Multi-axial Evaporation through Nano-Hole Masks: a 3D-printer for the nanoscale

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Nanospain 2017, San Sebastián

3D printer

X, Y, Z stage

Low melting point plastic wire

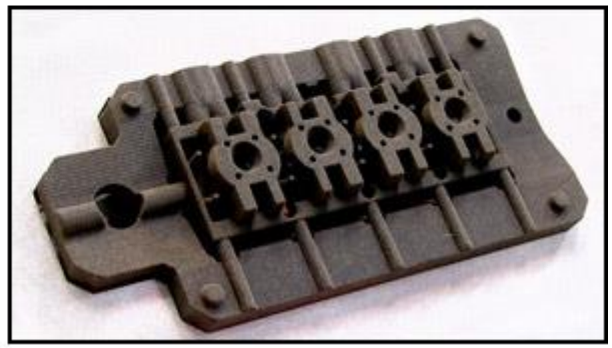
Nozzle

Applications:

Medicine (organs, prothesis, skin…)

Industry (automotive, space …)

Glassware, tools toys, decoration, clothing, shoes, ……… you name it.



A 3D Chocolate Printer for the Home

New Standards in 3D Micro Printing

Sofía Rodríguez

Nanoscribe GmbH, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany
rodriguez@nanoscribe.com

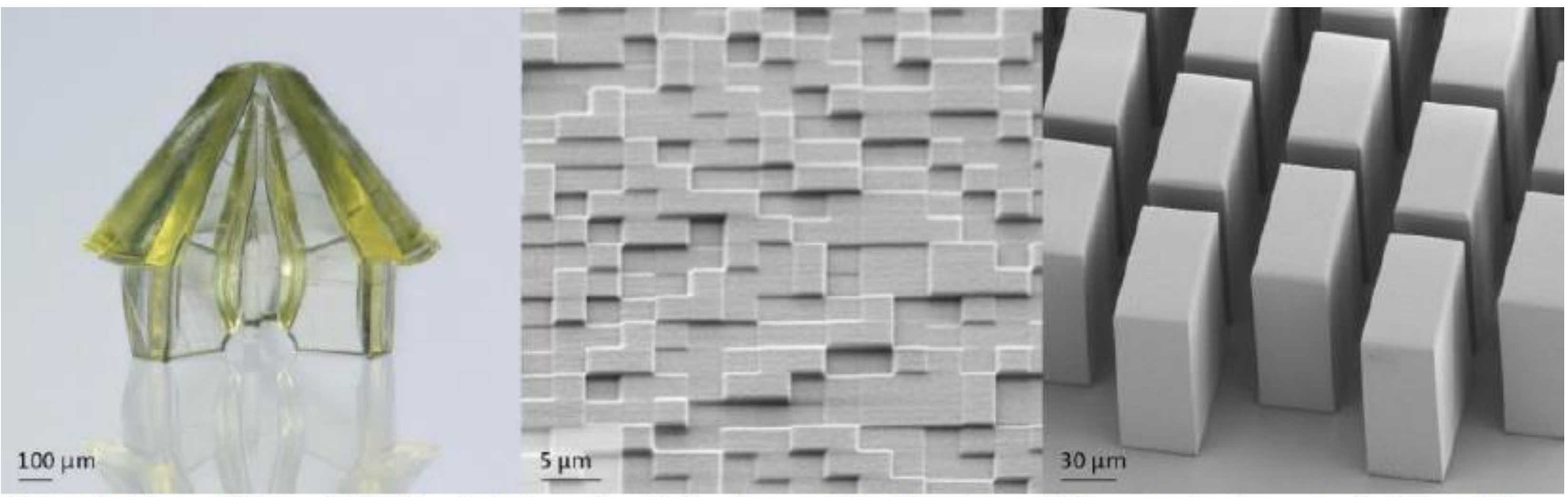


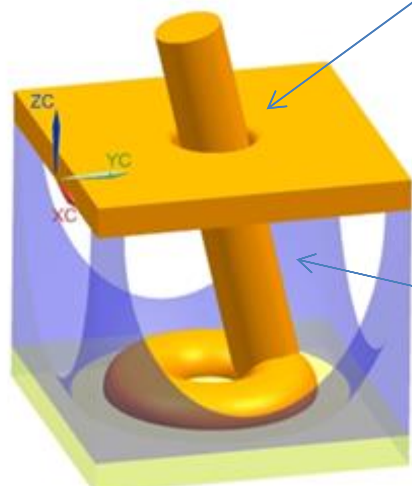
Figure 1: (from left to right) 3D printed nozzle. Diffraction multilevel pattern. High aspect ratio microfluidic capillary pump.

Wouldn’t be great taking this 3D printing concept all the way down to the nanoscale??

Multi-axial Multi-material Evaporation through Nano-Hole Masks

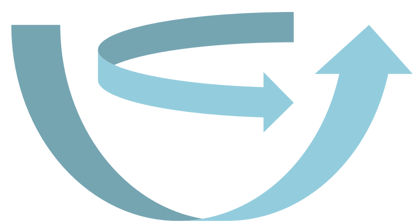
Evaporated material(s)

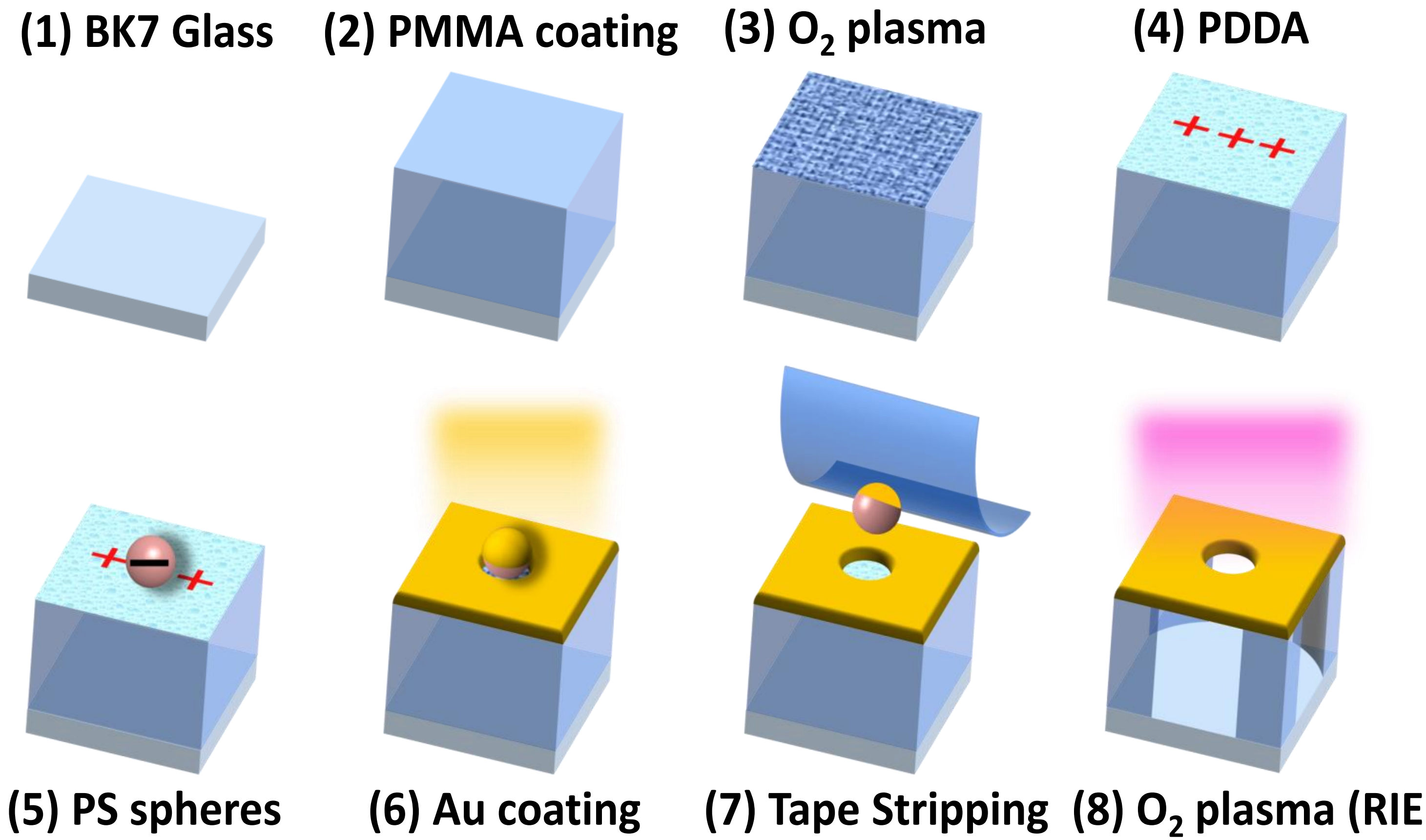
Hole Diameter:
60 – 500 nm - .....

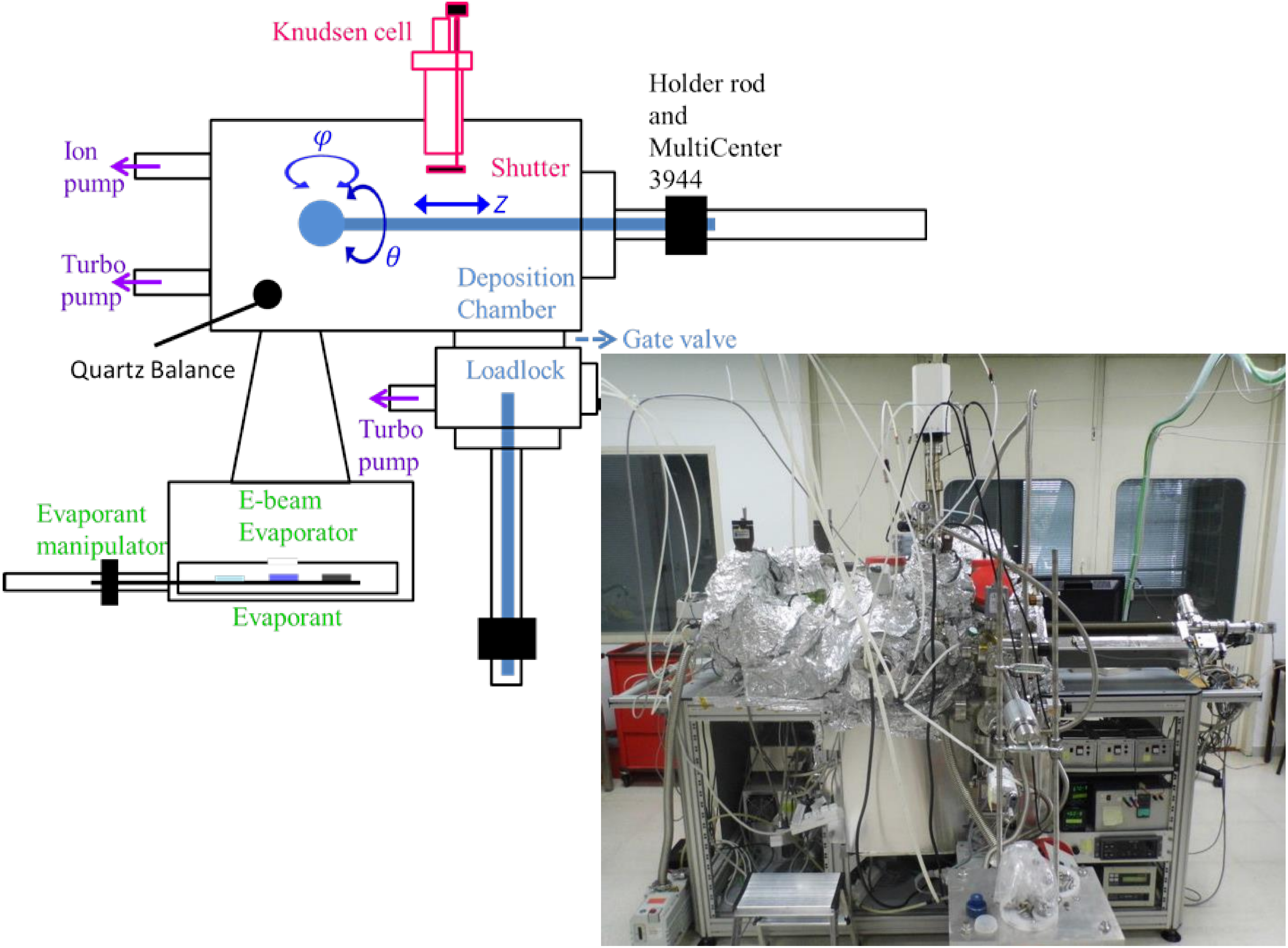


Cavity in PMMA

Substrate




(1) BK7 Glass
(2) PMMA coating
(3) O_2 plasma
(4) PDDA
(5) PS spheres
(6) Au coating
(7) Tape Stripping
(8) O_2 plasma (RIE)


Knudsen cell
Holder rod
and
MultiCenter
3944
Ion
pump
φ
Shutter
z
θ
Turbo
pump
Deposition
Chamber
Gate valve
Quartz Balance
Loadlock
Turbo
pump
E-beam
Evaporator
Evaporant
manipulator
Evaporant

Characteristics

Large area (cm^2), parallel production

Multimaterial

Single step fabrication

10's nanometer in plane resolution

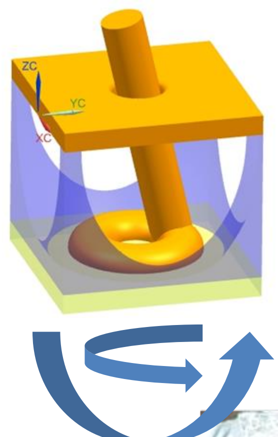
Subnanometer out of plane resolution

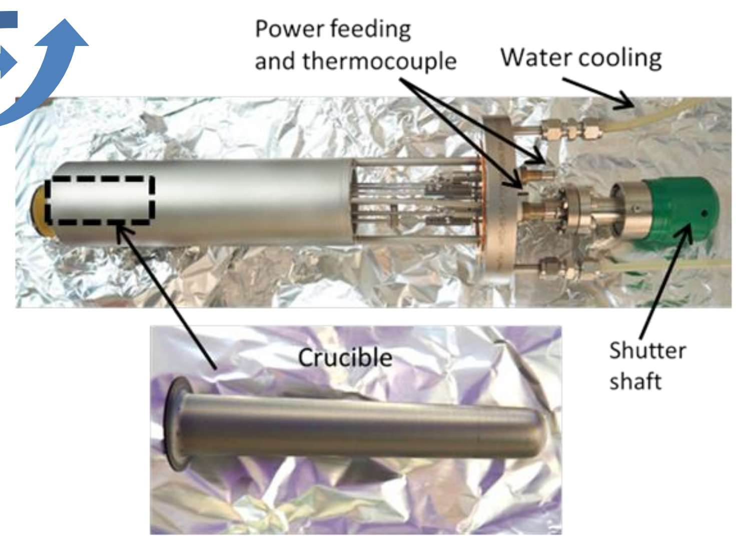
Inexpensive

Obviously, truly 3D objects

3D printer **Hole mask multiaxial deposition**

X, Y stage .... Polar(θ) and azimuthal(φ) orientation
Z stage .... Sequential deposits
Nozzle .... Hole (diameter determined by the sphere)
Extruder and heating mechanism.............................. Evaporator
Low melting point plastic wire.................................. Evaporants





PRECURSOR WORKS: Chalmers University of Technology, Göteborg (Sweden)

<u>Hole–Mask Colloidal Lithography</u>

ADVANCED MATERIALS

H. Fredriksson, Y. Alaverdyan, A. Dmitriev,* C. Langhammer, D. S. Sutherland, M., and B. Kasemo. **Adv. Mater. 2007, 19, 4297–4302**
290 citations

Plasmonic Properties of Supported Pt and Pd Nanostructures
C. Langhammer,* Z. Yuan, I. Zoric´, and B. Kasemo.
NANO LETTERS 2006 Vol. 6, No. 4 833-838.
200 citations

NANO LETTERS

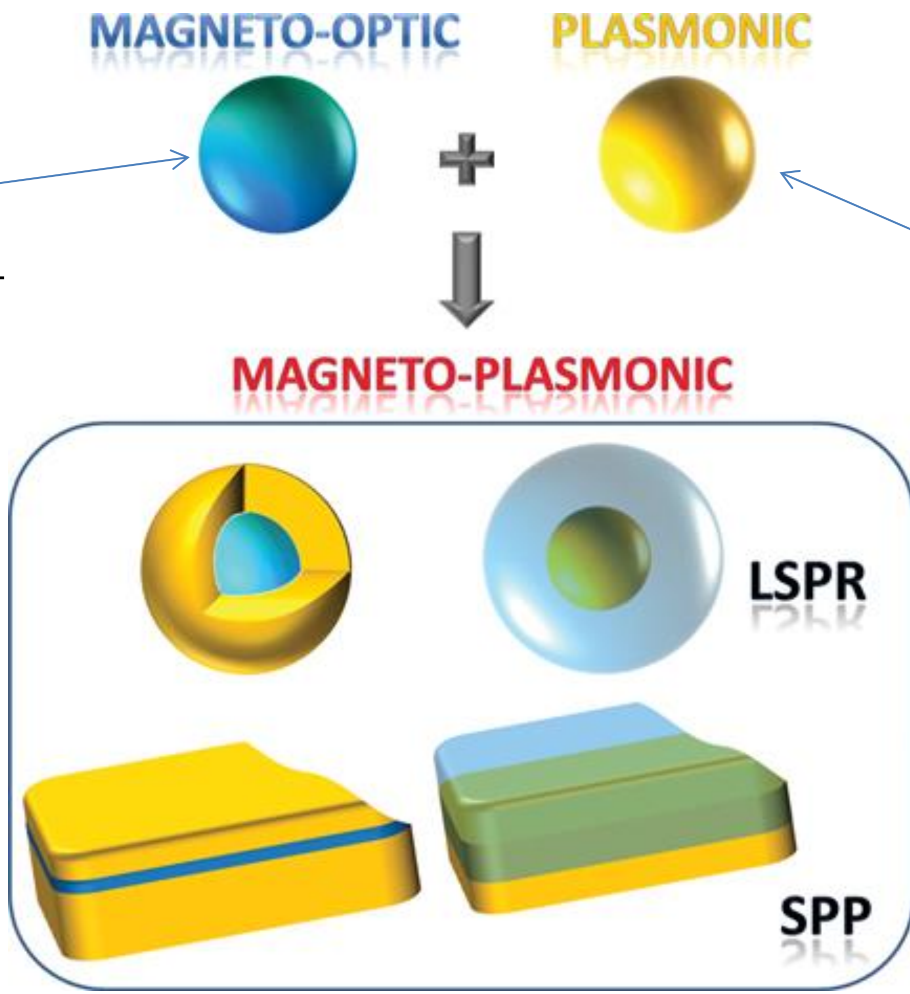
APPLICATION OF THIS TECHNIQUE TO OBTAIN NANOPLASMONIC ARCHITECTURES (not exhaustive)

Chalmers University: M.Käll (nanoplasmonics, chiral,…) , C.Langhammer (nanoplasmonics, sensing), A.Dmitriev (magnetoplasmonics Ni)

Universtity of Stuttgart: H.Giesseen (nanoplasmonics, chiral…)

IMM-Instituto de Microelectrónica de Madrid (multicomponent magneto-plasmonics, chiral ….)

Magnetoplasmonic systems



<u>Ferromagnetic metal:</u>
<u>Fe, Co.</u>

High MO activity at moderate magnetic fields.

But large optical absorption.

(garnets are good alternative candidates

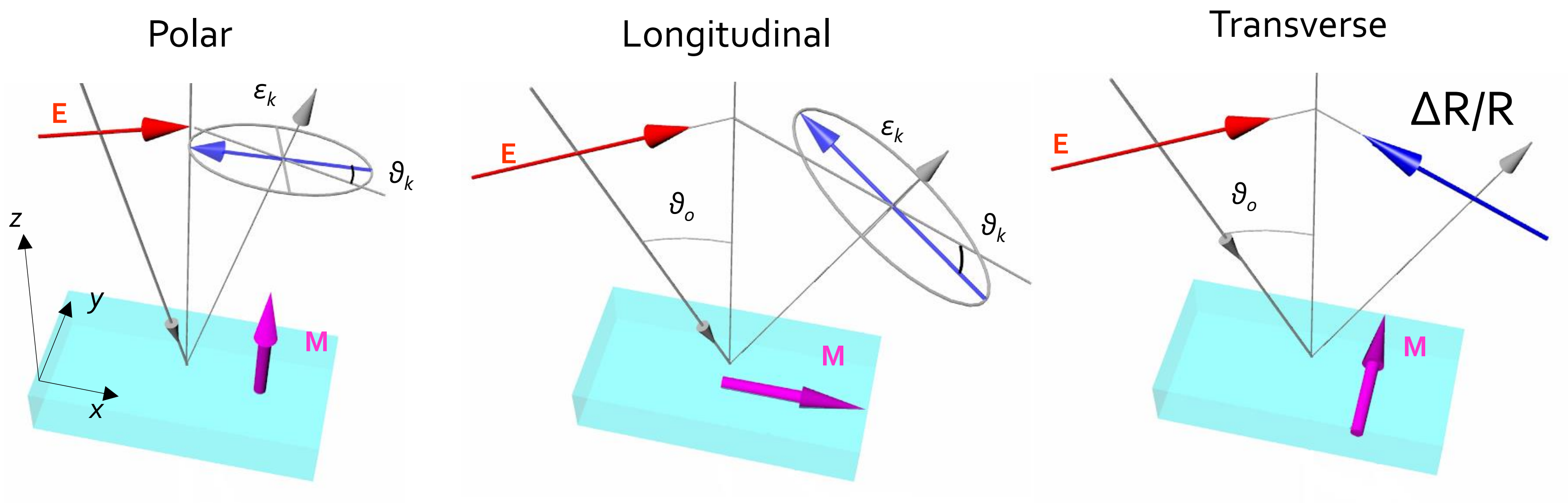
<u>Noble metal:</u>
<u>Au, Ag.</u>

Low optical absorption

But very small MO activity even at large magnetic fields

<u>By combining noble metals and ferromagnetic metals, systems with both magnetic and plasmonic functionalities are obtained.</u>

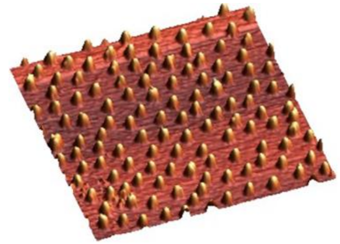
MO effects



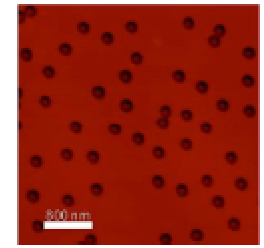
$$MO = |\Phi| = \sqrt{\theta^2 + \varepsilon^2}$$

Some examples of our "3D printed" nanostructures

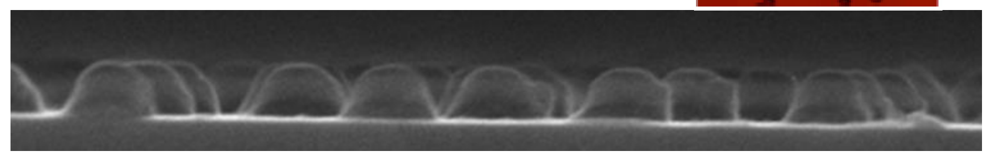
Metallic nanodisks (single resonant)



Membranes (localized + propagating plasmons + disk Babinet inverted)

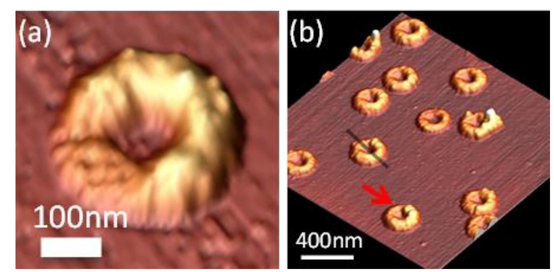


Metal-dielectric nanodisks (bimodal)

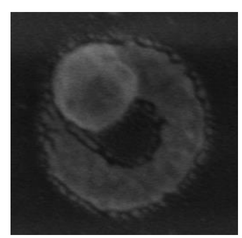


Metallic nanorods (bimodal)

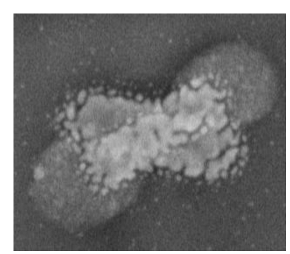
Rings and split rings on rings (bimodal + near IR + hot spot)



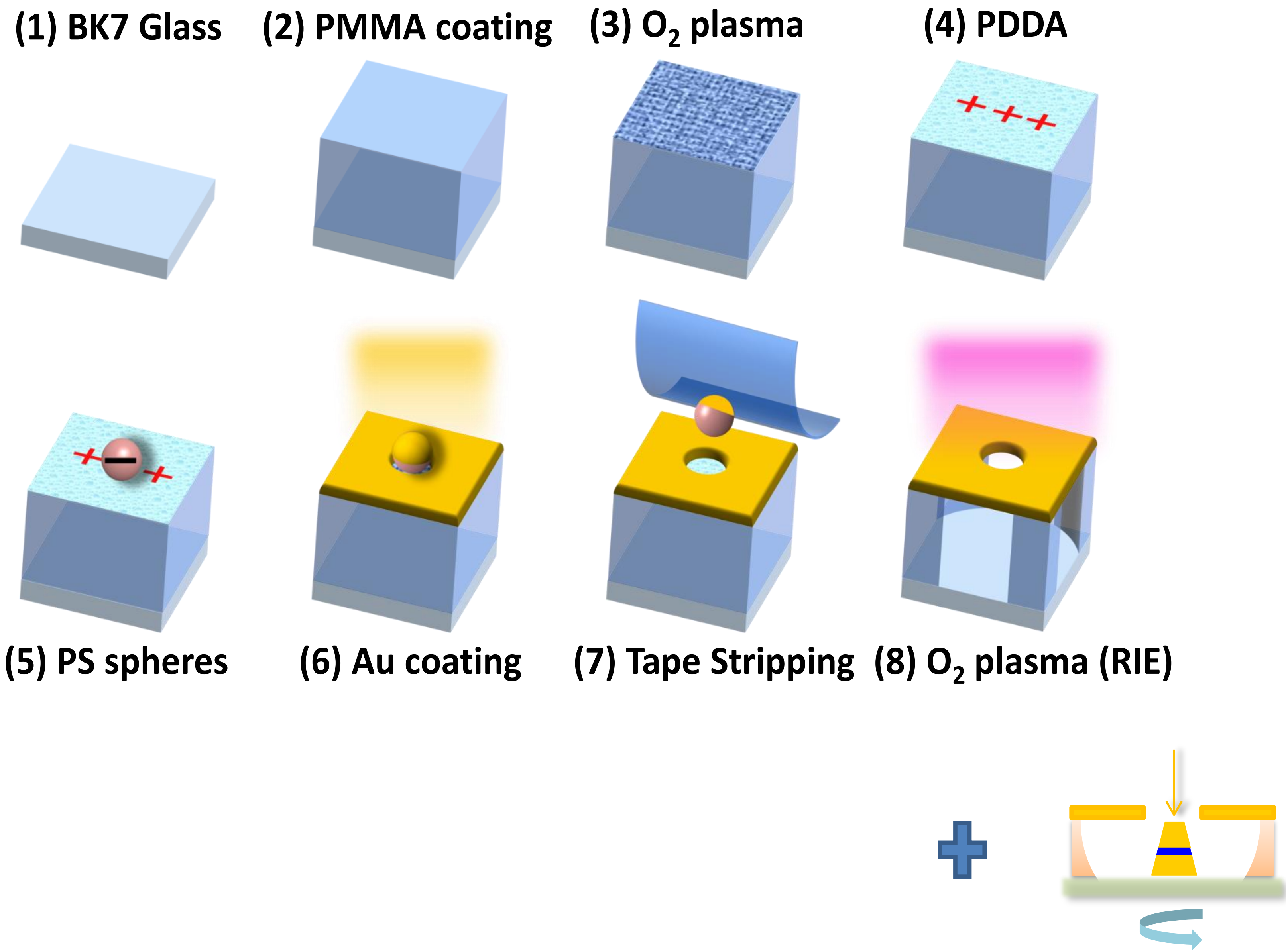
Chiral split ring-rings (bimodal + CD)



Chiral stacking of metallic rods (bimodal + CD)

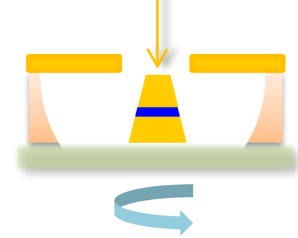


1.- NANODISKS

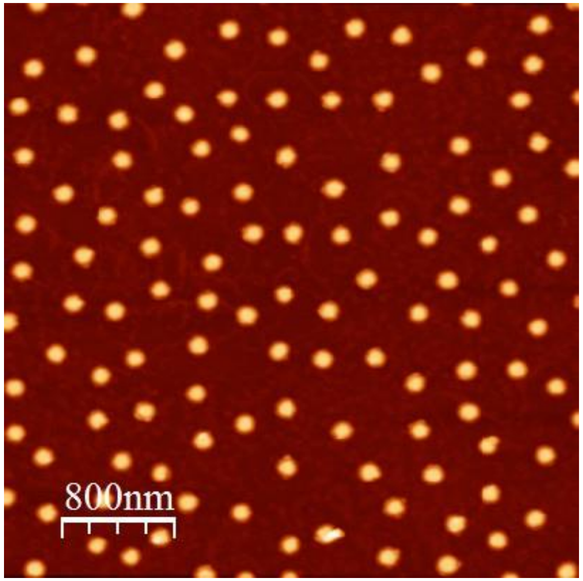


(1) BK7 Glass
(2) PMMA coating
(3) O_2 plasma
(4) PDDA
(5) PS spheres
(6) Au coating
(7) Tape Stripping
(8) O_2 plasma (RIE)

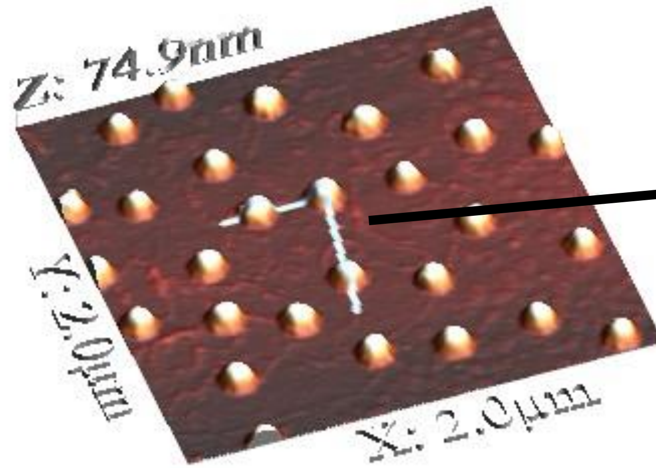
Metallic nanodisks: Au/Co/Au



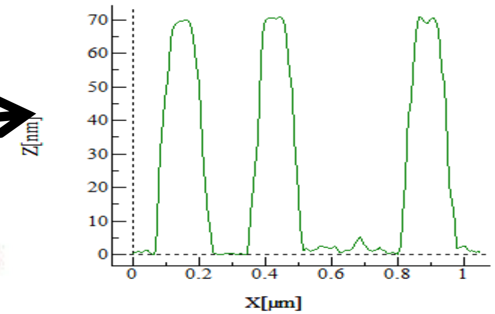
AFM image



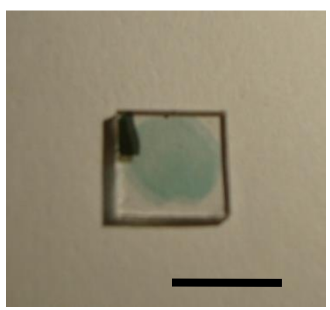
Ø≈130 nm, h ≈ 68 nm



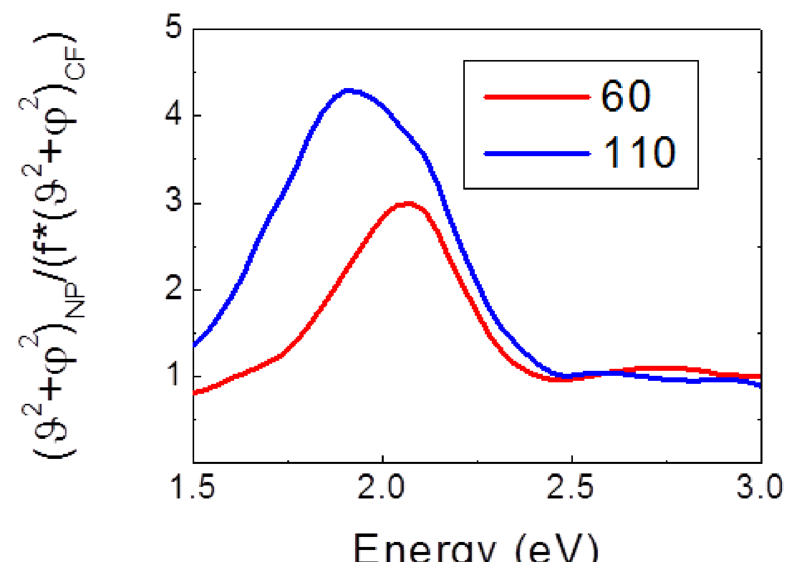
Height profile



- Homogeneous distribution & size distribution
- Size : controlled by PS diameter and deposition time
- Large Areas

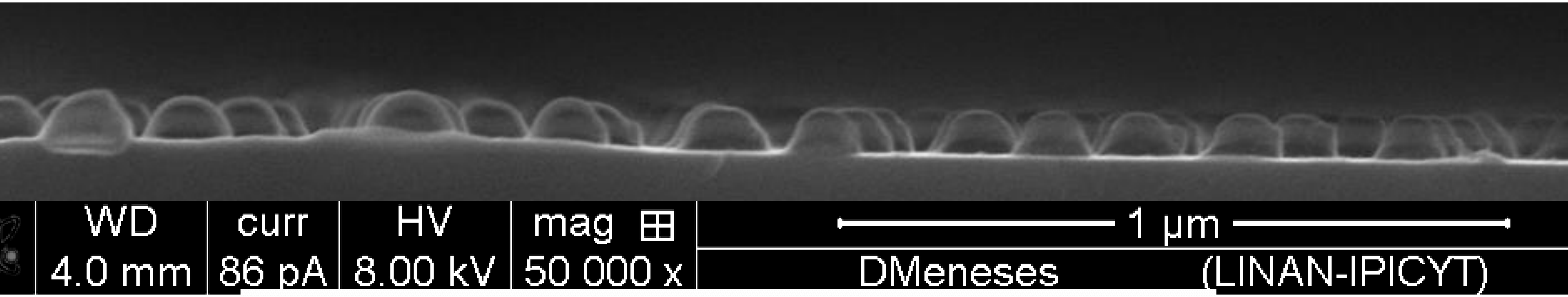


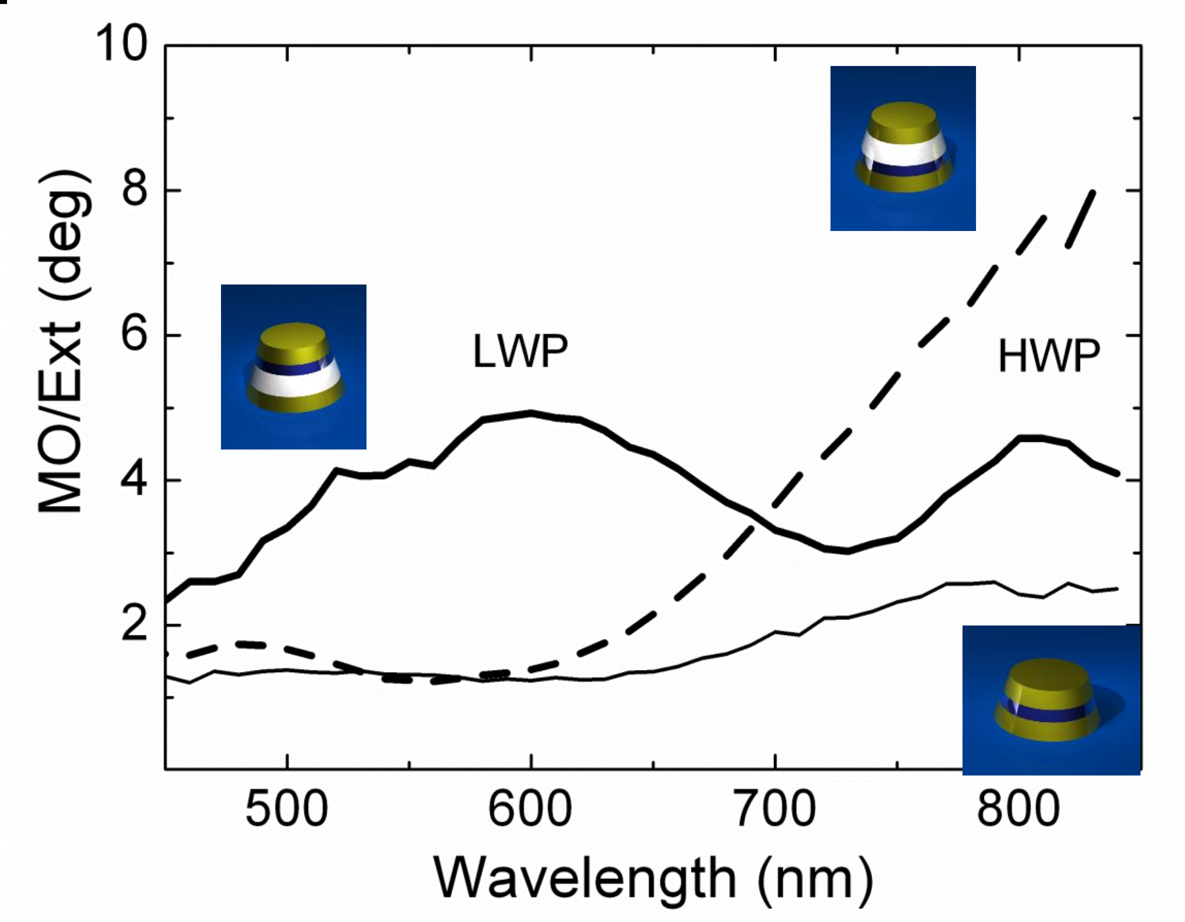
1 cm



J.B. González-Díaz, et al.; Small **4** (2008) 202

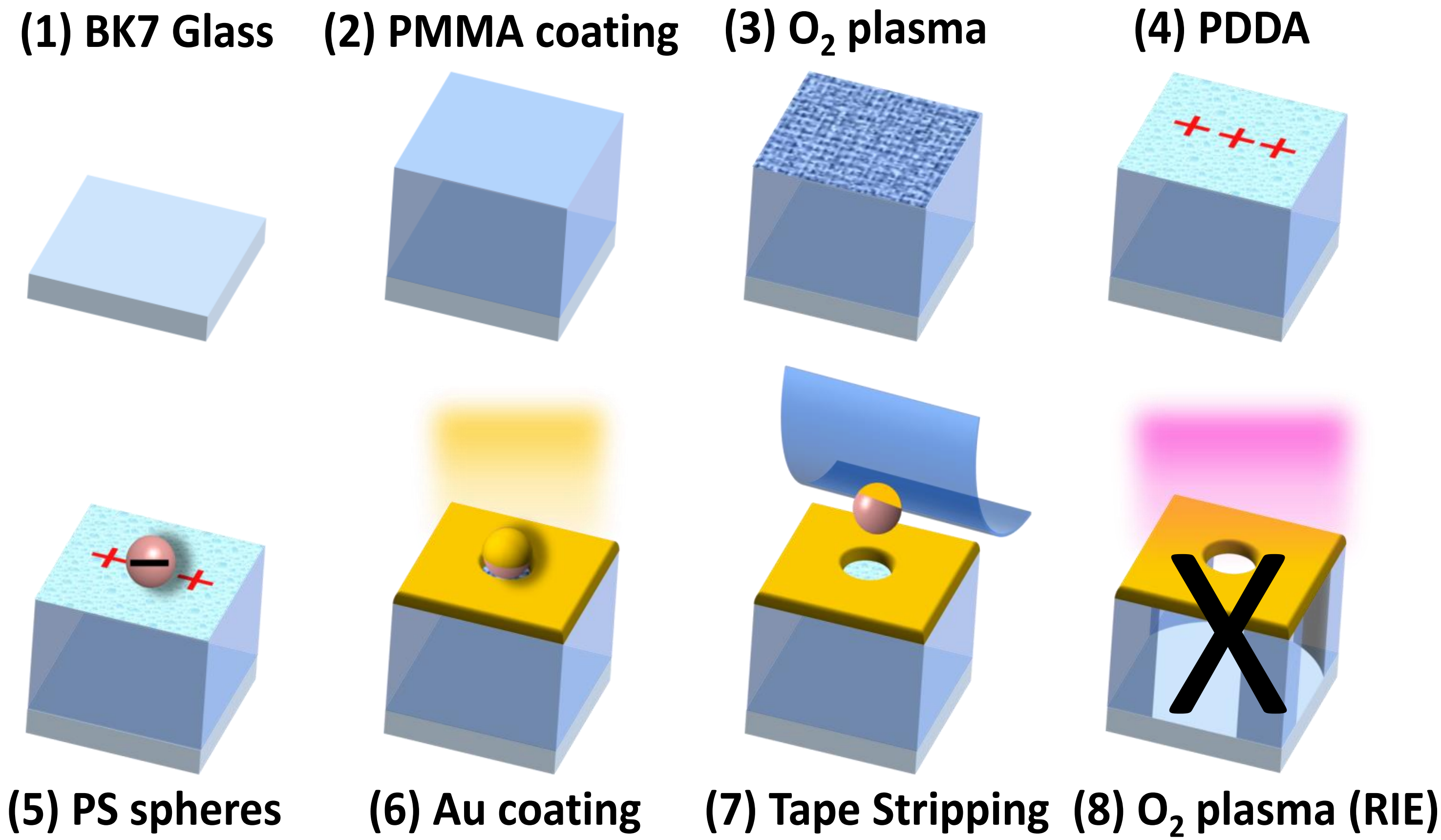
Metal-dielectric-Metal nanodisks: Au/Co/Cu – SiO_2





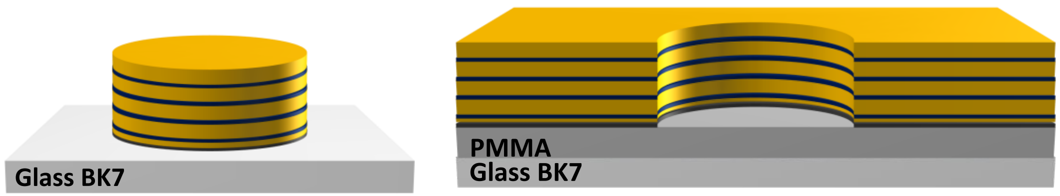
J.C. Banthí et al., *Adv. Mater.* **2012**, 24, OP36

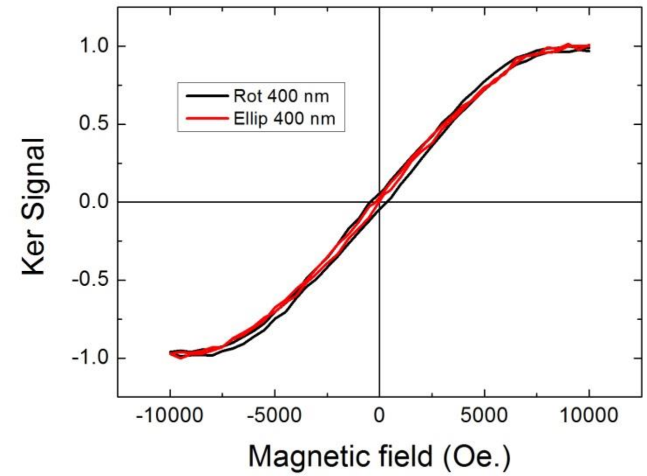
2.- MEMBRANES

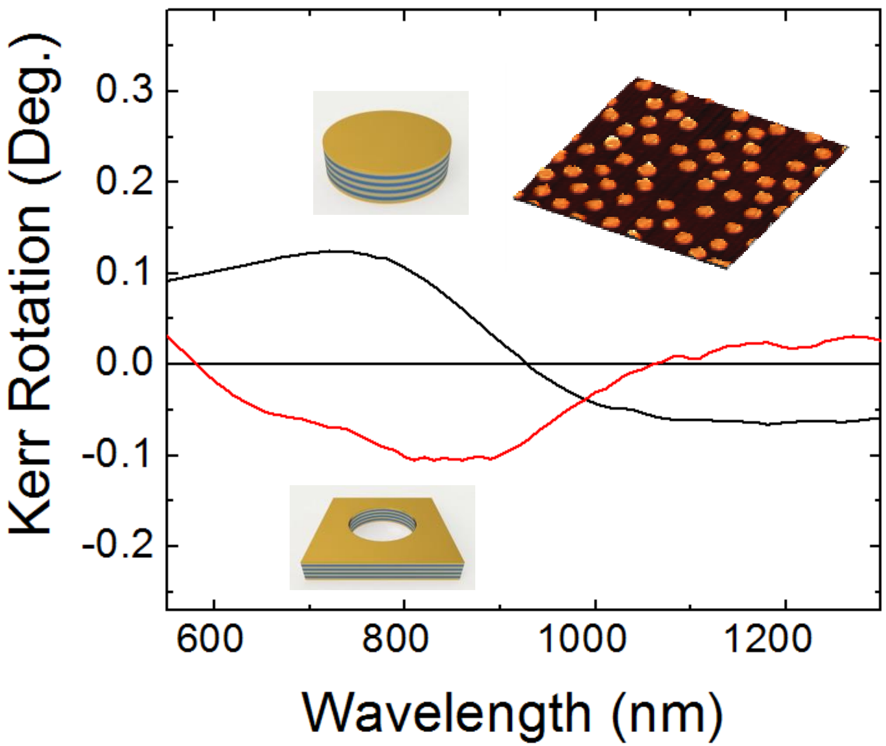


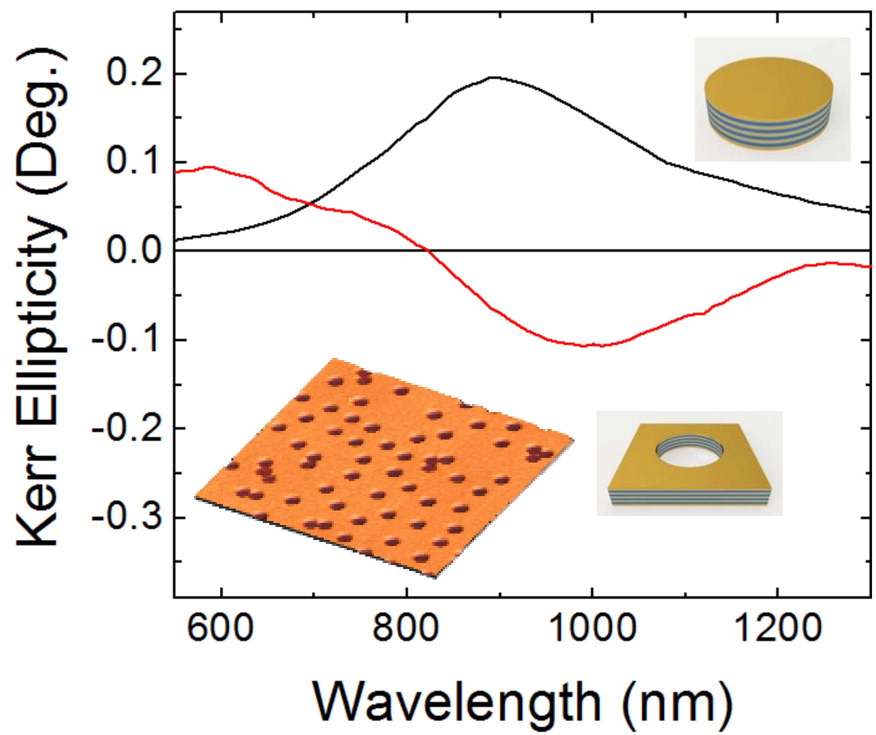
(1) BK7 Glass
(2) PMMA coating
(3) O_2 plasma
(4) PDDA
(5) PS spheres
(6) Au coating
(7) Tape Stripping
(8) O_2 plasma (RIE)

Babinet inverted Au/Co multilayers
(Perpendicular magnetic ansitoropy)



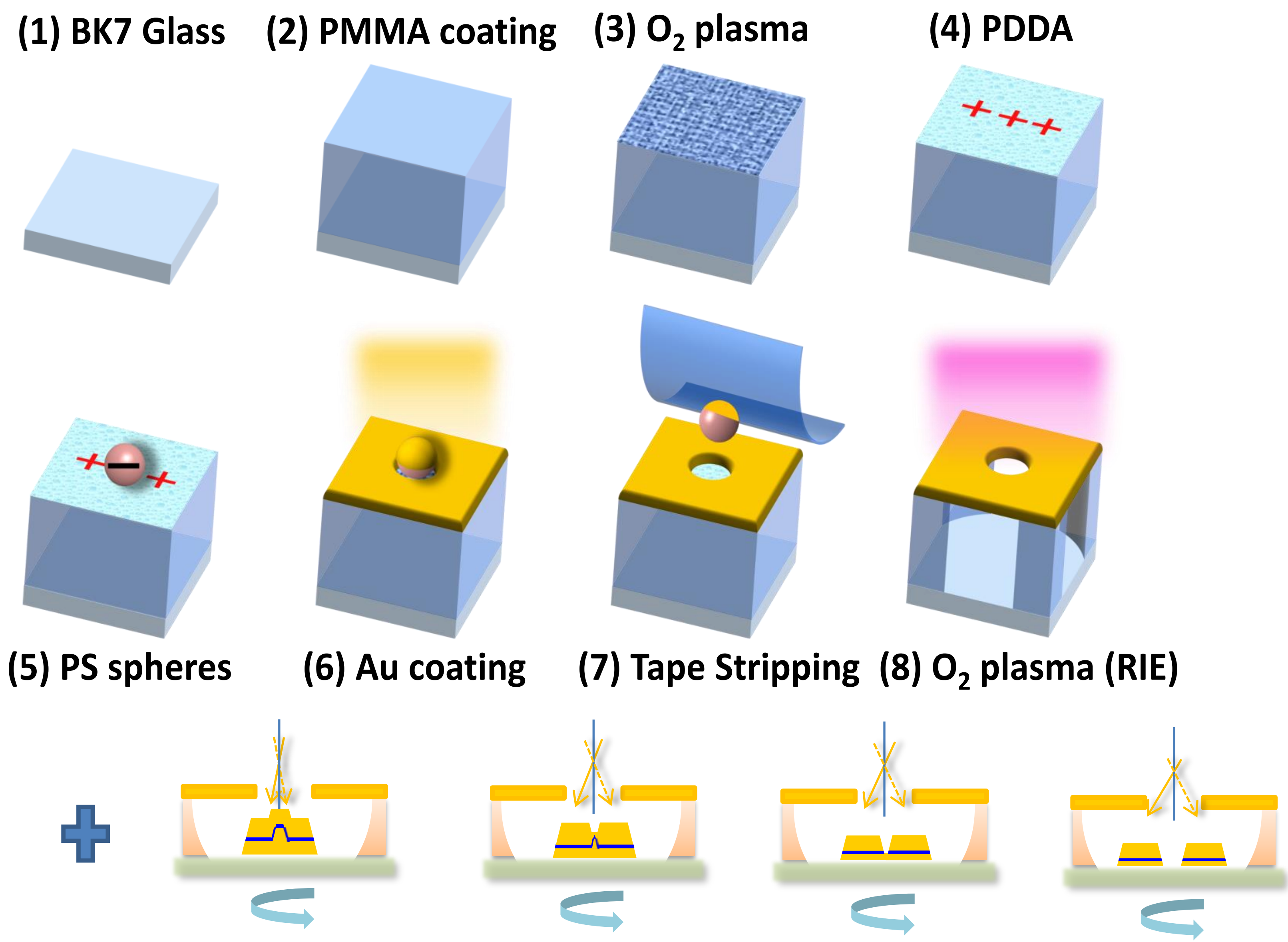






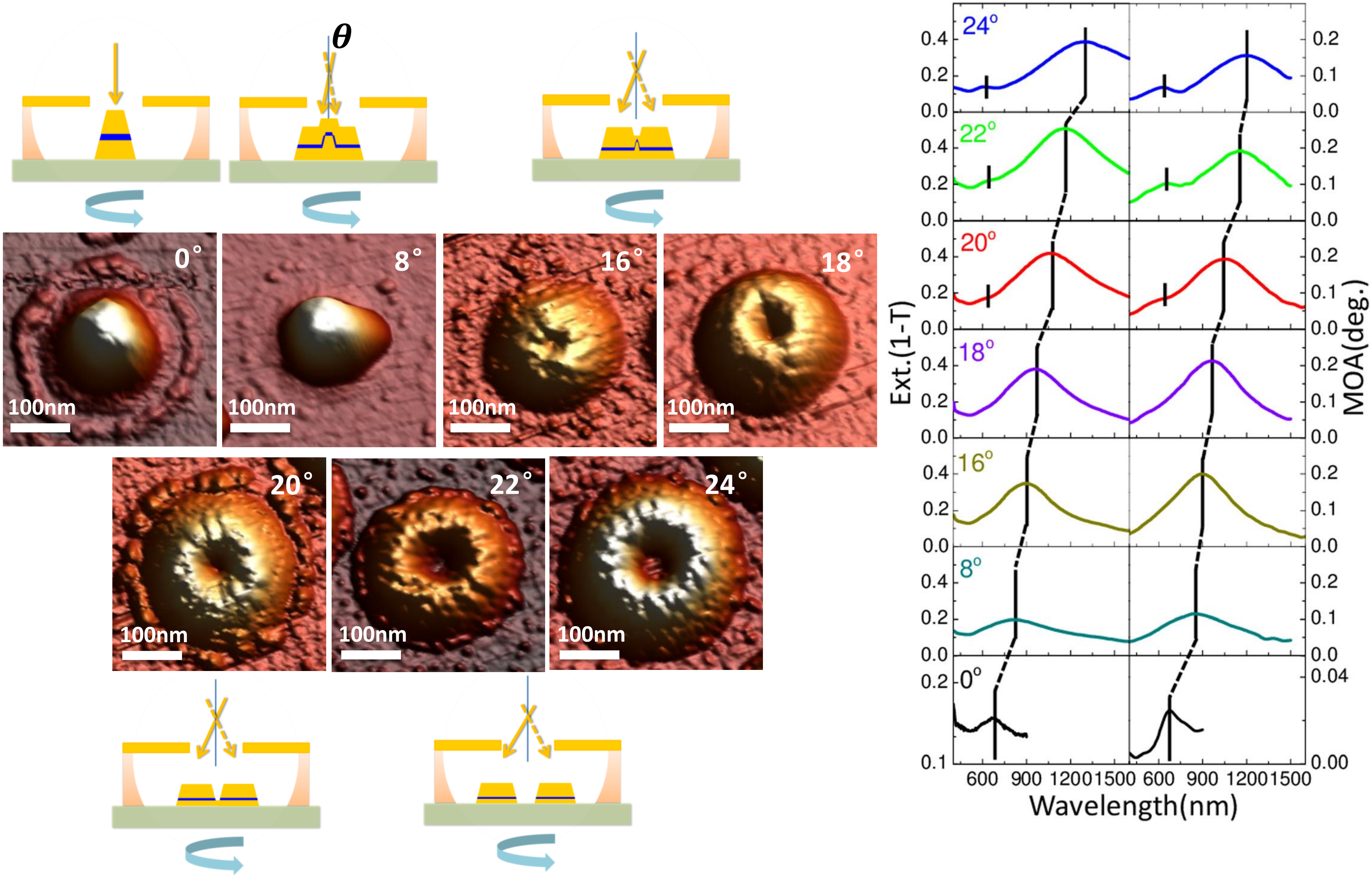
Armelles et al. Nano Letters **15** (2015) 2045

3.- NANORINGS



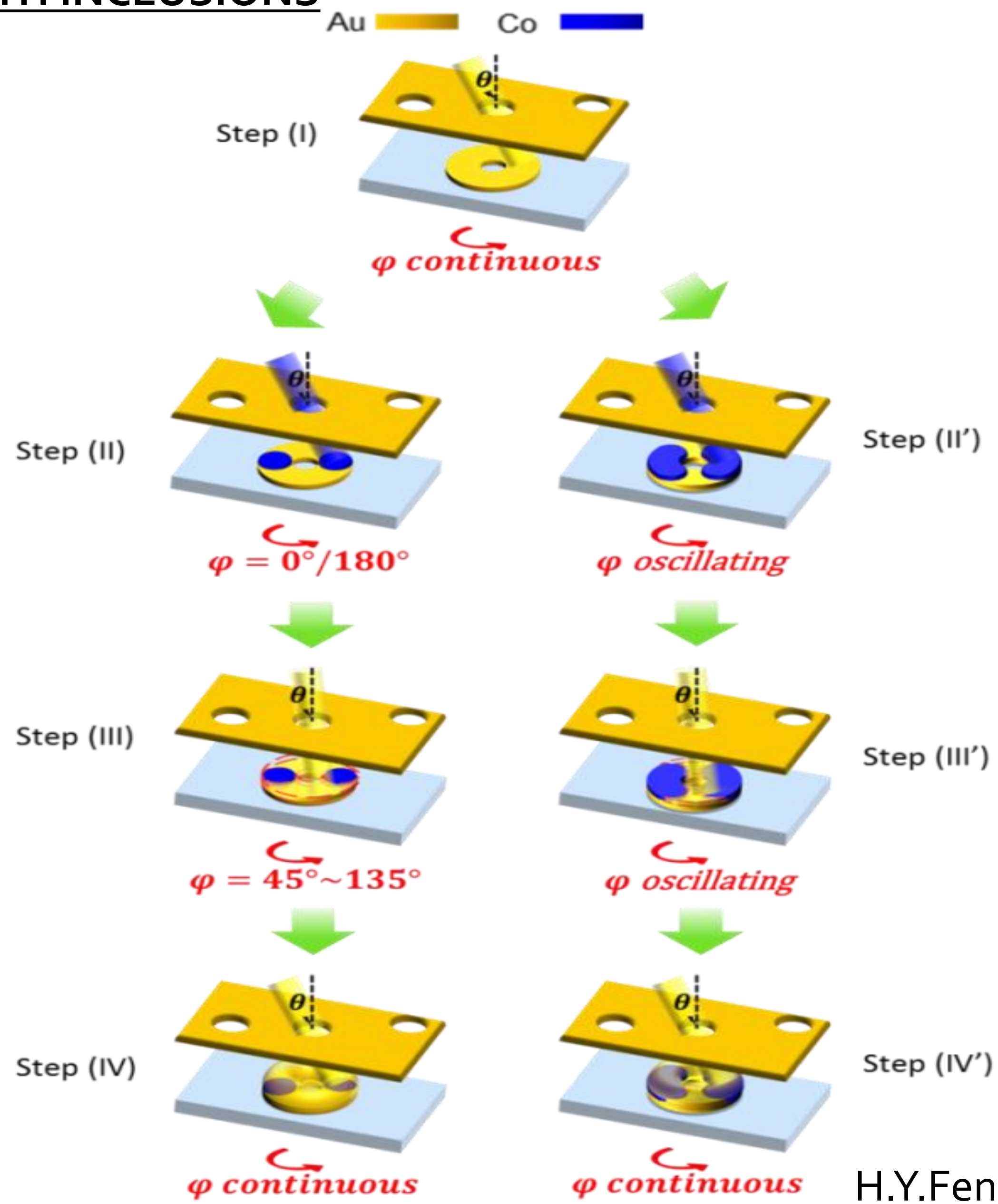
(1) BK7 Glass
(2) PMMA coating
(3) O_2 plasma
(4) PDDA
(5) PS spheres
(6) Au coating
(7) Tape Stripping
(8) O_2 plasma (RIE)

FROM NANODISK TO NANORING (Au/Co/Au)

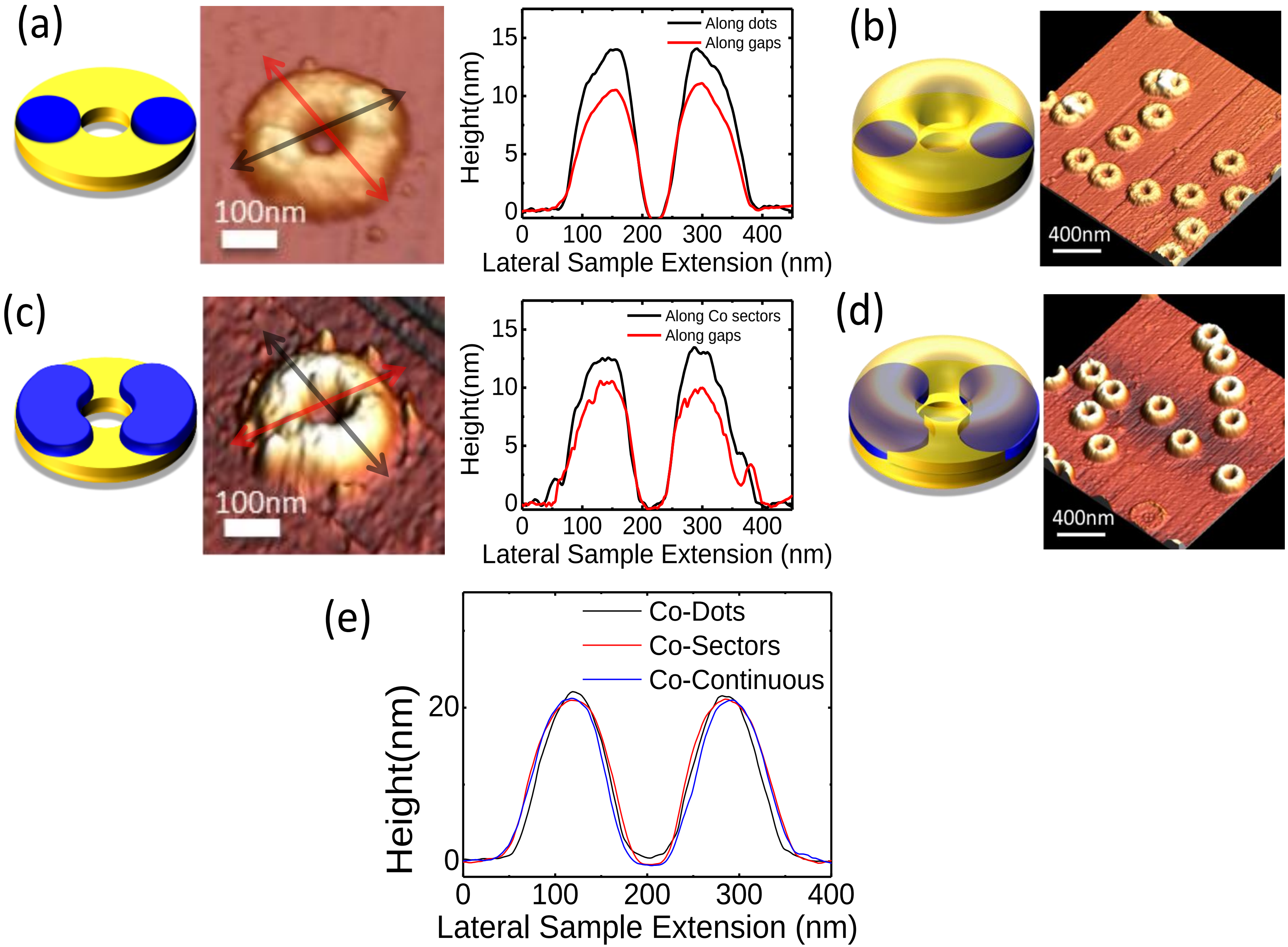


H.Y.Feng Thesis (et al., APL 106 (2015) 083105)

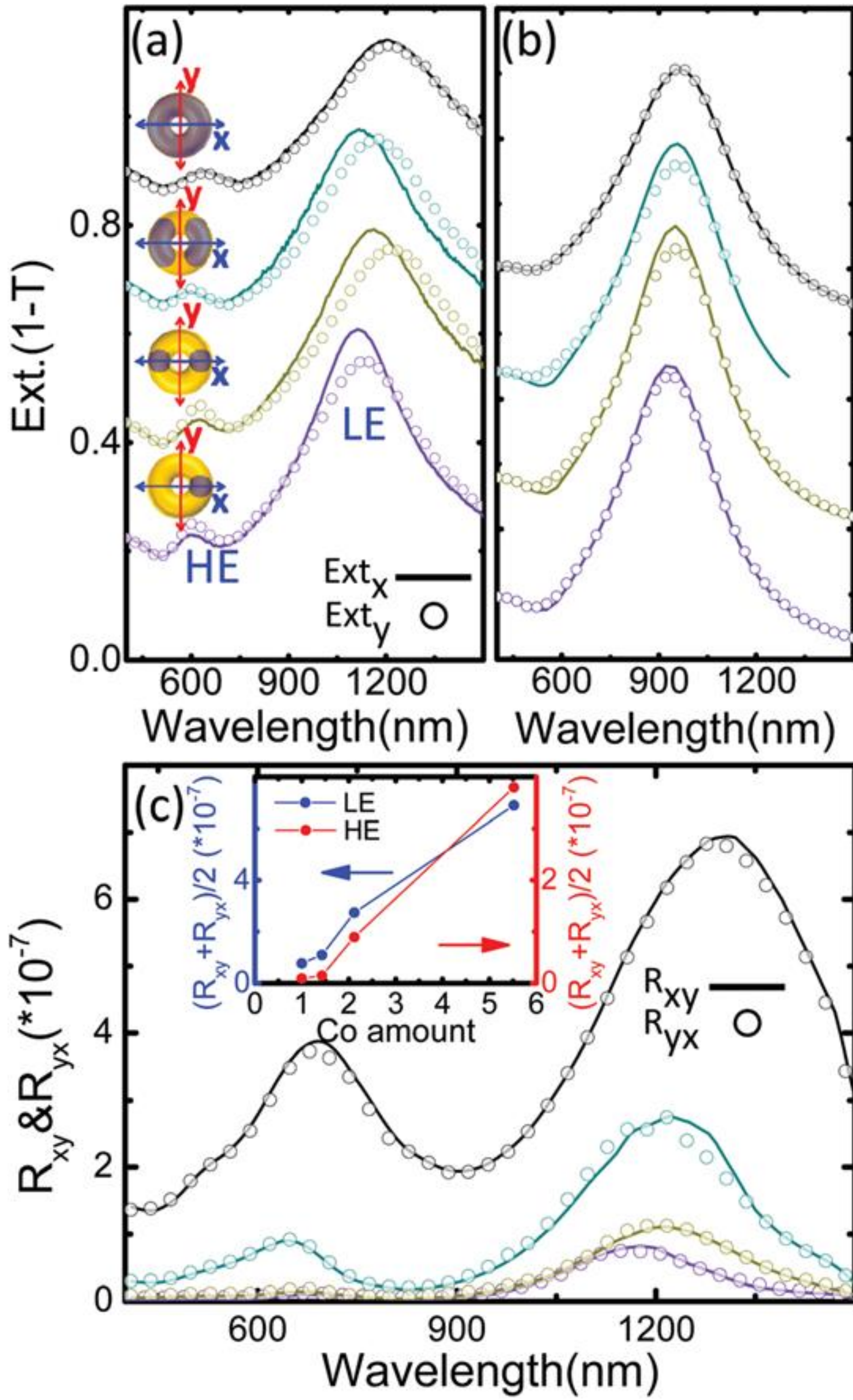
NANORINGS WITH INCLUSIONS



H.Y.Feng Thesis (et al., Nanoscale **9** (2017) 37)

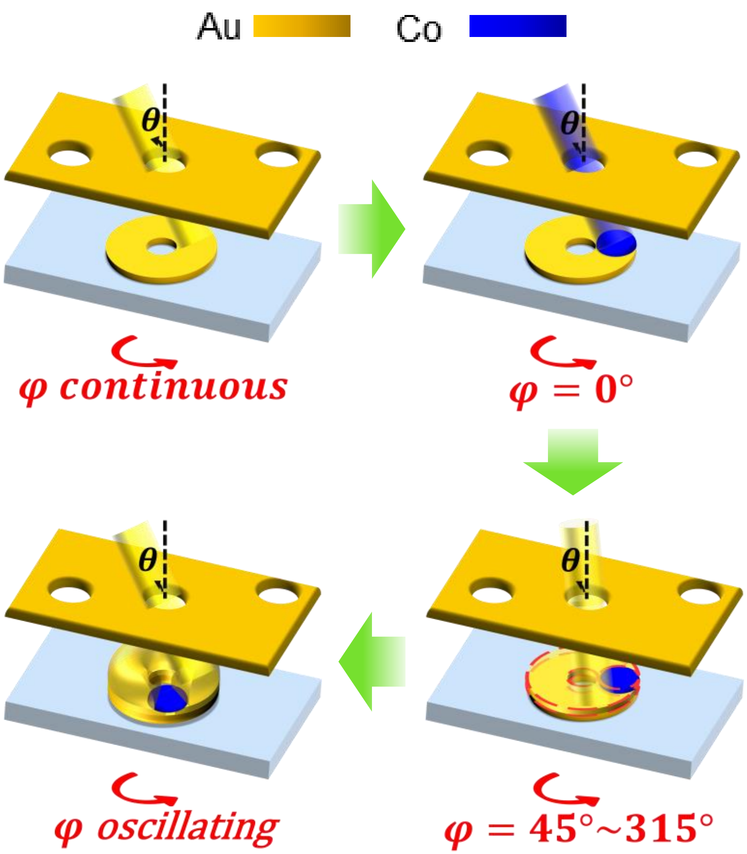


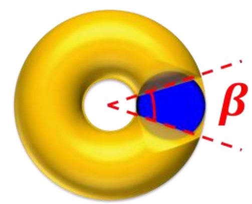
H.Y.Feng Thesis (et al., Nanoscale **9** (2017) 37)

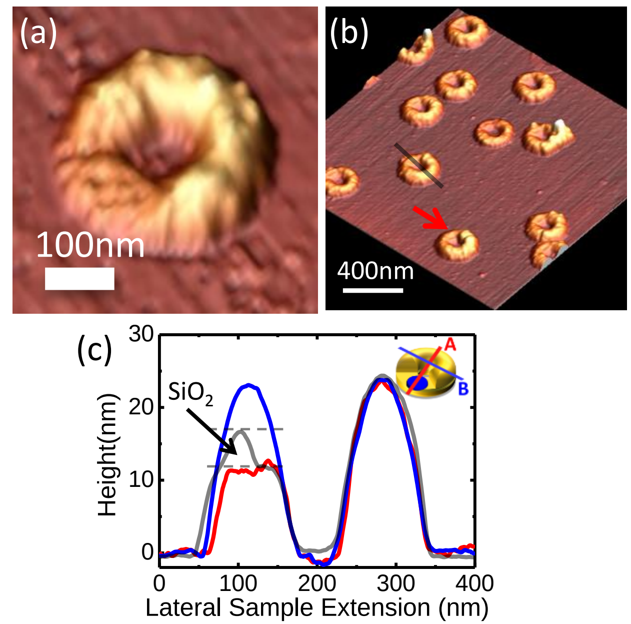


H.Y.Feng Thesis (et al., Nanoscale **9** (2017) 37)

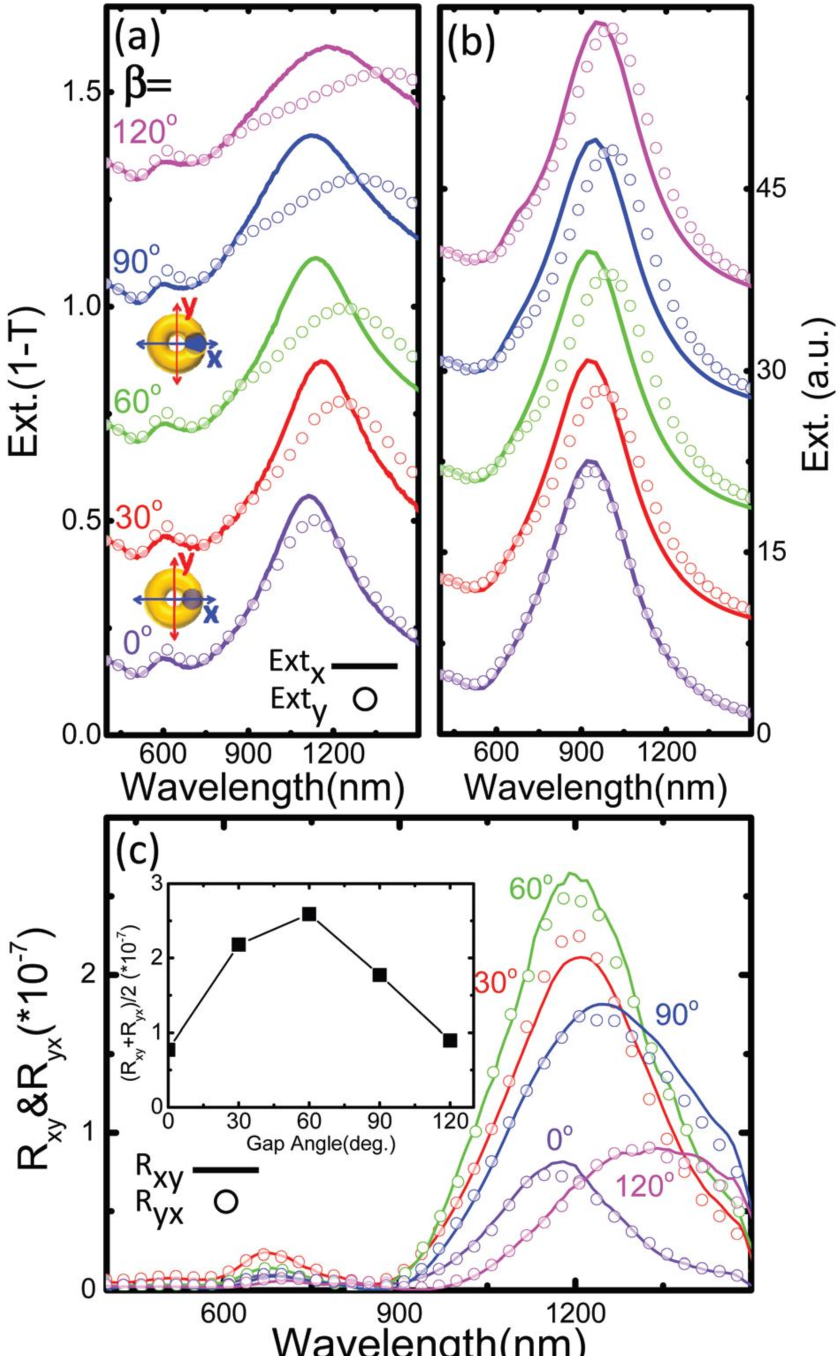
3.- NANORINGS WITH INCLUSIONS + SPLIT RINGS







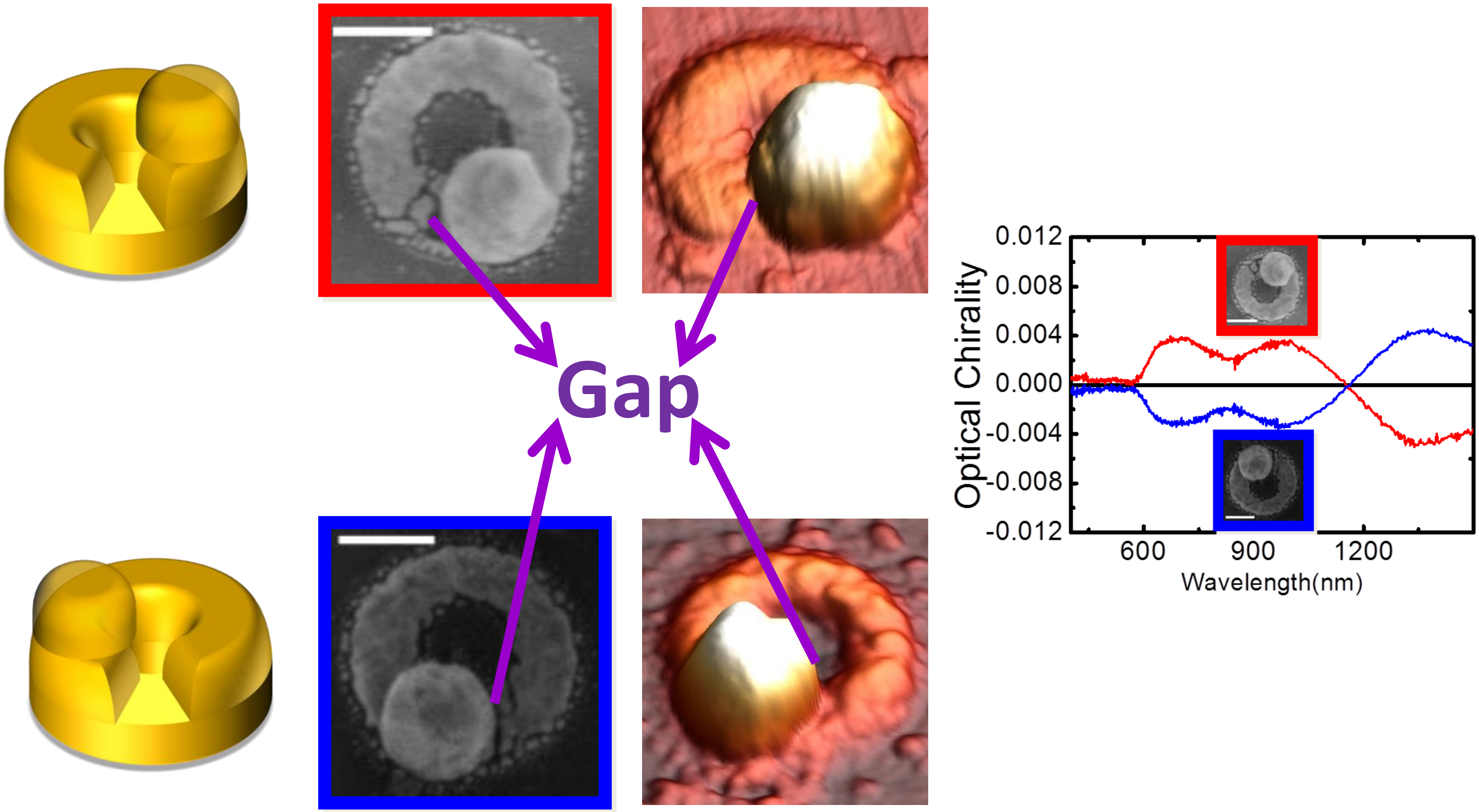
H.Y.Feng Thesis (et al., Nanoscale **9** (2017) 37)



MAXIMUM MO ACTIVITY FOR 60º GAP OPENING

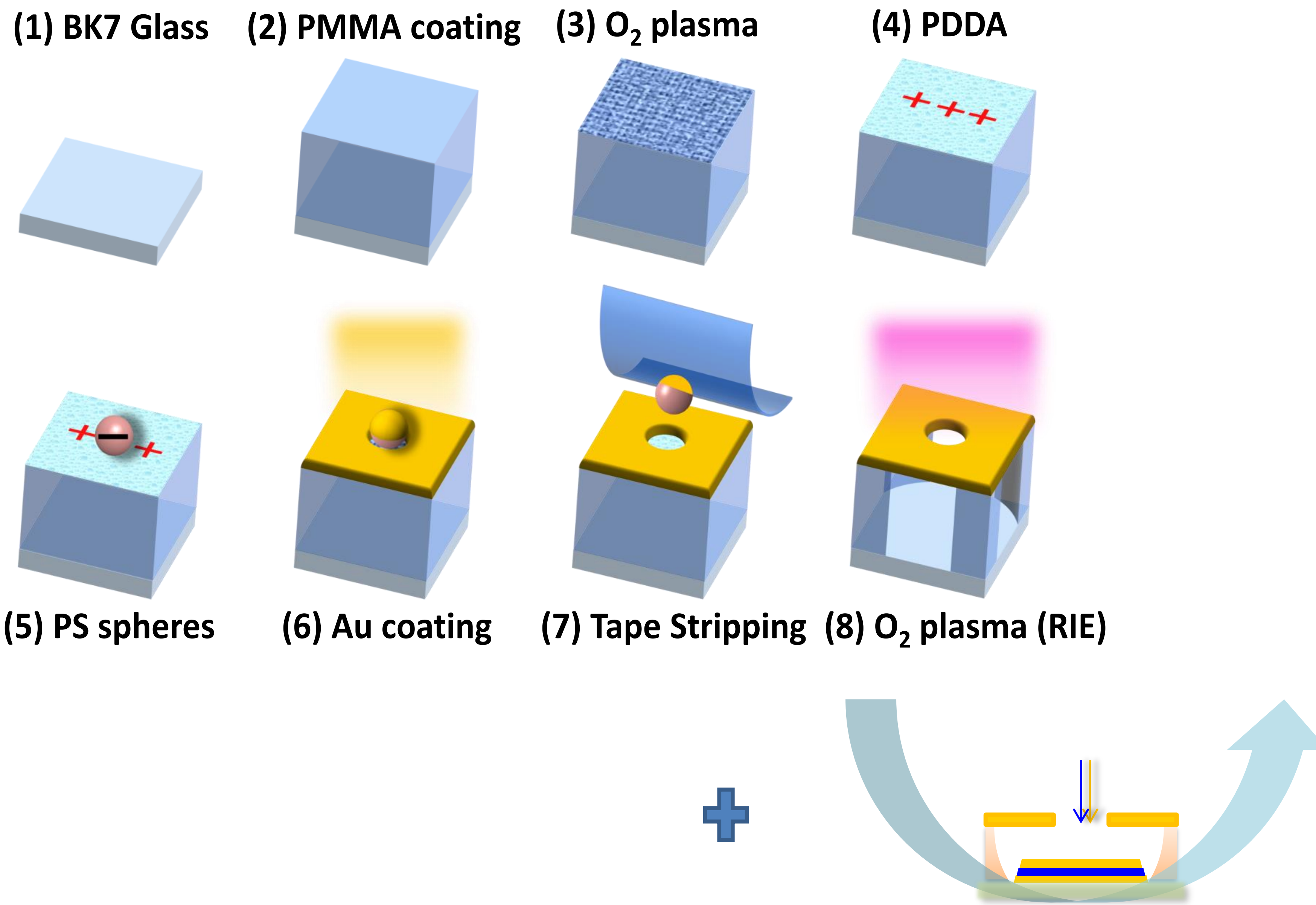
H.Y.Feng Thesis (et al., Nanoscale **9** (2017) 37)

3.- CHIRAL SPLIT RING – RING STRUCTRUES (Wed. 08; 18:30 (PhD student talk) Optical Chirality in the Stacked 3D Ring-Split Ring Nanostructure Hua Yu Feng)



Scale bar: 100nm

4.- NANORODS


(1) BK7 Glass
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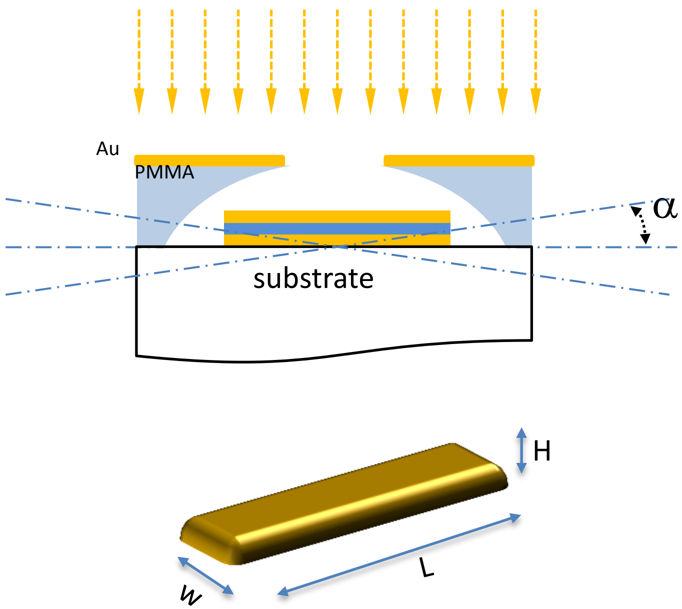
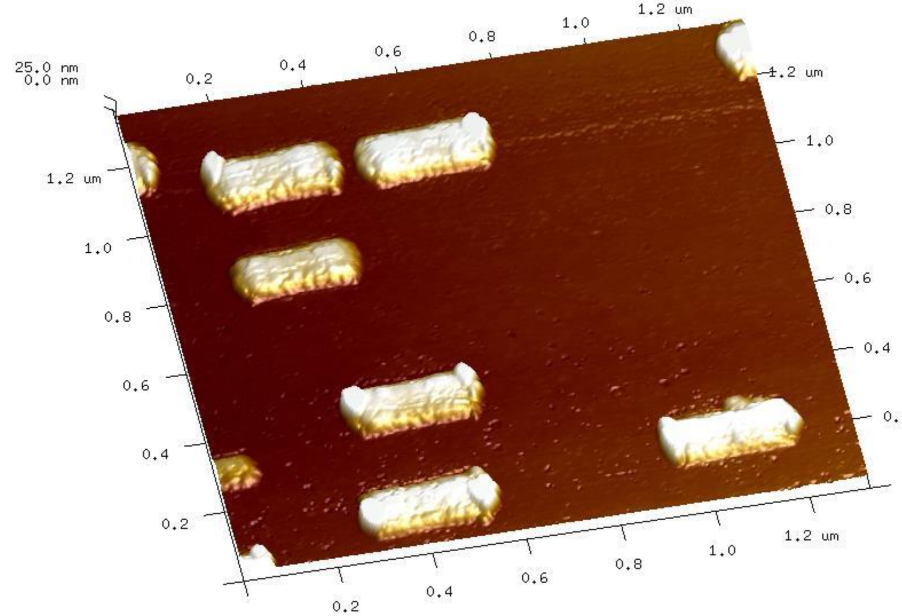
(8) O_2 plasma (RIE)

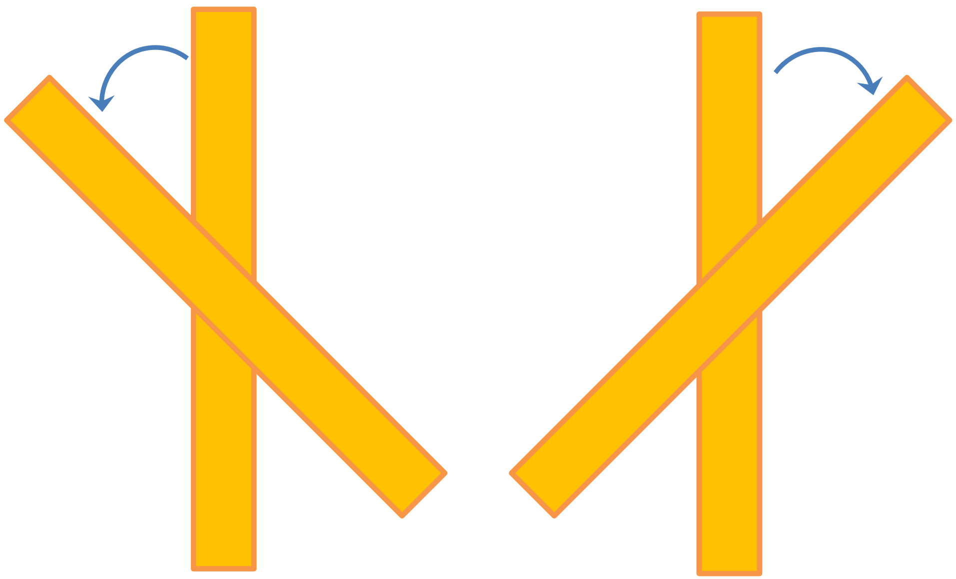
Nanorods.

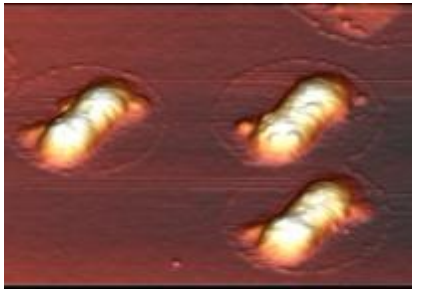


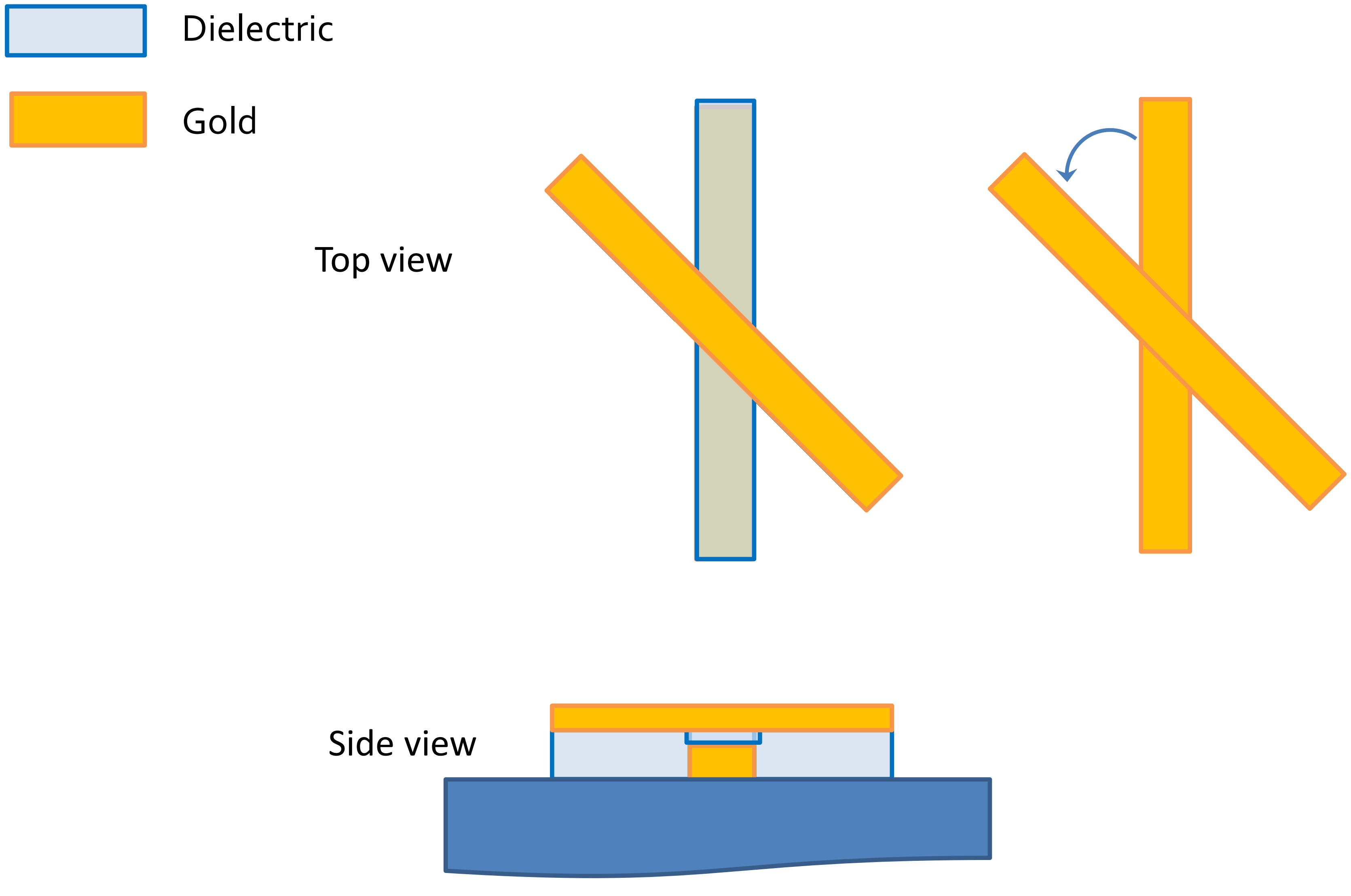


Armelles et al. ACS Photonics 3 (2016) 2427

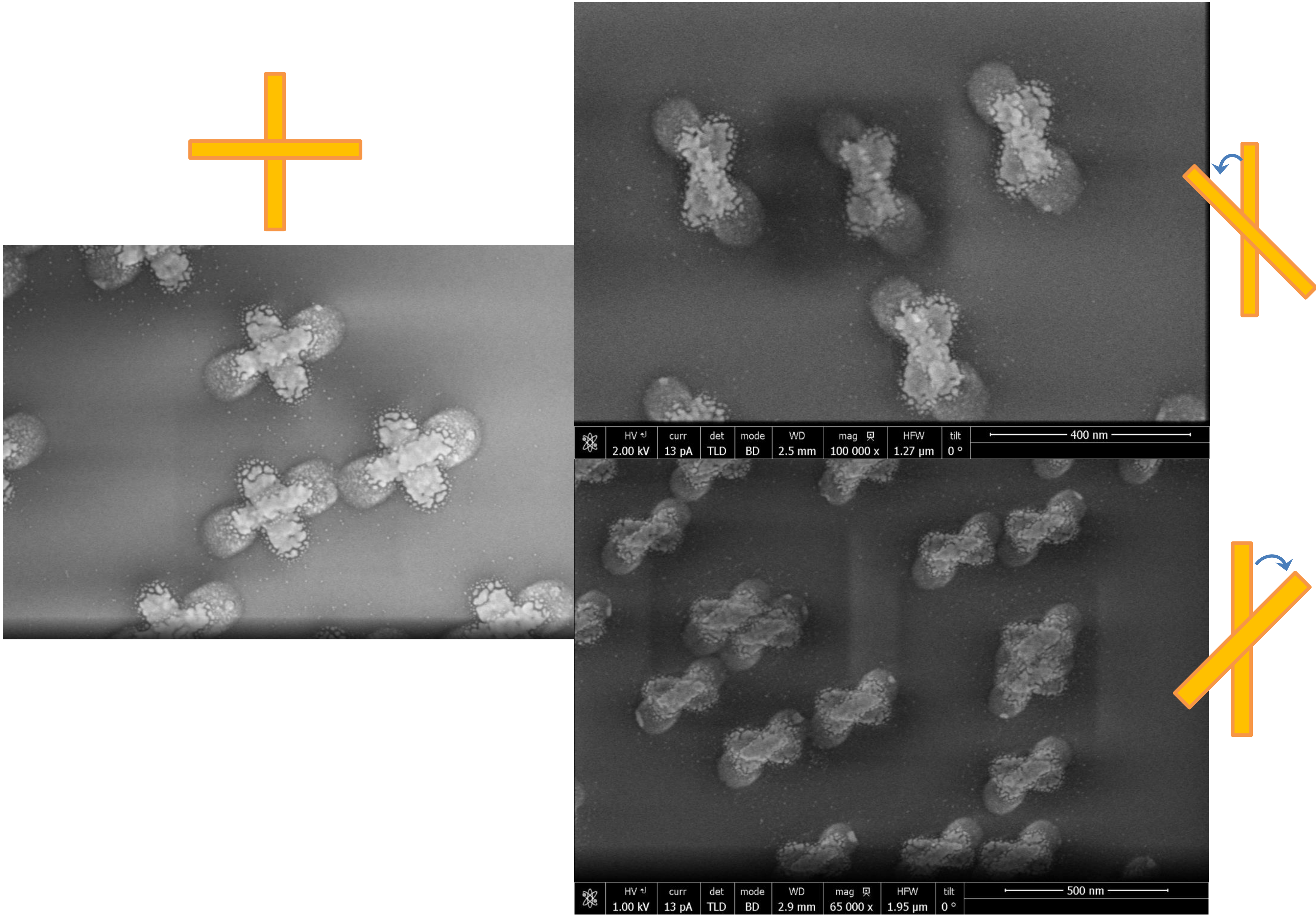
4. CHIRAL STACKING OF PLASMONIC RODS (Thu. 09; 11:30 (Poster)
Growth and characterization of chiral gold nanorods .Carolina De Dios)







Dielectric
Gold
Top view
Side view


HV 2.00 kV
curr 13 pA
det TLD
mode BD
WD 2.5 mm
mag 100 000 x
HFW 1.27 µm
tilt 0 °
400 nm
HV 1.00 kV
curr 13 pA
det TLD
mode BD
WD 2.9 mm
mag 65 000 x
HFW 1.95 µm
tilt 0 °
500 nm


PORTLANDIA
TV 14
We can pickle that.

Mr. Mayor (Kyle MacLachlan) tries to solve Portland's problems with a 3D printer.

THANKS!

We acknowledge funding from the Spanish MINECO (CSD2008-00023, MAT2014-58860-P).
H. Y. Feng acknowledges funding from CSC (Chinese Scholarship Council), grant no. 201206220112.
We acknowledge the service from the X-SEM Laboratory and MiNa Laboratory at IMMat IMM, and funding from MINECO under projects CSIC13-4E-1794 and S2013/ICE-2822 (Space-Tec) with support from EU (FEDER, FSE).