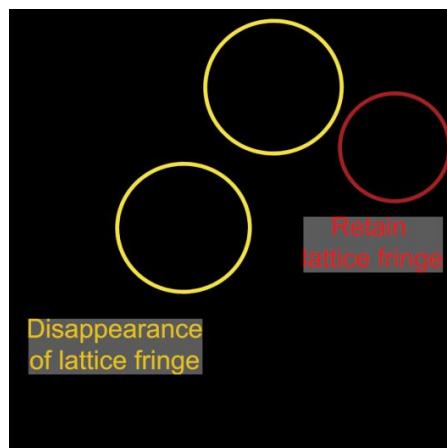
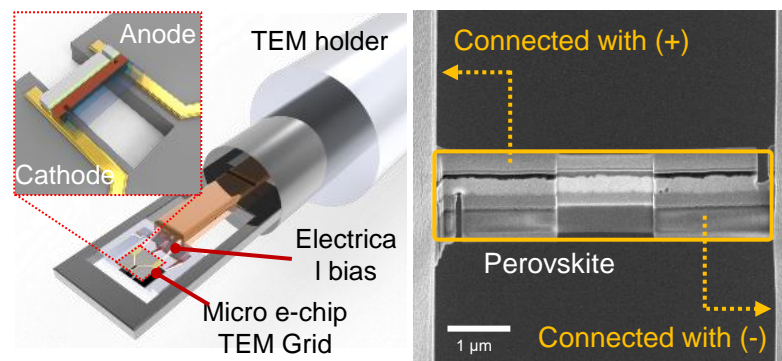
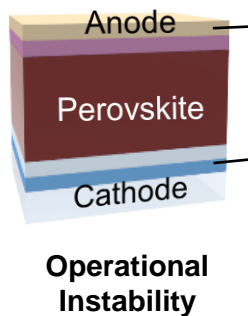
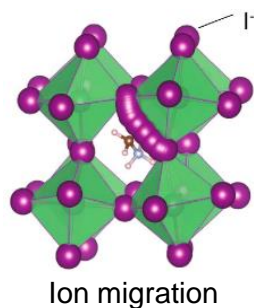
Ultra-flexible **Foldable** Power sources



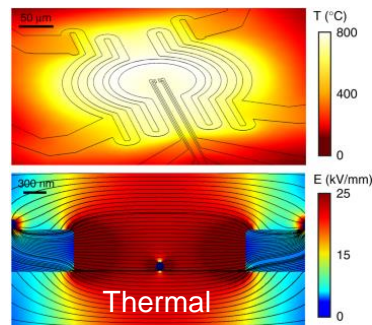
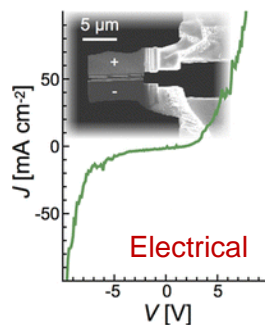
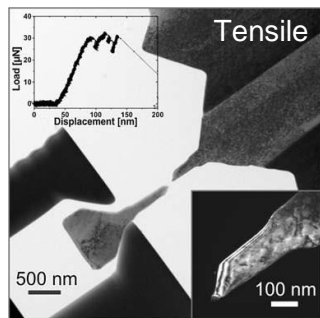
Research Interest (2): Advanced Nanoscale Characterization

❖ Advanced *in-situ* characterization (under electrical biasing)

ACS Energy Letters (2021)



❖ Advanced *in-situ* characterization



**MEMS / NEMS
characterization**

in-situ mechanical testing

in-situ electrical testing

in-situ thermal testing

...

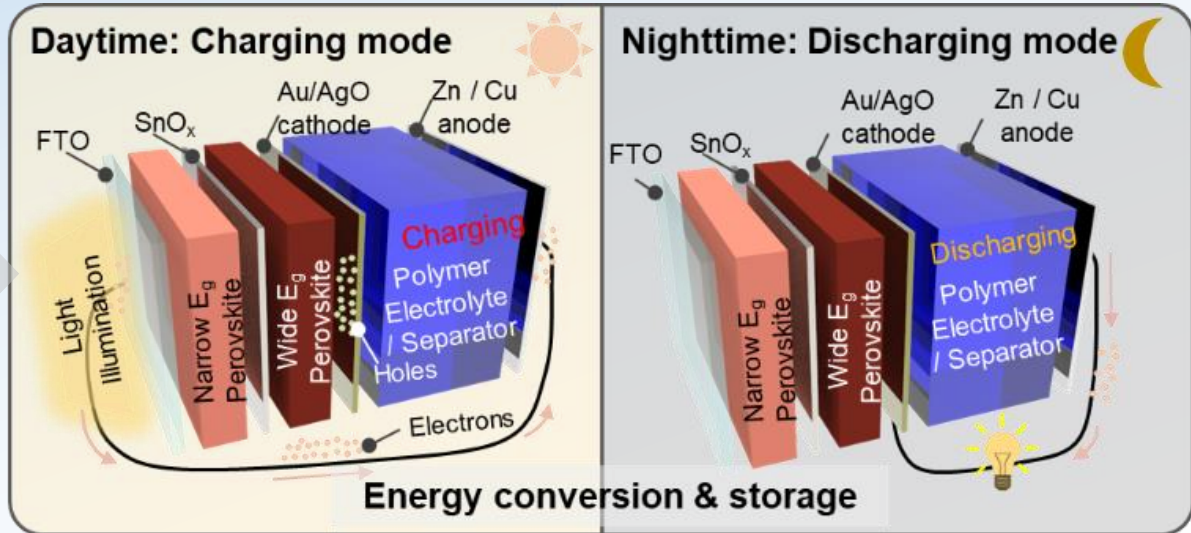
Research Interest (3): Integrated Energy Conversion & Storage Devices

❖ Integrated Flexible Solar Battery

Flexible Solar Cells



Flexible Battery

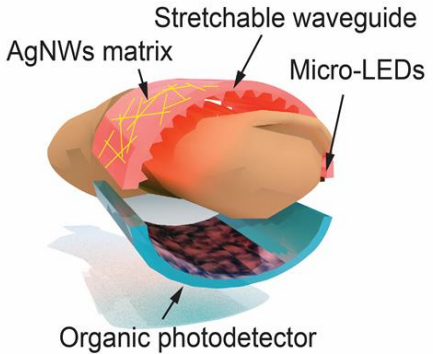


In preparation

❖ Wearable Power Sources



Health-care Application (Self-powered E-skins)



Bio + Electronics

VTT ElasticECG

Stretchable flexible electrocardiogram skin sensor

- Printed antenna
- Printed elastic PCB on TPU
- Stretchable conductive ink
- Ultra-low-power integrated ECG IC
- Bluetooth data streaming to mobile devices
- Direct component assembly via R2R pick-and-place

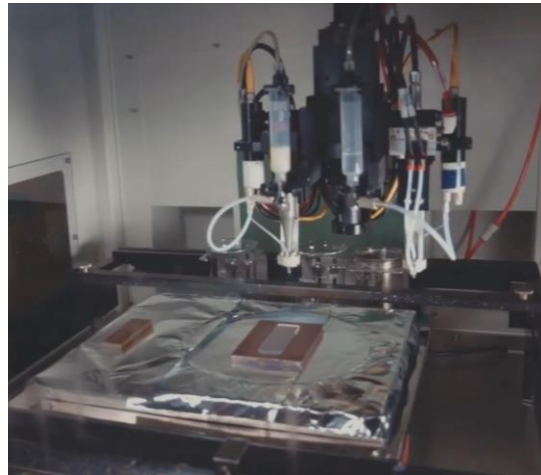
Perovskite Fabrication Procedure

Fabrication methods



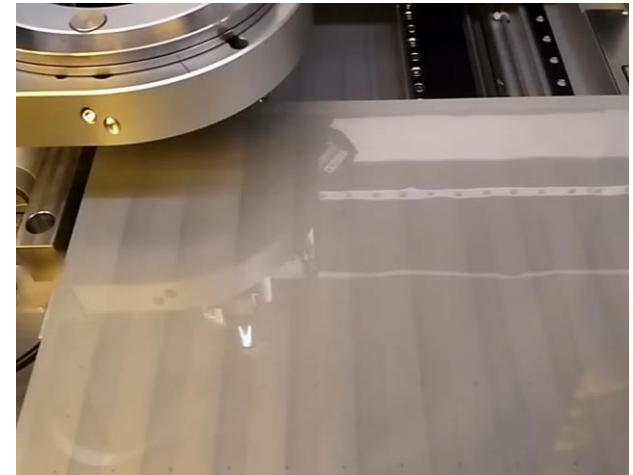
Spin-coating

- High efficiency
- Material loss \uparrow
- Small area



Spray-coating

- Low efficiency
- Material loss \downarrow
- Large area
- R2R process



Blade-coating/Ink-jet printing

- Low efficiency
- Material loss \downarrow
- Large area
- Patterning

Acknowledgements



부산대학교
PUSAN NATIONAL UNIVERSITY



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SEOUL NATIONAL UNIVERSITY

UC San Diego
JACOBS SCHOOL OF ENGINEERING



CALIFORNIA
ENERGY COMMISSION



U.S. DEPARTMENT OF
ENERGY



KETEP
한국에너지기술평가원



Thank you for kind attention.