

Nanoimprint Transfer Technology in Optoelectronic Application

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Korea Institute of Machinery & Materials

About KIMM

KIMM 한국기계연구원
KOREA INSTITUTE OF MACHINERY & MATERIALS



Five Research Divisions;

1. Advanced Manufacturing Sys.
2. Extreme Mechanical Eng.
3. Nano-Convergence Mechanical Systems
4. Environmental and Energy Sys.
5. Mechanical Systems Safety

Facilities/Infra.

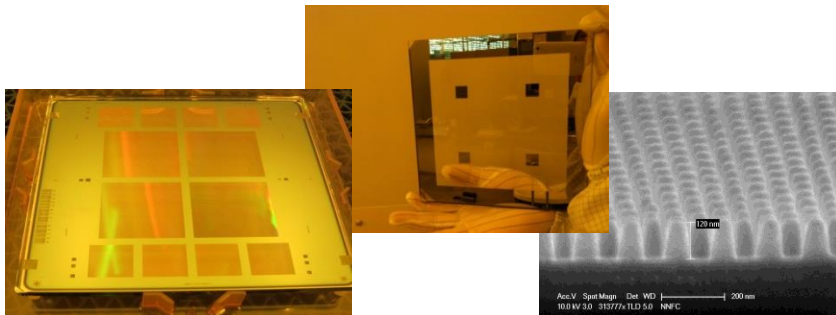
For Nanoimprint at wafer scale



For Nanoimprint in Large area

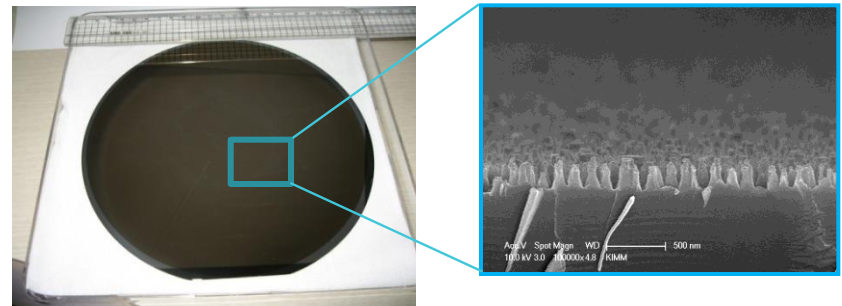


Master/Molds

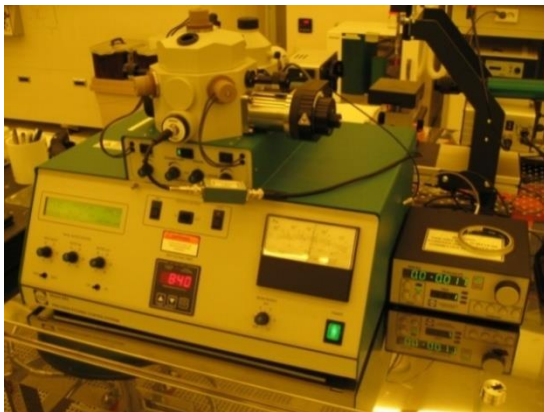


Large area Mold fabrication

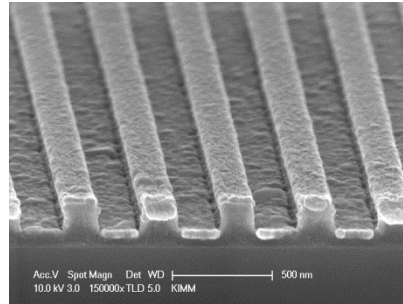
Etched master at 8" wafer



Metal patterning infrastructures

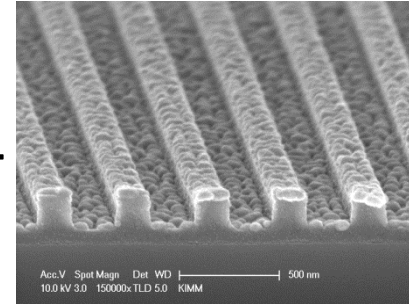


Film Quality w.r.t. dep. rate



5.0 Å/S

VS

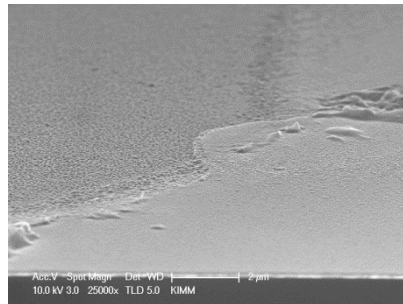


0.5 Å/S

Ag deposited
By E-beam

Sliver Milling Test

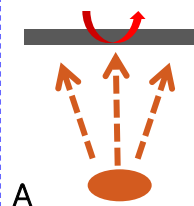
w.r.t. the variables of current, time, and tilting angle



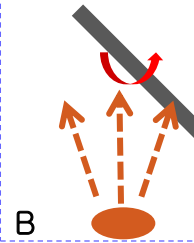
- Tilting angle ~0
- Current 300 μA
- Time 1min



Target Sub.



A



B

Outlines

1 Laboratory Introduction

- Members / Facility
- Researches for Nanoimprint

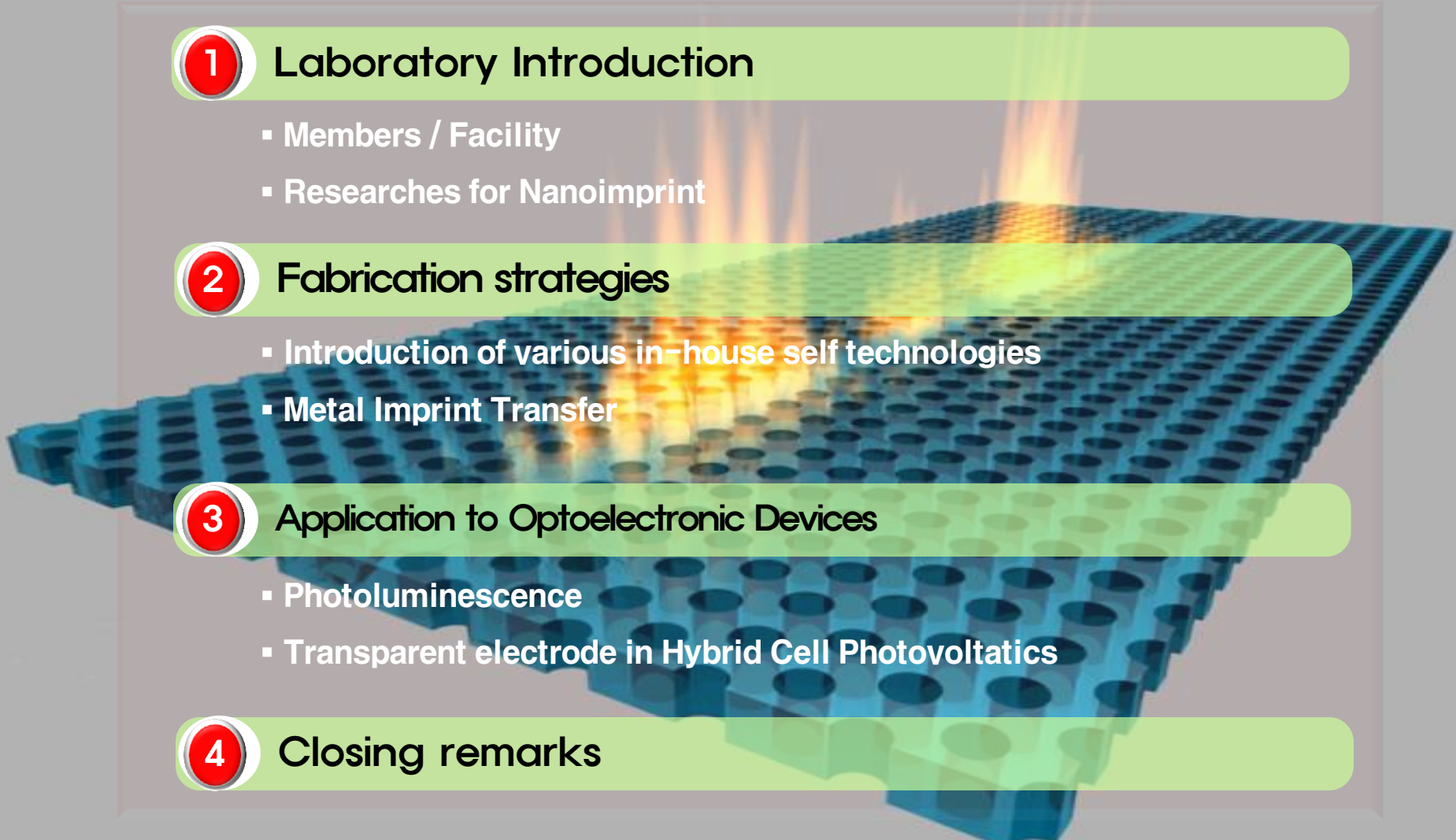
2 Fabrication strategies

- Introduction of various in-house self technologies
- Metal Imprint Transfer

3 Application to Optoelectronic Devices

- Photoluminescence
- Transparent electrode in Hybrid Cell Photovoltaics

4 Closing remarks

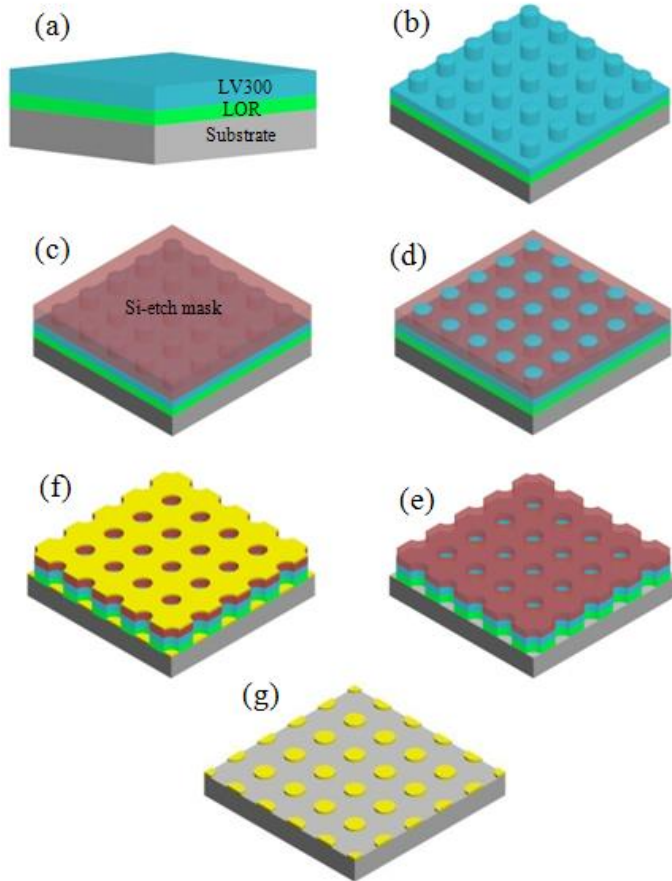




Fabrication Strategy

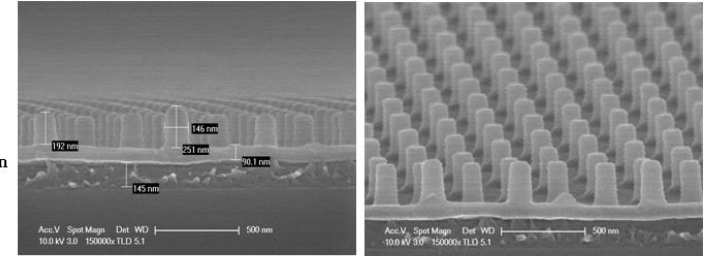
Lift-off for well-round shaped Metal dots

Process Scheme



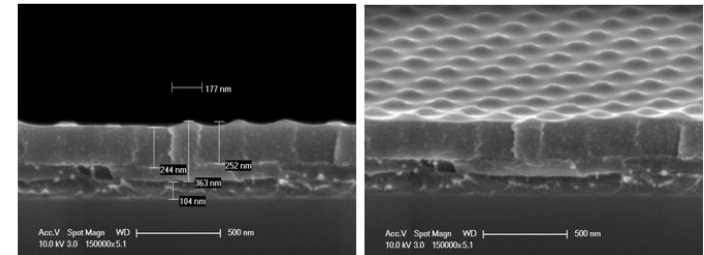
Step 2: Bilayer Imprint

- 150nm, Pillar형, 1:2 A.S.
- LOR 90nm / LV 300nm
- UV Imprint at 2 bar, 90s
- Transferred Height 250nm
- 잔류층 50~60nm



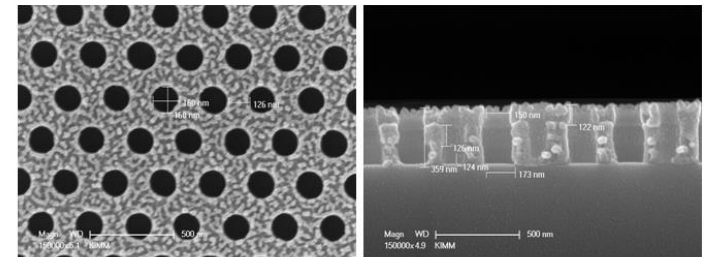
Step 3: Silipin 중착

- 4,000 rpm, 30sec
- 150도에서 3분 어닐링



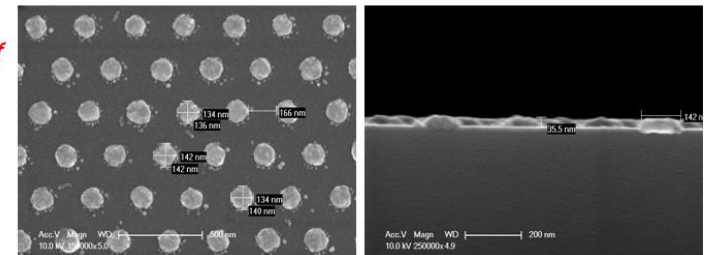
Step 5: Etch-down

- Silspin Etch 20s, O₂+CHF₃
- Imprint Resist & LOR Etch : 50 sccm of O₂, 90s

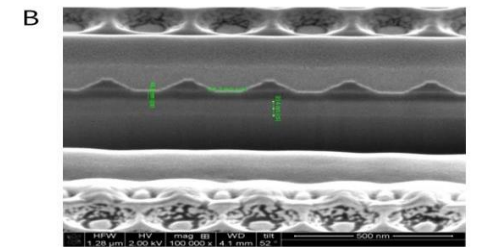
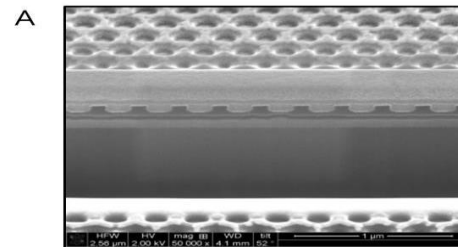
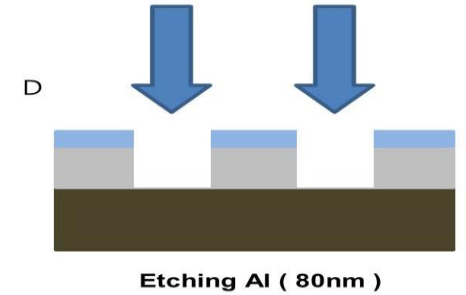
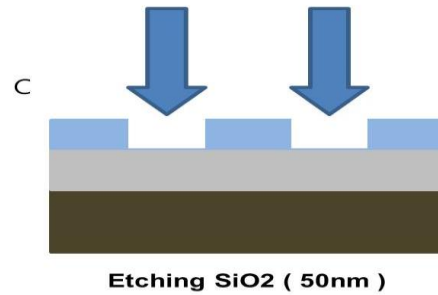
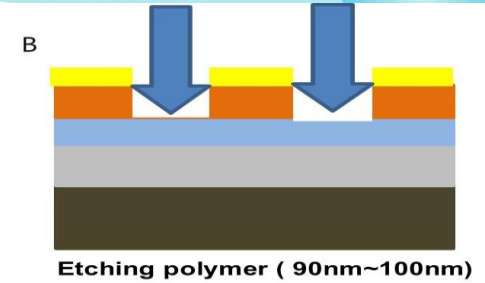
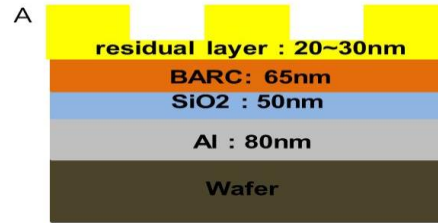
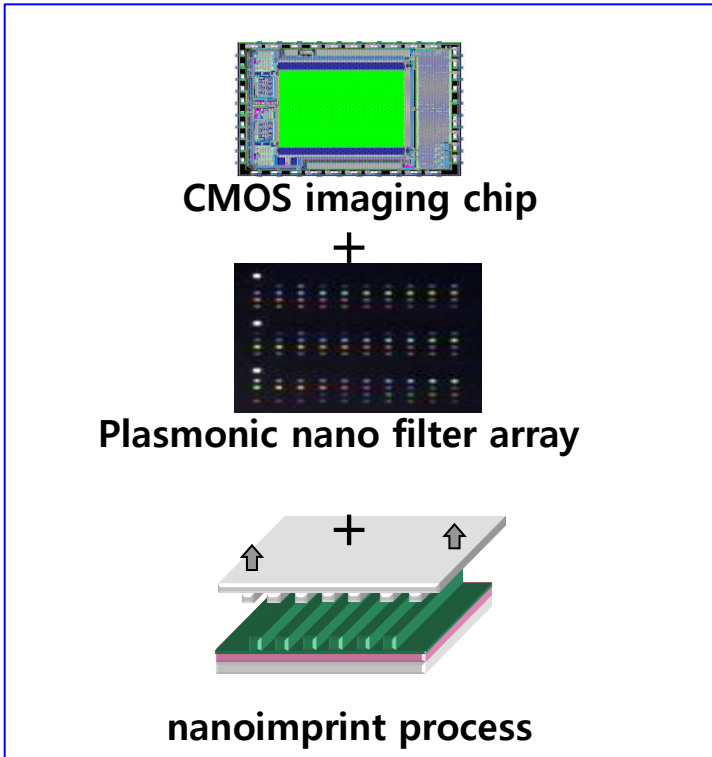


Step 7: Ag 중착) Lift-off

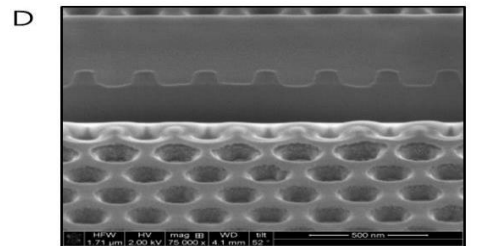
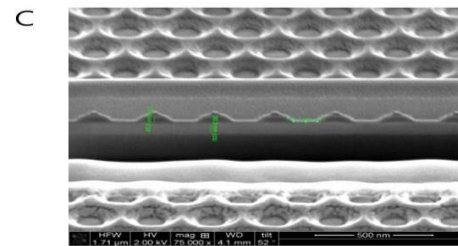
- Thermal Evap. 30nm
- Developer 400K



Metal direct etch, Nanoimprint



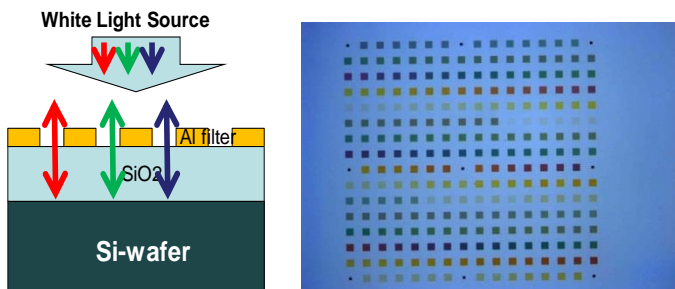
Etching polymer (90nm~100nm)



Etching SiO₂ (50nm)

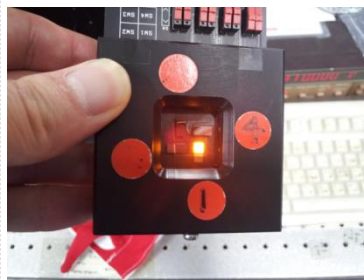
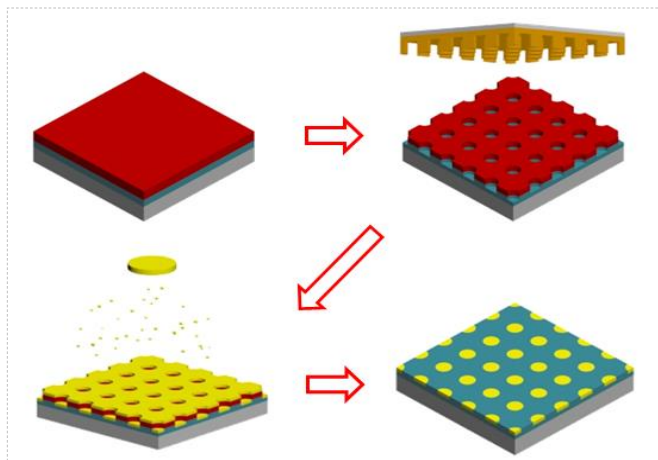
Etching Al (80nm)

□ Front Illumination & Reflection

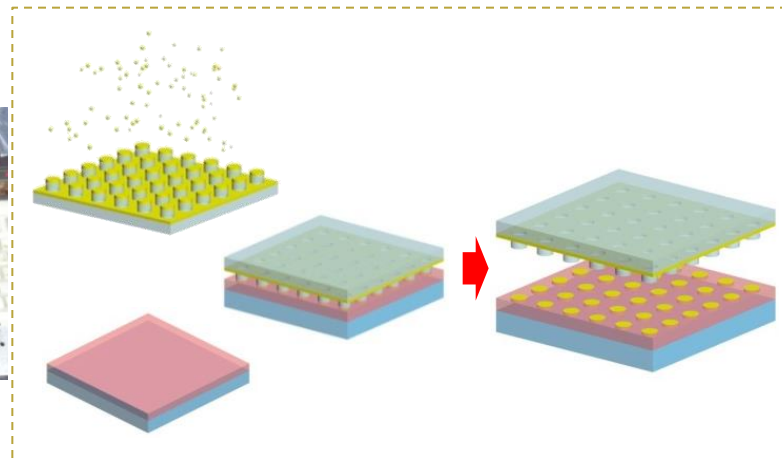


Embedded Ag nanopatterning

1. Bilayer Hybrid NIL → Lift-off

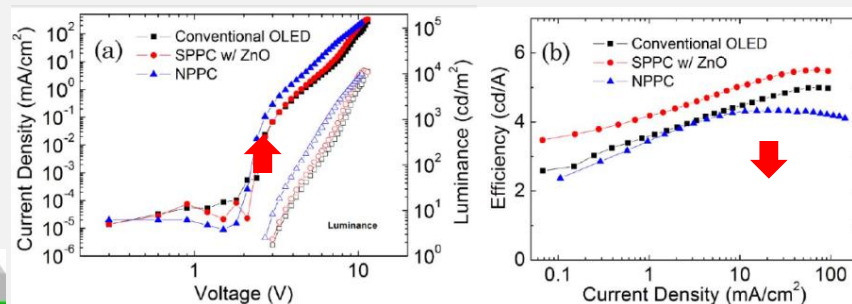
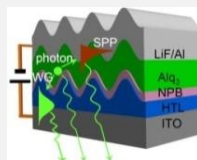


2. Metal Imprint Transfer



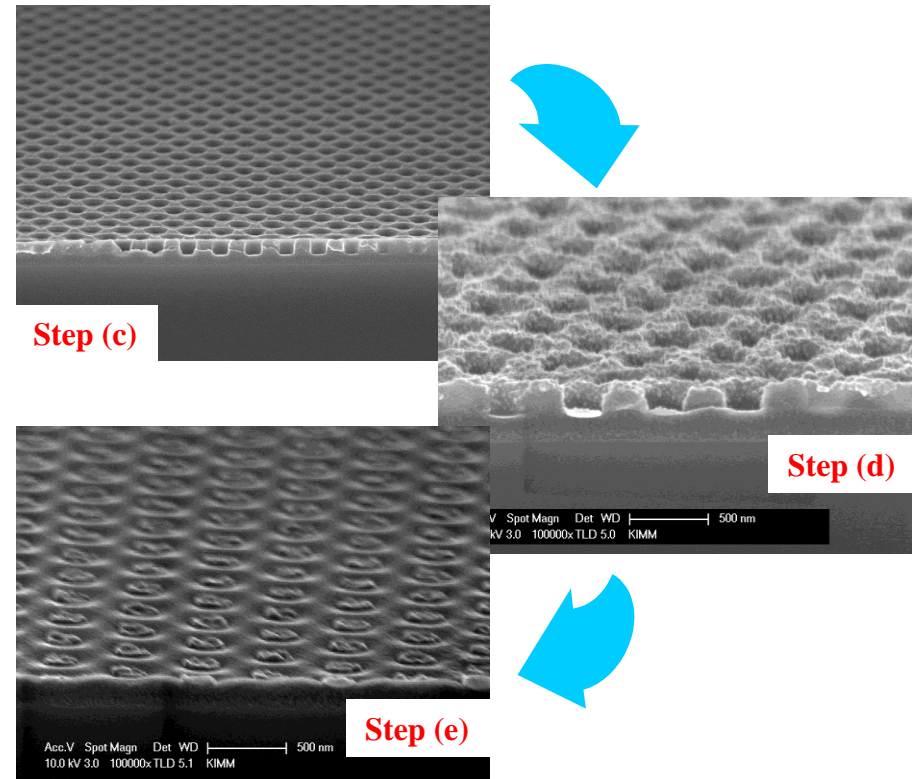
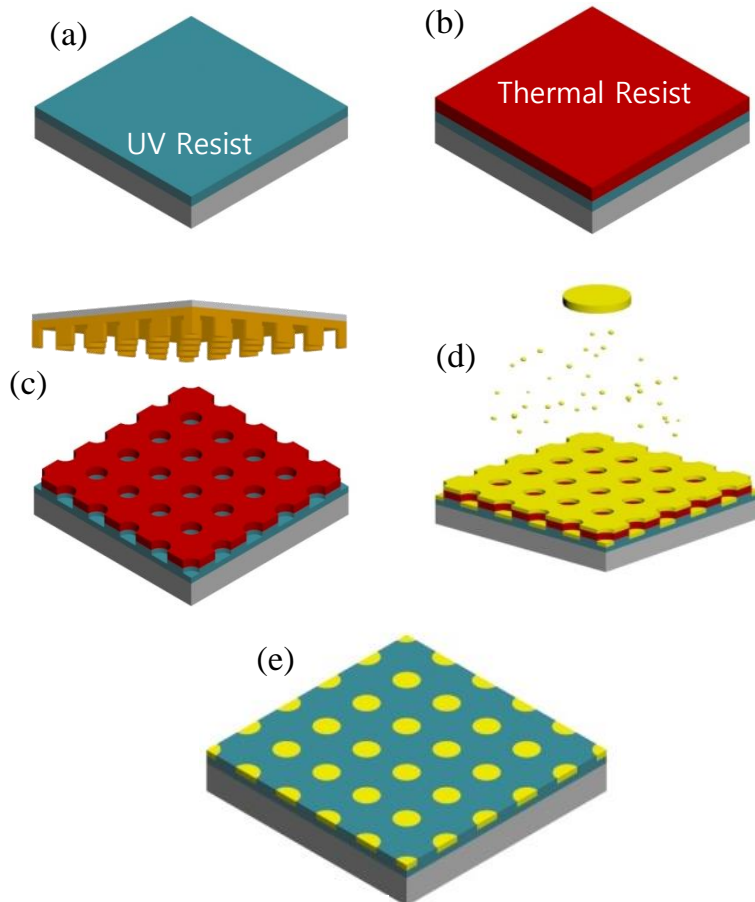
Point of the embedded configuration on multilayer optoelectronics

- **Non-uniform current flow (Leakage current)**
⇒ Reduced efficiency
- **Electric field/Electron injection enhancement**
⇒ Electron transport effects
⇒ Thermal decay, reduced life-time
- **Charge recombination in solar cells**
⇒ Thermal decay, reduced efficiency

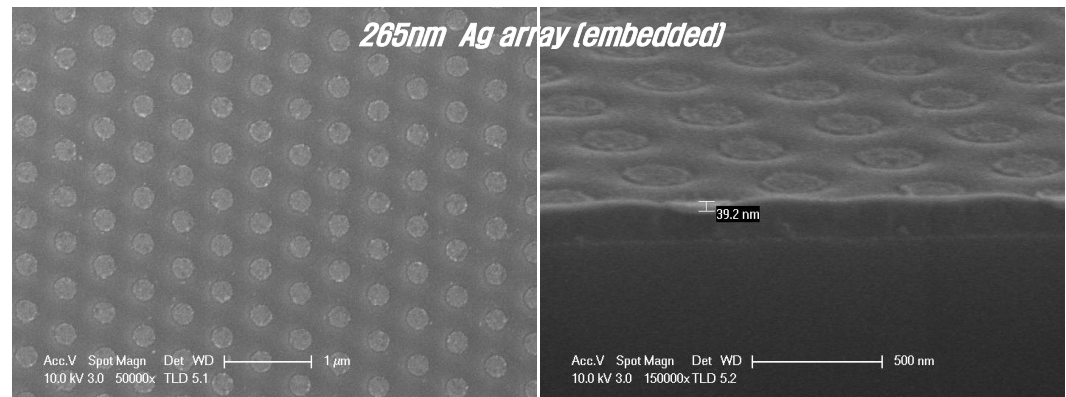
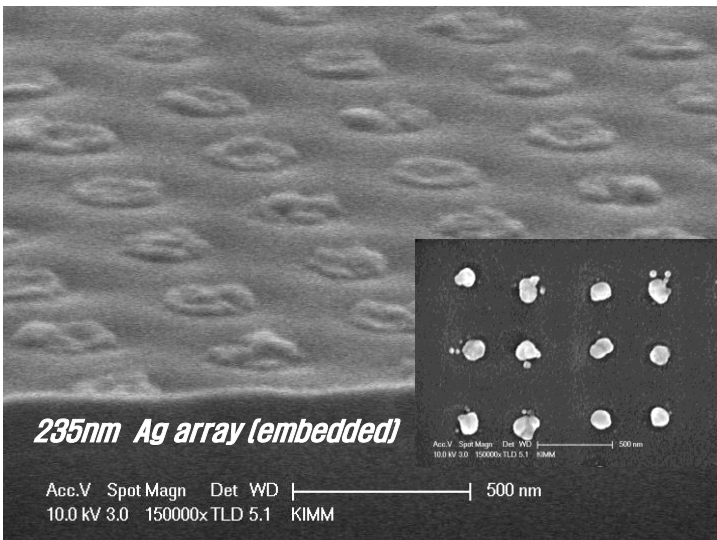
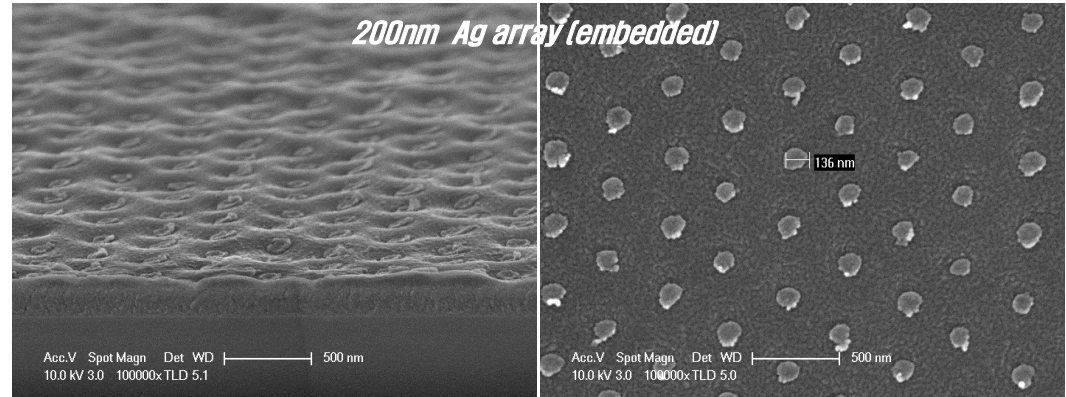
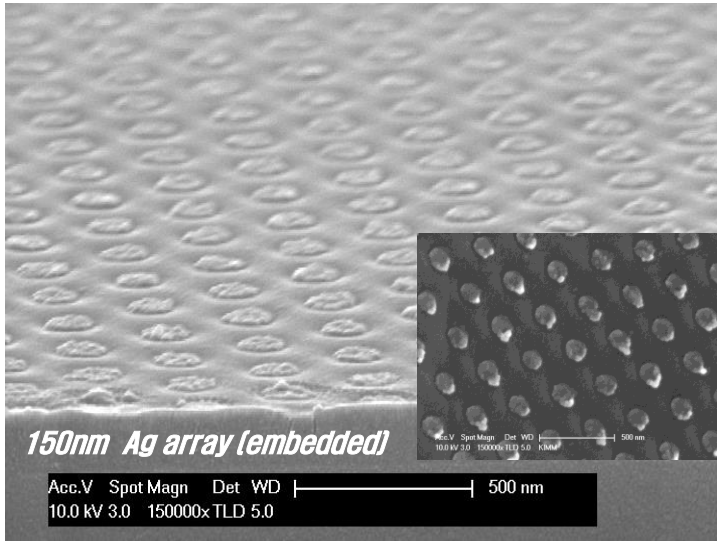


1. Bilayer Hybrid NIL and following Lift-off

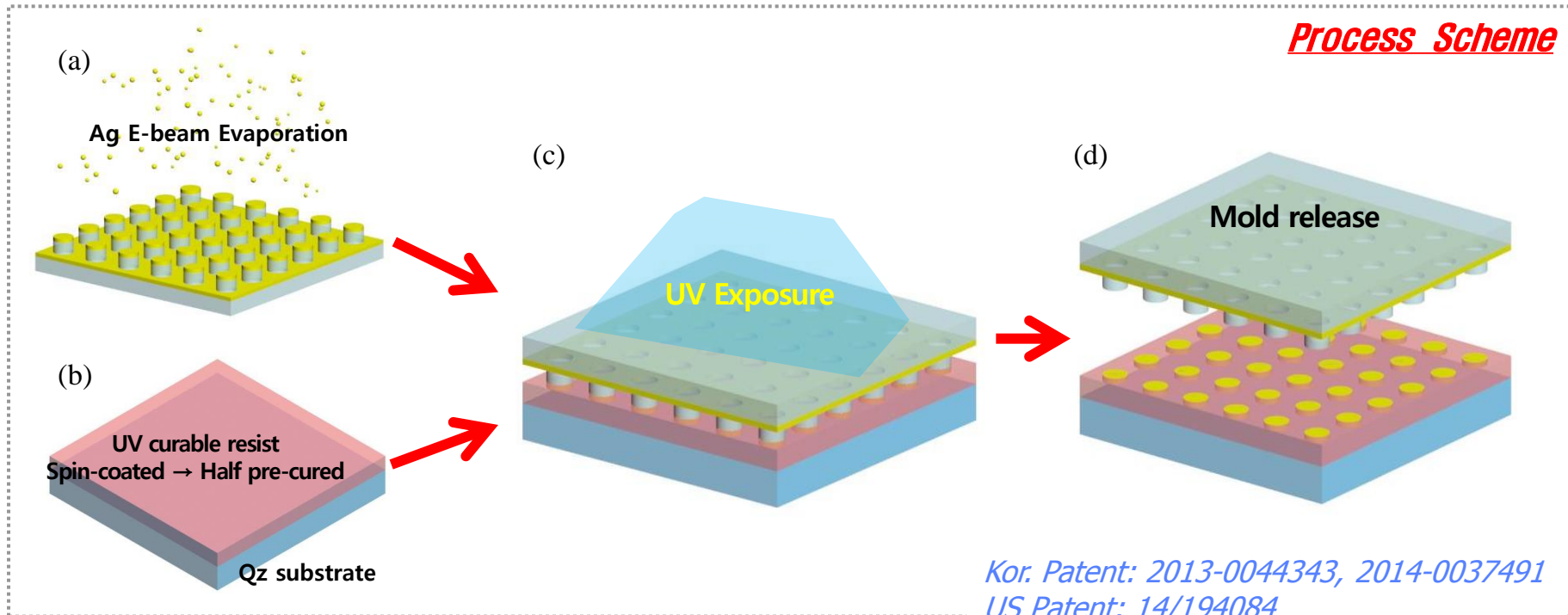
Process Scheme



- (a) Half pre-cure of the coated UV resist
- (c) Thermal Imprint, UV exposure while pressed
→ Complete cure of UV resist
- (d) Ag deposition by E-beam evaporation
- (e) Lift-off of thermal resist on top layer



2. Metal Imprint Transfer



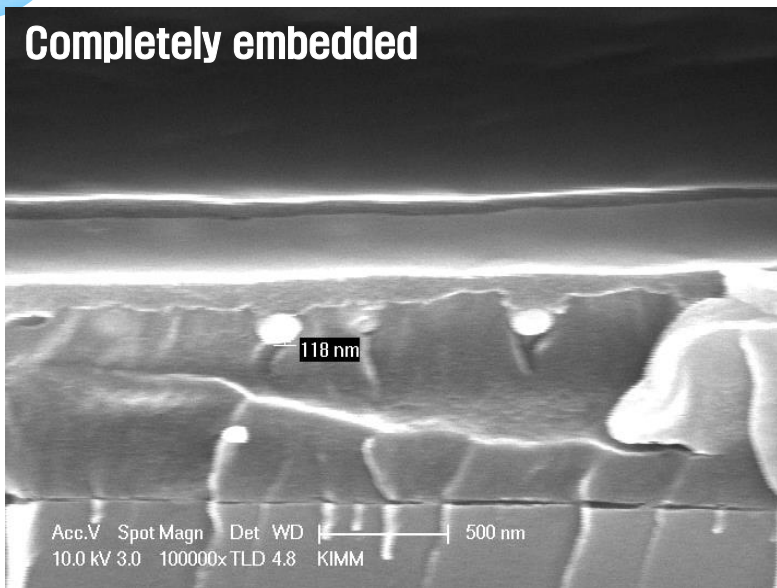
Kor. Patent: 2013-0044343, 2014-0037491
US Patent: 14/194084
Small 2014, Published

- (a) E-beam evaporation of Ag on mold pattern
- (b) Half pre-cure of UV curable resist
- (c) Only Ag on the top surface of mold in contact with half-cured resist, and UV exposure
- (d) Mold release

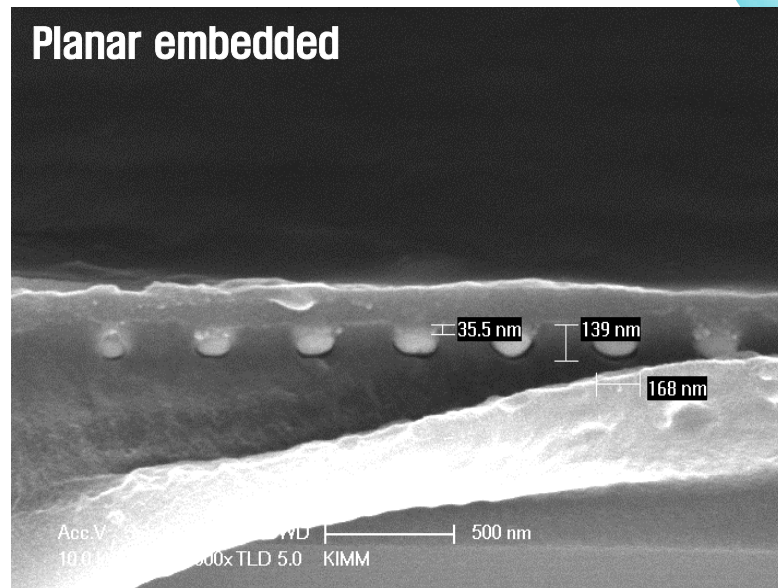
⌘ **Note: *Embedded Dot Arrays***

- 1) Half pre-cured UV-NIL resist
- 2) Limitedly Imprinted Depth via Pressure Control
- 3) Minimized Leakage Current at device depo.

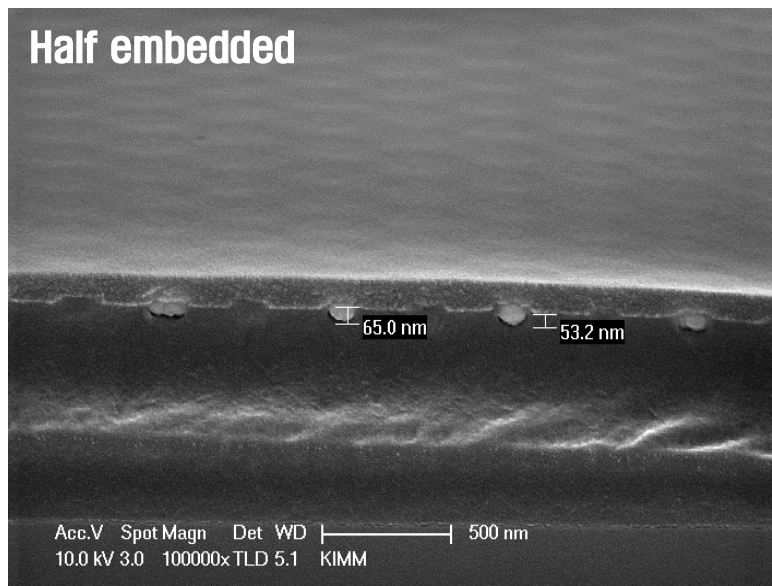
Completely embedded



Planar embedded



Half embedded

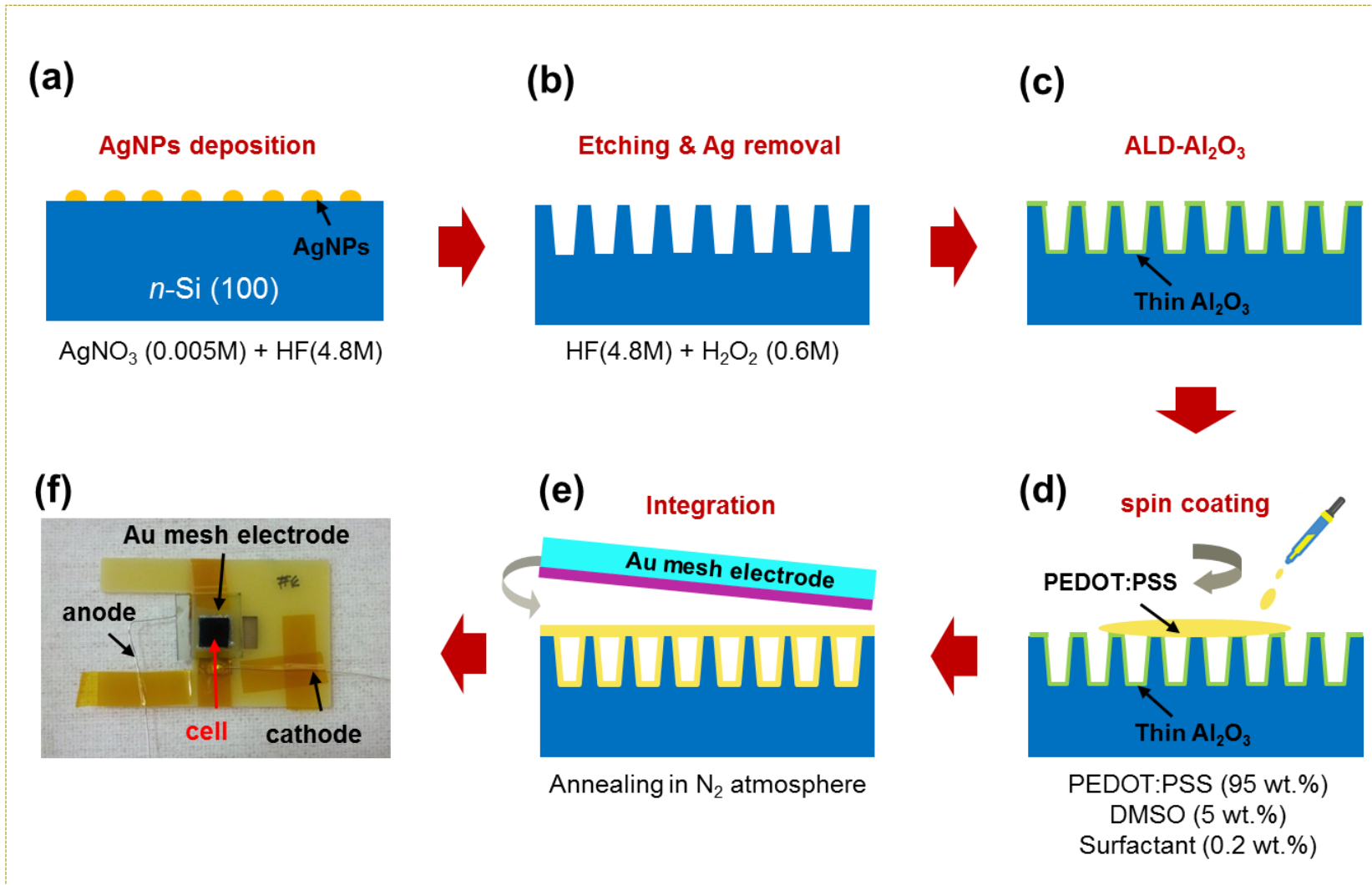




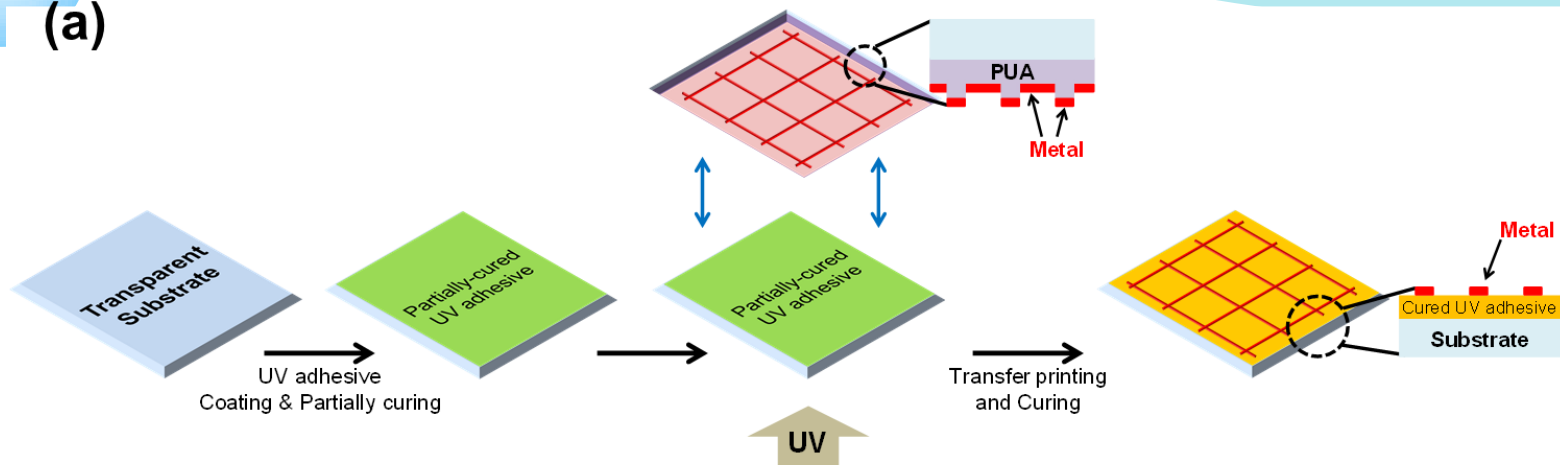
Application to Optoelectronics

Metal Meshes in Hybrid Cell

Process Scheme for Si-PEDOT Hybrid Photovoltaic cell



(a)



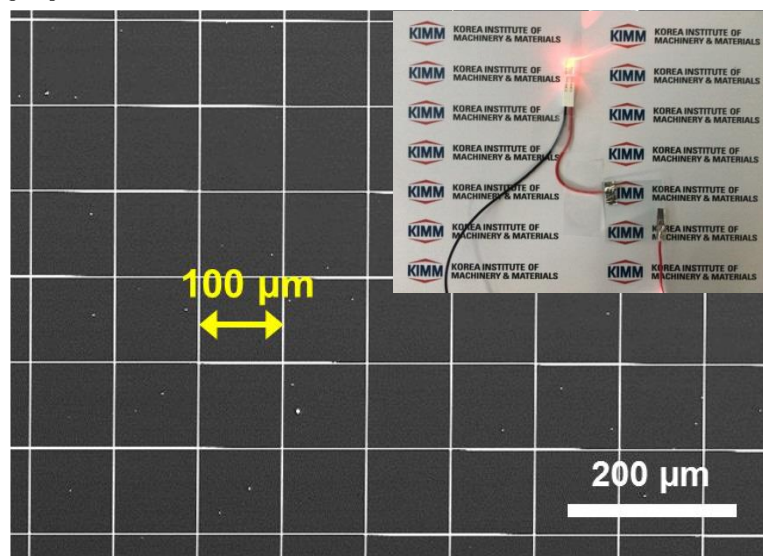
<Metal-based Meshes fabricated by Metal Imprint Transfer >

T_{peak} of 91.6% @ 24 Ω/sq

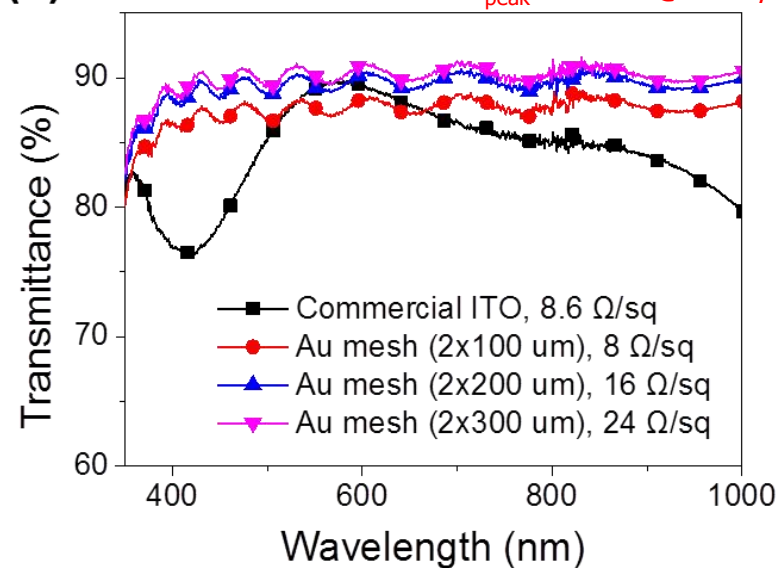
T_{peak} of 90.9% @ 16 Ω/sq

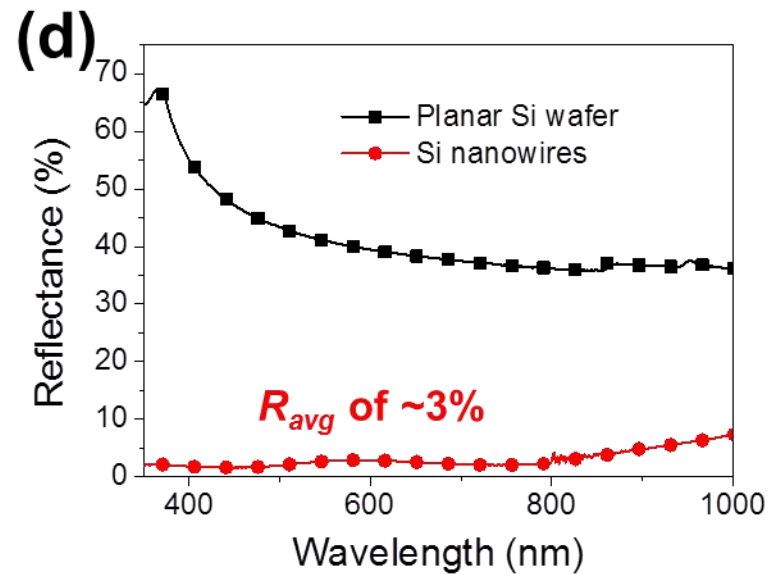
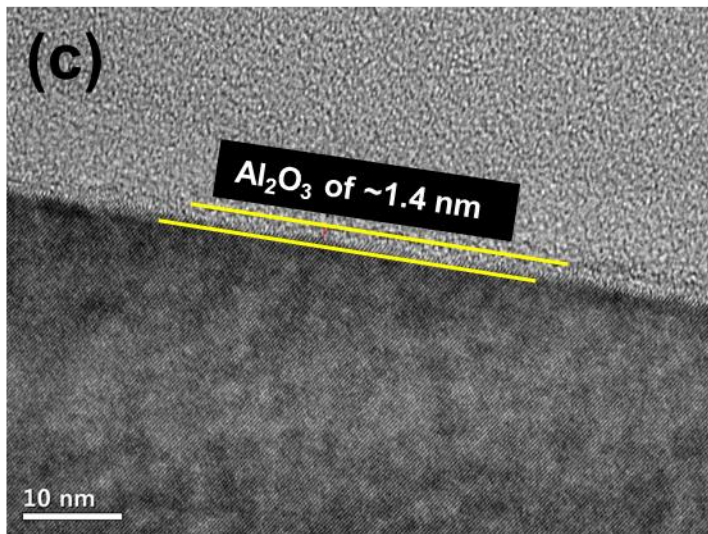
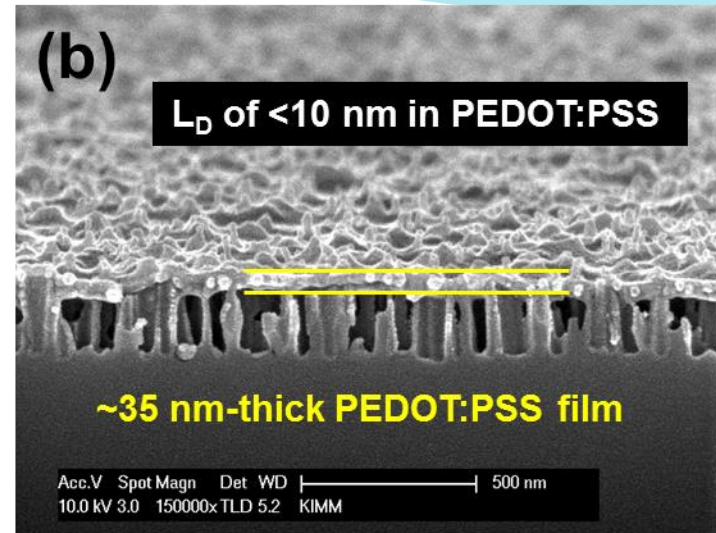
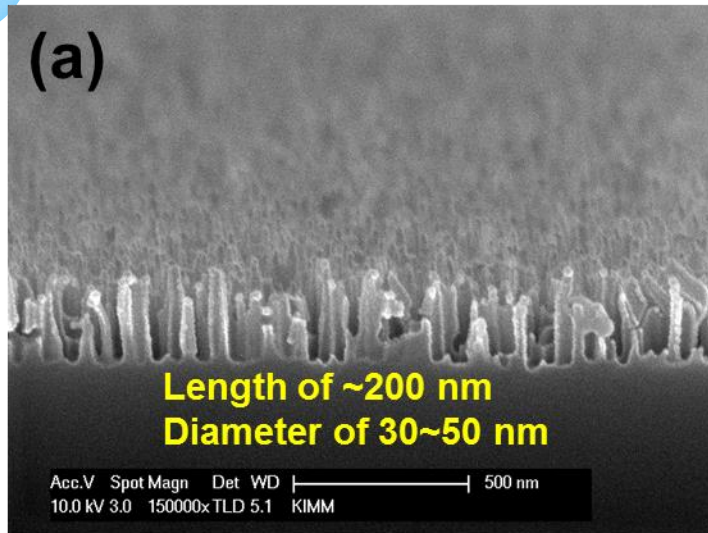
T_{peak} of 89% @ 28 Ω/sq

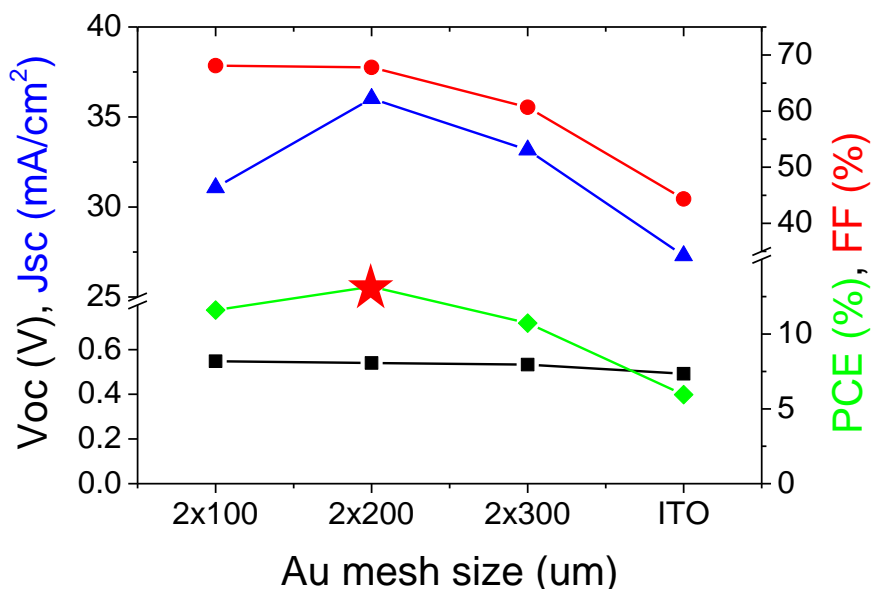
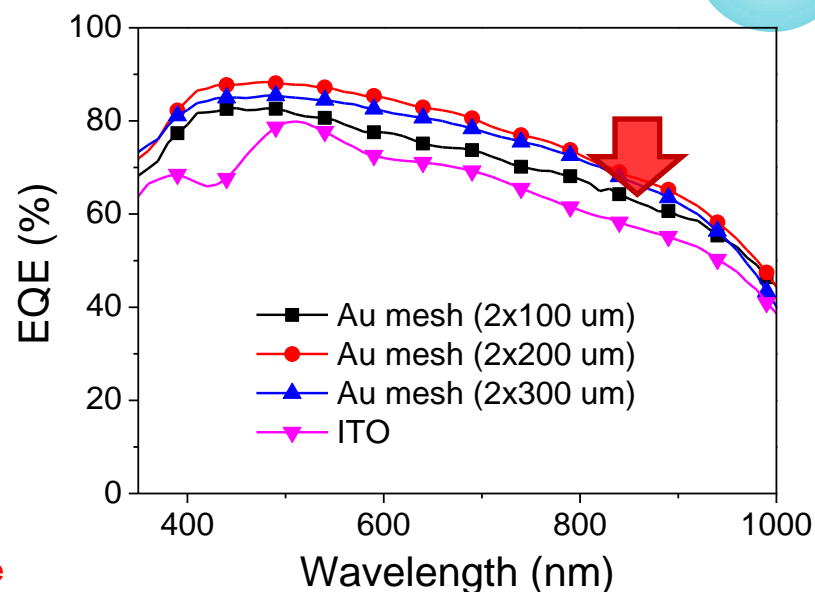
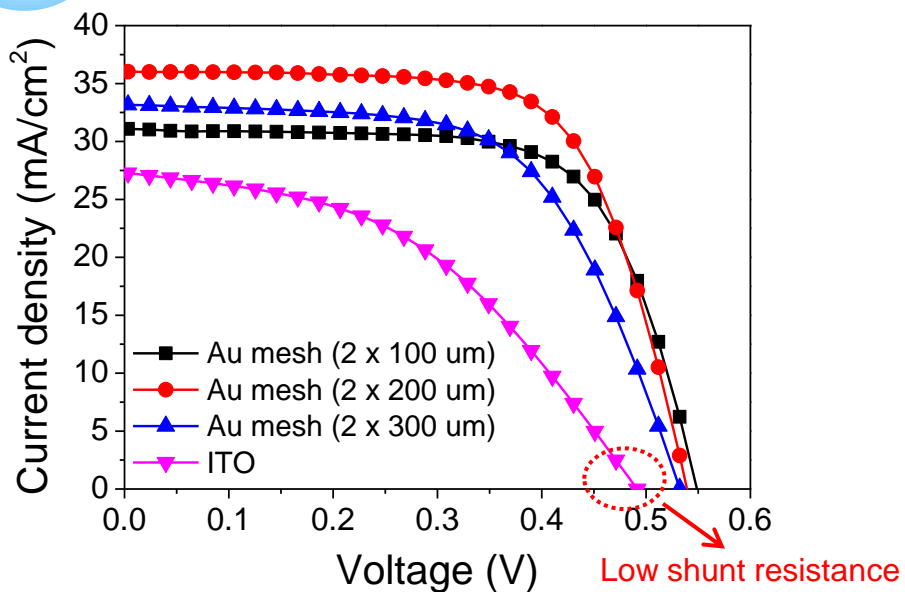
(b)



(c)



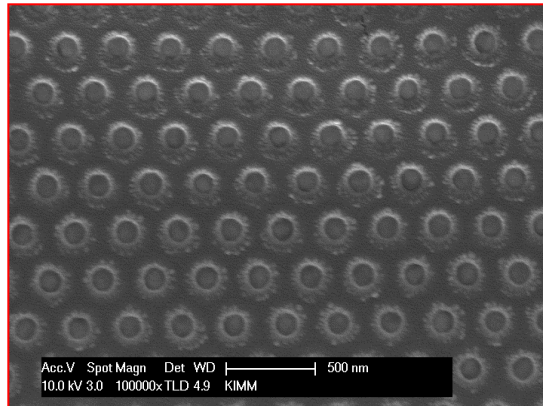
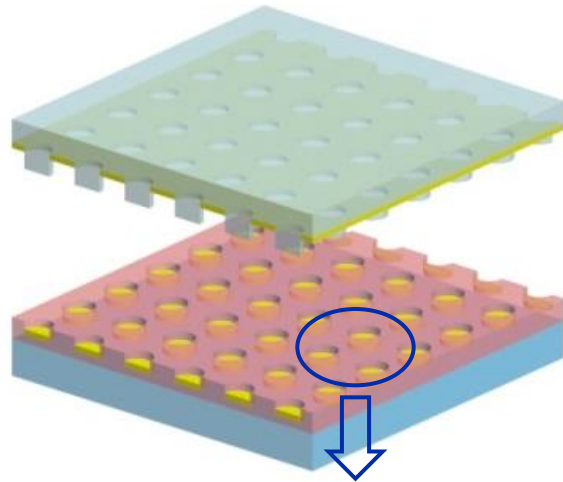




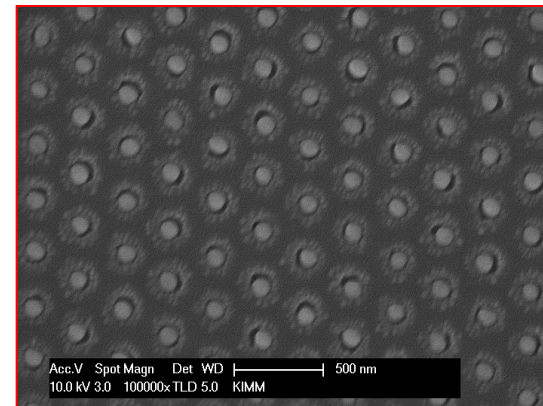
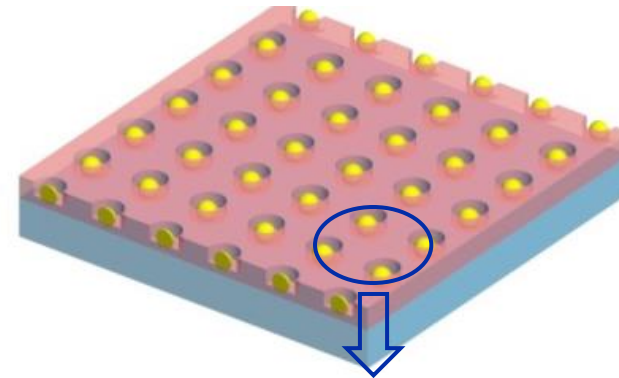
Sample	V_{oc} (mV)	J_{sc} (mA/cm^2)	FF (%)	PCE (%)
ITO	491.5	27.3	44.35	5.95
Au mesh (2x300 μm)	532.5	33.17	60.7	10.73
Au mesh (2x200 μm)	539.2	36.03	67.8	13.17
Au mesh (2x100 μm)	548.7	31.08	68.1	11.6

Tunable Plasmonic Nanostructures

Metal Imprint Transfer

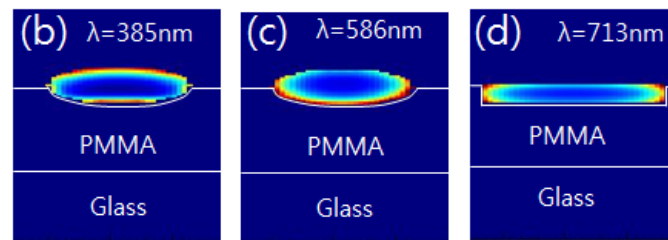
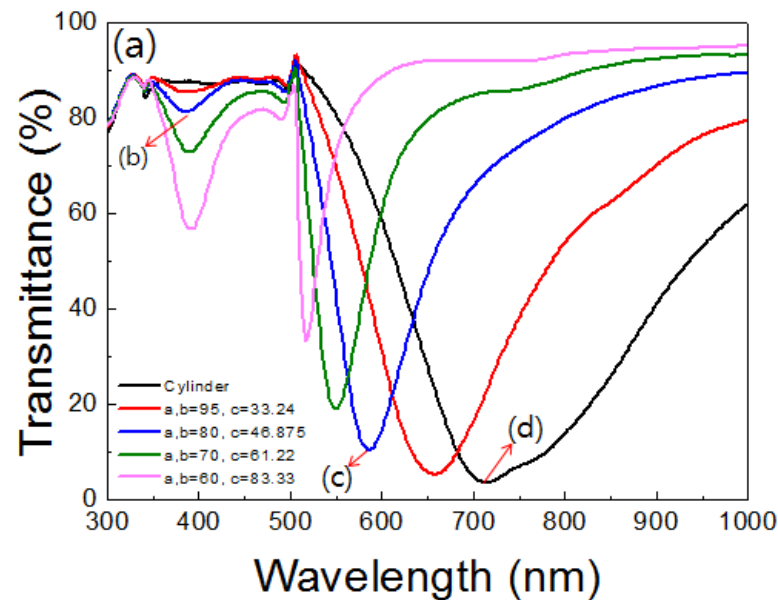
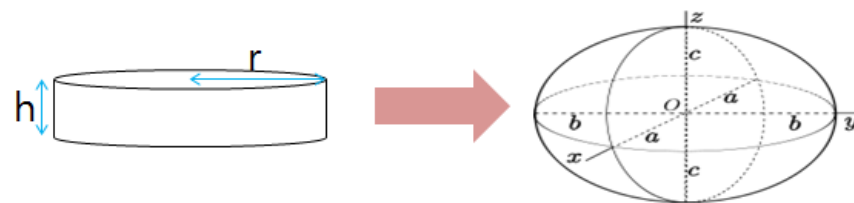
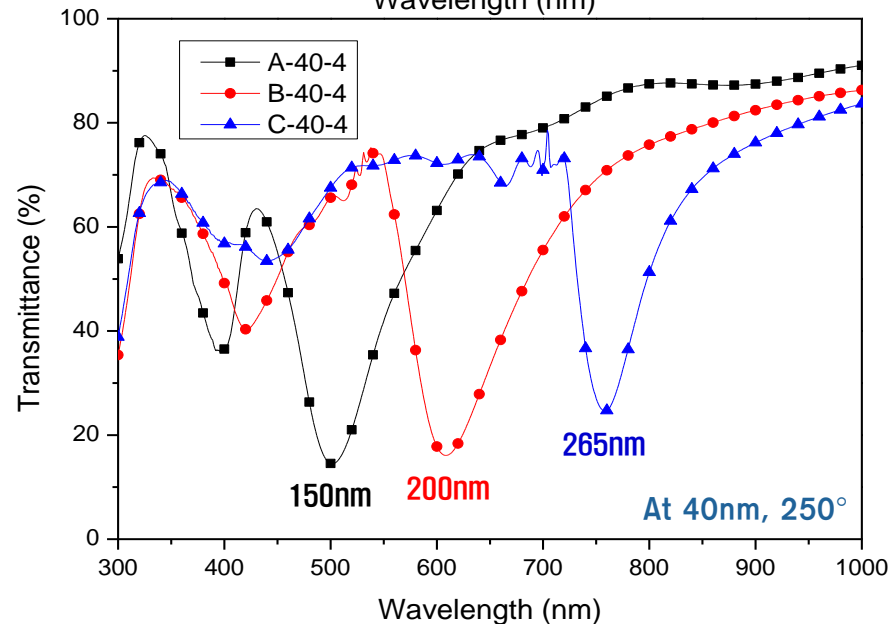
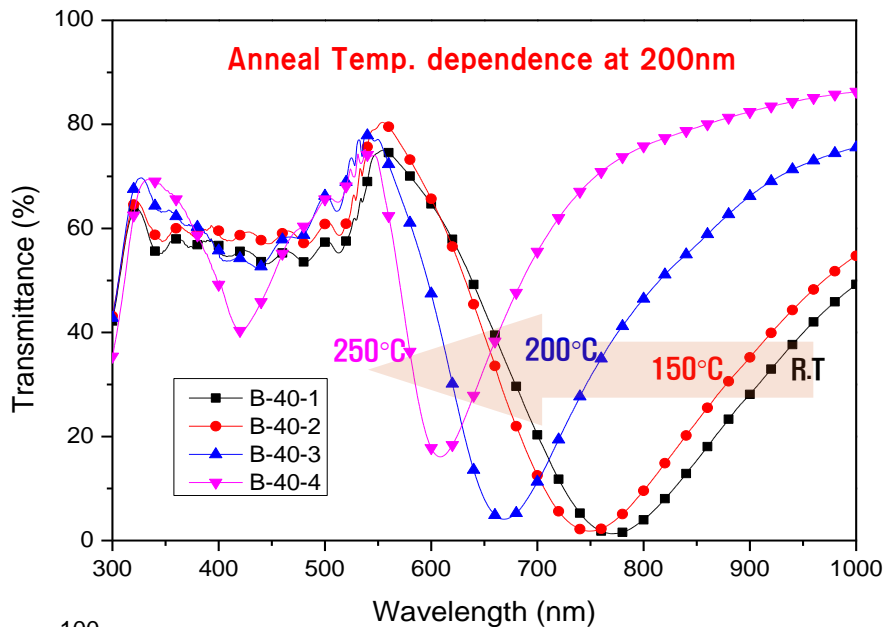


Annealing
at $> 150^{\circ}\text{C}$



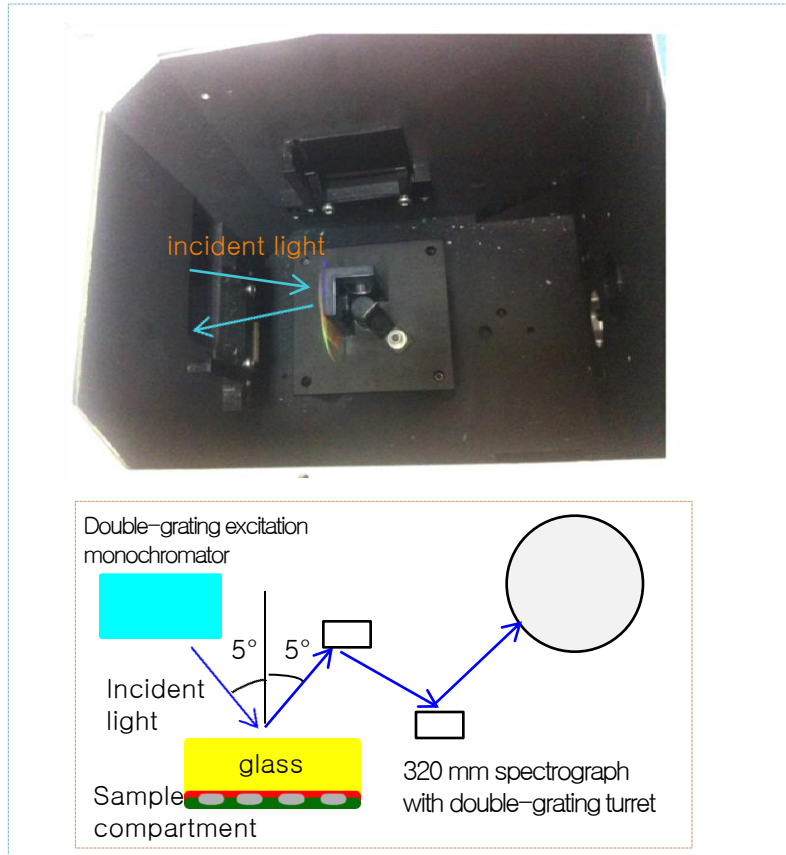
- Confirmed Tunable plasmonic Properties
- Plasmonic peak shifts as annealing temperature increases.
- Green PL Intensity increased more than 400%, w.r.t. Ref.

Spectral Transmittance - Measured & Simulated



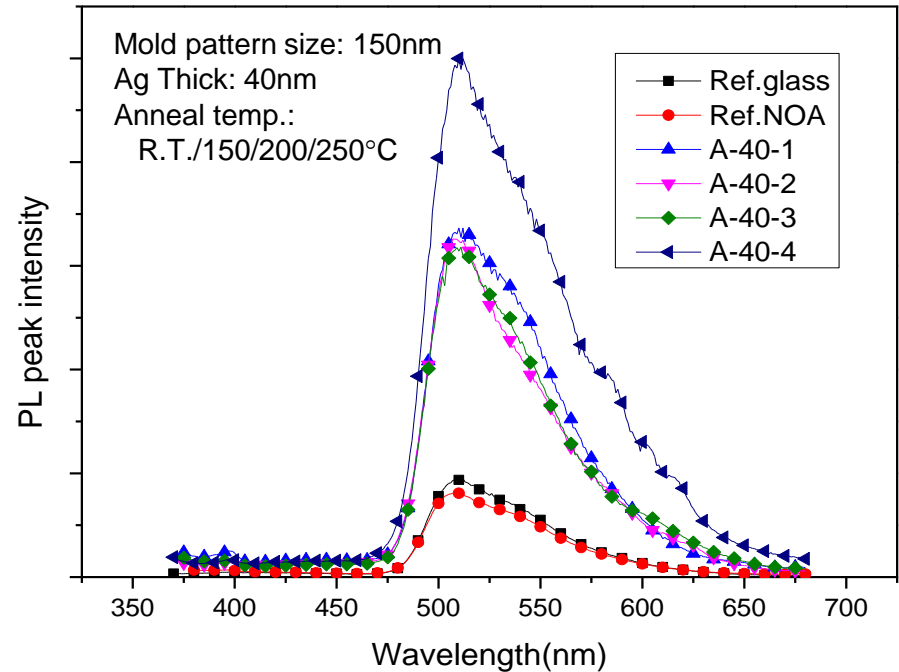
(a) cylinder shape에서 ellipsoidal로 변하는 과정의 transmittance
 (b)~(d) Electric field intensity of cylinder shape & ellipsoidal shape with $a, b=80\text{nm}$

Photoluminescence Improvements



- A/B/C ; 150/200/265 - nm in mold pattern dia.
- 20/40/60; 20/40/60 - nm in Ag thickness
- 1/2/3/4; RT/150/200/250°C for annealing temp.

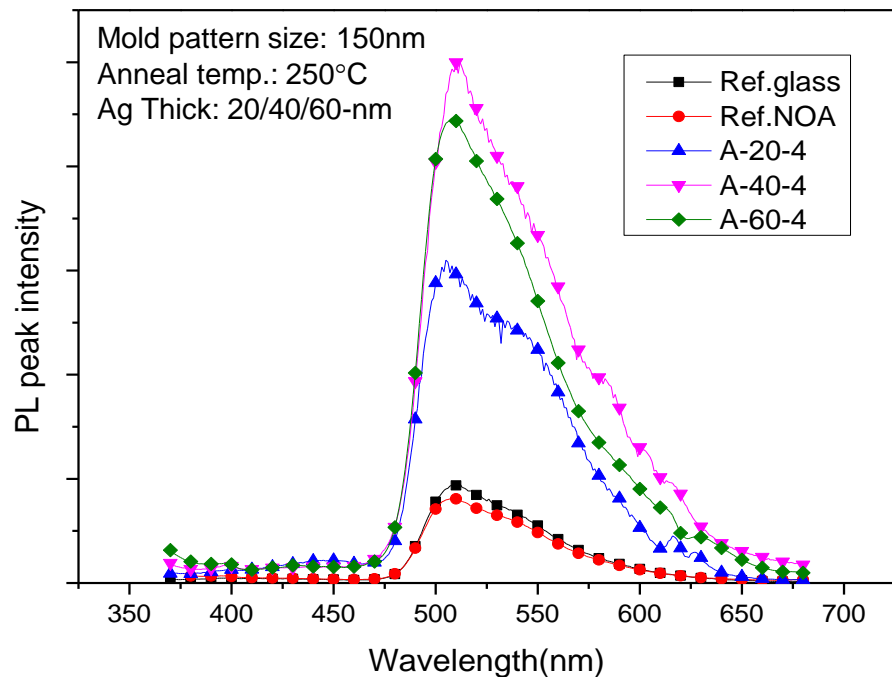
<Annealing Temp.-dependence>



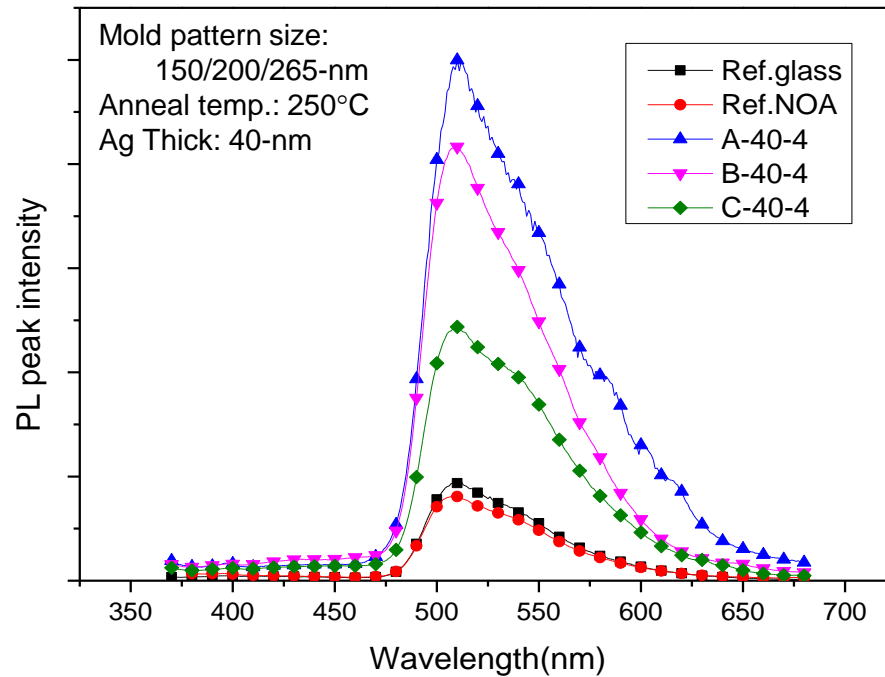
> PL enhancement rate

Sample	w.r.t Ref. glass	w.r.t. Ref - NOA
A-40-1	280%	317%
A-40-2	268%	303%
A-40-3	259%	293%
A-40-4	465%	518%

<Ag Thick.-dependence>



<Mold pattern size.-dependence>



➤ PL enhancement rate

Sample	w.r.t Ref. glass	w.r.t. Ref - NOA
A-20-4	243%	276%
A-40-4	465%	518%
A-60-4	399%	446%

➤ PL enhancement rate

Sample	w.r.t Ref. glass	w.r.t. Ref - NOA
A-40-4	465%	518%
B-40-4	371%	415%
C-40-4	174%	200%

Closing Remarks

- Research Infrastructures for Nanostructures/Patterning
- Nanoimprint – based nanopatterning and its application in Optoelectronics
- Several approaches for metallic nanopattern fabrications in plasmonic fields

- **Global Collaborations**

UC Berkeley–Micromechanical Analysis and Design (BMAD)

IMRE, Singapore

AMO GmbH Aachen



- **Industrial Collaborations**

APN

Hutem Co.

nanoLambda Korea Company

Samsung Electronics–Manufacturing Institute

Youngchang Chemical Co. Ltd



Members

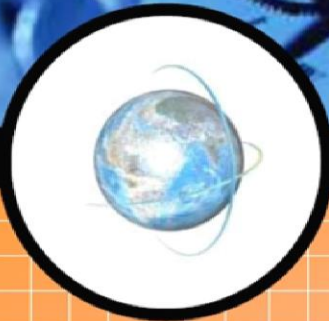


Staffs

- Lee, Eung-sug: Ultrafine fabrication, Nanomechatronics
- Jeong, Jun-ho: Nanolithography, Nanoimprint
- Choi, Jun-hyuk: Metal nanopatterning, Direct/Roll Imprint
- Choi, Dae-geun: Nanoimprint mater. Process chemistry
- Lee, Ji-hye: Nanowire, mask fabrication, biosensors
- Jeong, Joo-yeon: Electronics, Plasmonic optics

- Nanoimprint
 - Process, Tools, Functional mater.
 - Appl.: R-RAM, Sensors, (O)LED
- 3D Multiscale Architecturing
 - Nanowire structuring
 - Nanomaterials self-assembly
- Plasmonic sensors, Light emitting
 - Metal nanostructuring
 - Metal NP. Self-growth





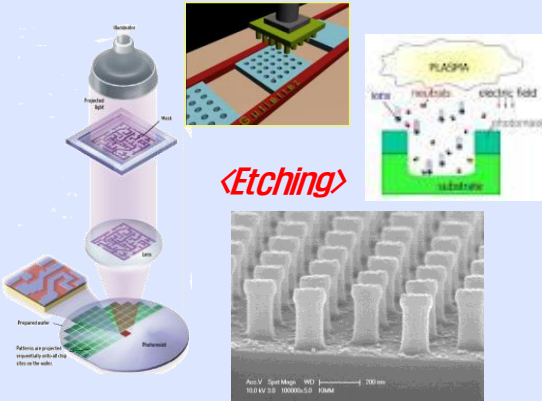
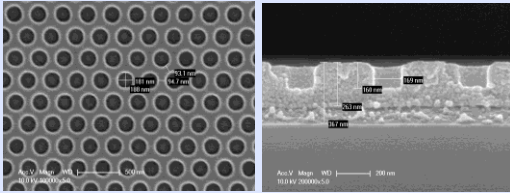
KIMM

Thank you for your attentions



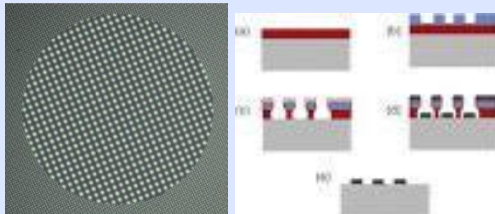
Research area

<Nanopatterning, Lithography>

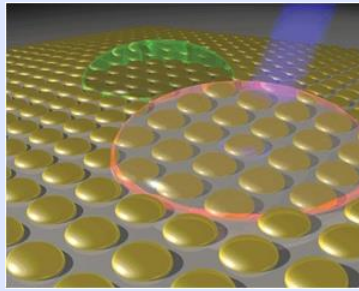
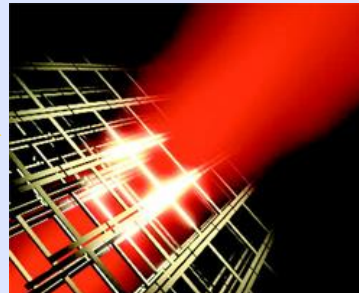
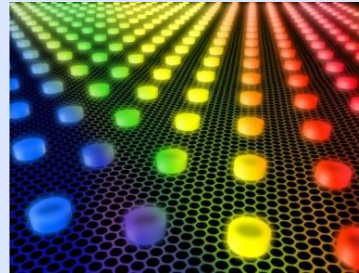


<Etching>

<Metal pattern, Lift-off>



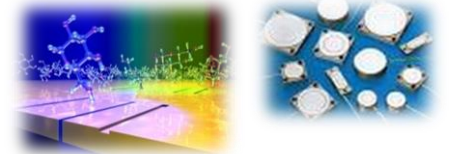
<Metal nanopattern array>



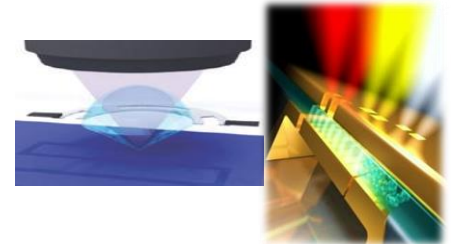
<Optoelectronic Applications>



<Optics-based Sensors>



<Plasmonic Lithography>





Research directions

- Multilayer, Enlarged
- Solar cells

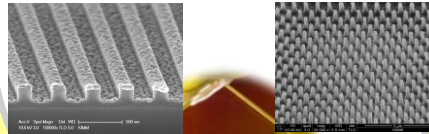
- Planarized Struc.
- Plasmonic Litho. Mask

- Plasmonic sensors
- Undercut 3D Struc.

- Optoelectronics
- Embedded structure profile

Multiscale Nanofabrication

Nanoimprint



3D Plasmonic Nanopatterns

Infrastructure of metallic nanopatterning

