Fabrication and Characterization of Perovskite-Based Photovoltaic Solar Cells

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Introduction

The demand for new material in order to increase the power conversion efficiency and to reduce the cost has triggered our interest to study the $CH_3NH_3PbI_3$ organolead halide perovskite-based solar cells.

1) Relatively high power conversion efficiency (PCE) is expected:
PV cell based on $CH_3NH_3PbI_3$ exhibits relatively high efficiency PCE~20% and 24% is expected due to their unique properties of high Voc ~1.1 V (vs Eg=1.5eV), Jsc~22 mA/ cm^2 ,high carrier mobility ~10 cm^2 V^{-1} s^{-1} , diffusion length ~100 nm, long lifetime of both e and h.

2) Relatively low production cost is expected:
Low-cost and low-temperature processing technologies such as printing are possible, but the long term stability of the PV and the toxicity of the materials are crucial issues.

Experimental

The purpose of this study is to establish a reproducible method and to identify some of the issues related to organolead halide perovskite-based solar cells.

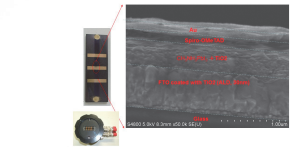
The methods (1, 2), which give a relatively good reproducibility are examined and typical results are presented, although our techniques are not yet fully optimized. In particular, we address the stability of the solar cell (encapsulated in Ar/N_2 atmosphere but not hermetically sealed) under continuous illumination (1 sun) or under light/dark cycles (illuminated at 1 sun, but store in dark/room light in glove box).

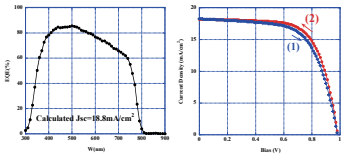
Materials are characterized by x-ray diffraction techniques, and the solar cells are characterized by recording I-V curves and EQE spectra.

Method 1

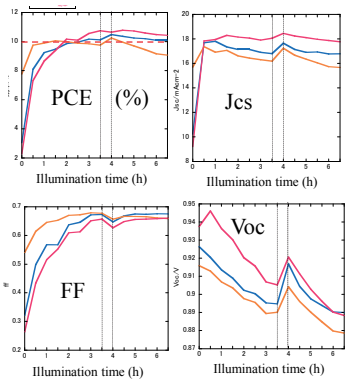
FTO/Glass → TiO_2 layer → $CH_3NH_3I + PbI_2$ → Spiro-OMeTAD → Au layer → PV Cell encapsulated

	Parameters
Glass/FTO substrate	FTO (TEC7, TEC15) patterned by etching with Zn+HCl or sand blasting. Rinsed with DI water, acetone, 2-propanol O_2 plasma (18W, 100Pa, 15min)
TiO_2 layers	1) dense TiO_2 made by PE-ALD at 300 °C, using RF O_2 plasma and TTIP (titanium tetrakis-isopropoxide). 2) porous TiO_2 made using TiO_2 paste (DSL18NR-T) spin coated at 2000 rpm, 30 s. Annealed at 120 °C/10 min then 450 °C/30 min in oven (air).
$CH_3NH_3PbI_3$ layer	$CH_3NH_3I + PbI_2$ + γ-butyrolactone /DMSO solution stirred at 70°C/3 h, spin coated hot in 2 steps 1000~5000 rpm, then washed with toluene (Seok's method, Ref. 3) . Annealed at 100 °C, ~10min in Ar /N_2 Glove-Box. $CH_3NH_3PbI_3$ structure confirmed by XRD
Spiro-OMeTAD layer	Spiro-OMeTAD+chlorobenzene + (Li-salt, TBP, Co(III), AN) solution . spin-coated at 3000 rpm, 30 s in Ar glove-box
Au electrode	100nm of Au deposition in UHV 2×10^{-4} Pa, 1500°C, 1-10Ås^{-1} PV cell encapsulated in Ar/N_2 glove-box

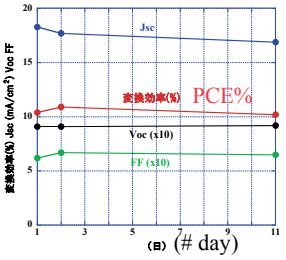




AM1.5 100mWcm^{-2} area 6mm^2	Scan 1	Scan 2
Jsc (mAcm^{-2})	18.28	18.20
Voc (V)	0.98	0.98
Power max (mWcm^{-2})	11.46	12.10
V–P max.(V)	0.74	0.75
Jsc–P max (mAcm^{-2})	15.49	16.13
FF	0.63	0.67
Power conversion efficiency (%)	11.46	12.10

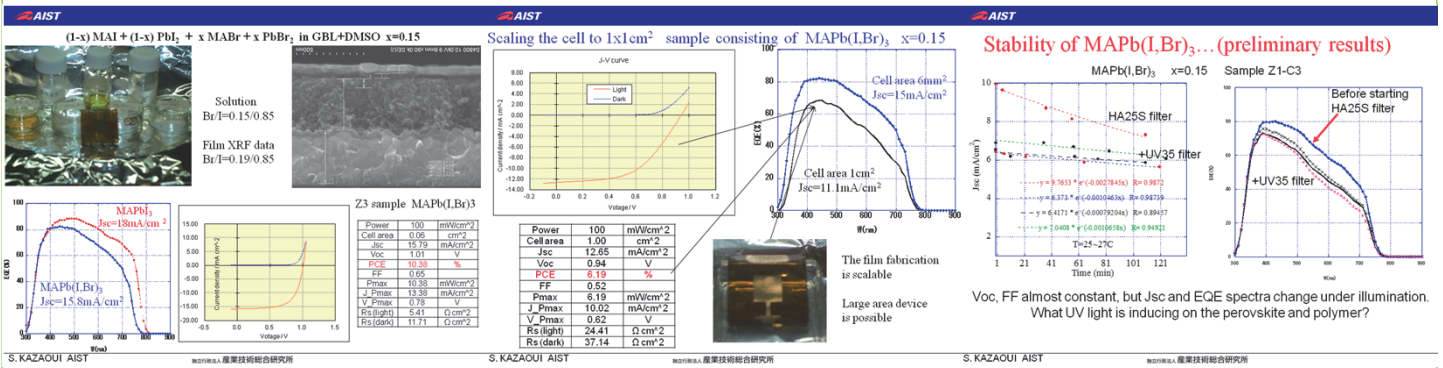


Light soaking/temperature effects on PCE, Jsc, Voc, FF. Mechanism?



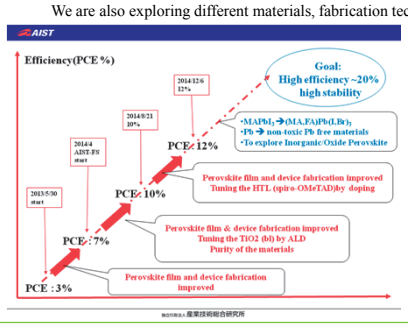
Measured after ~2 h under 1sun, stored in Ar/N_2 glove-box (H_2O, O_2<10ppm) in dark or room light

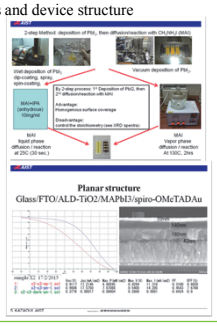
Method 2



Conclusions / perspectives

We are also exploring different materials, fabrication techniques and device structure





References / Acknowledgements

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