Magneto-plasmonic Au/$Tb_{18}Co_{82}$ nano-ring resonators

Initial patterning and update by Agnė Čiučiulkaitė

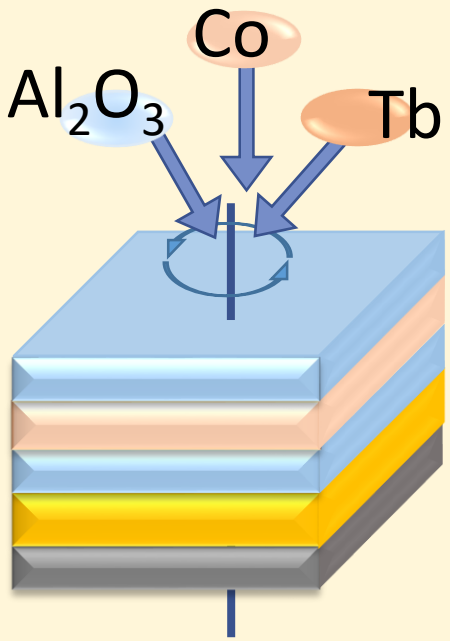
Uppsala University

Motivation

- Fabricate magneto-plasmonic nano-antenna arrays for all-optical switching of magnetization via focusing circularly polarised light
- Possible geometry for focusing circularly polarised light – nano-ring

$Tb_{18}Co_{82}$ amorphous layers

- Magnetron sputtering of AlO_x(2 nm)/$Tb_{18}Co_{82}$(18 nm)/AlO_x(2 nm) on fused silica/Au(20 nm)



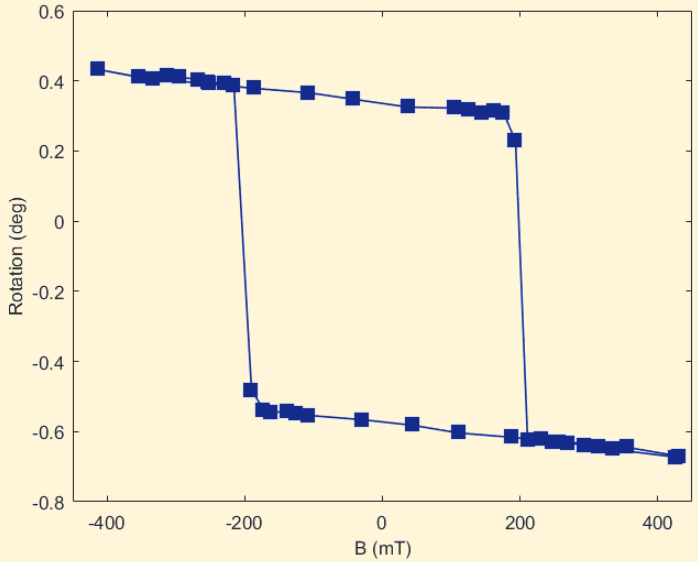
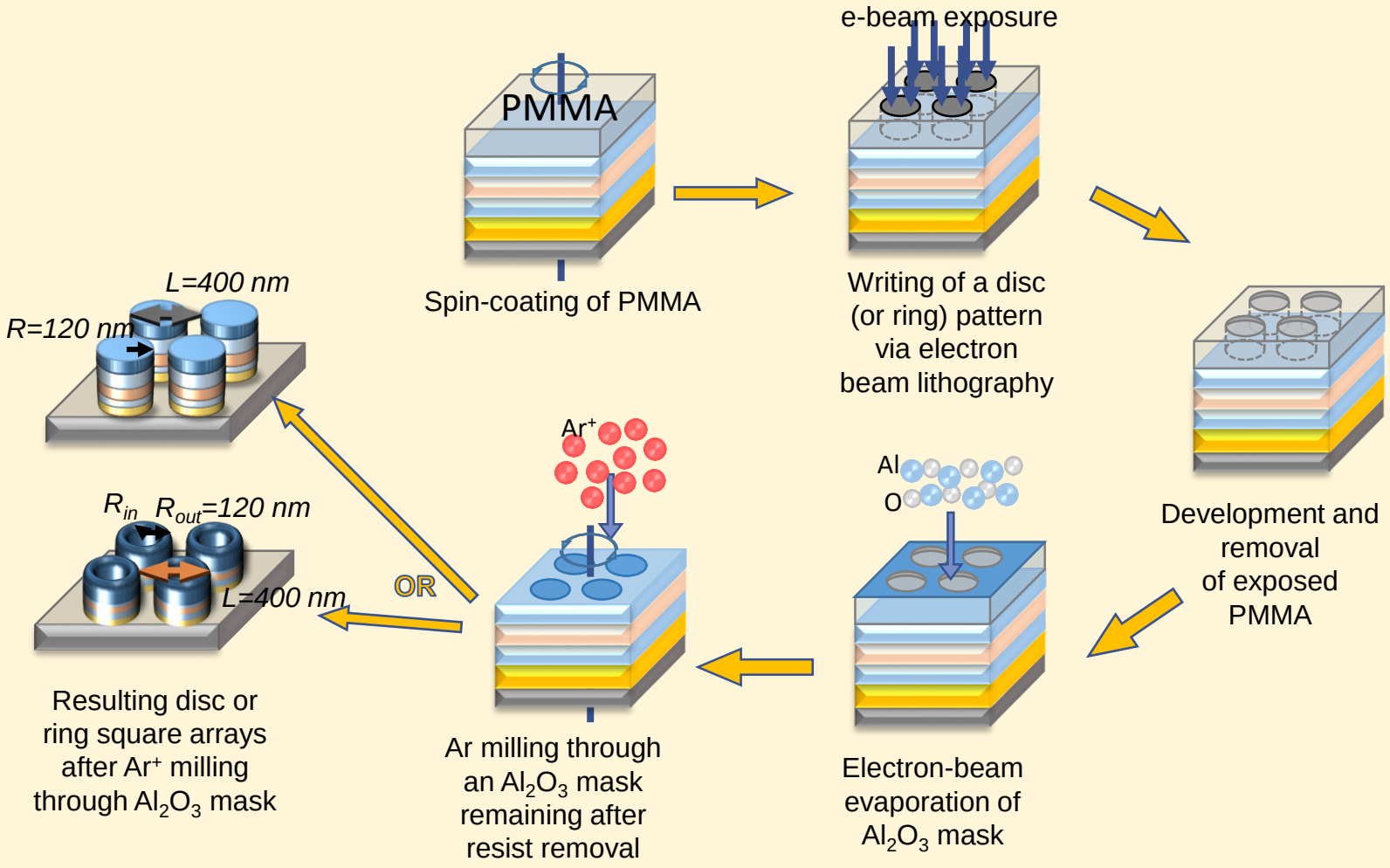


Figure 1. Faraday rotation measured at 600 nm wavelength of incident light for the hybrid structure film

Patterning


PMMA
Spin-coating of PMMA
e-beam exposure
Writing of a disc (or ring) pattern via electron beam lithography
Development and removal of exposed PMMA
Al
O
Electron-beam evaporation of Al_2O_3 mask
Ar^+
Ar milling through an Al_2O_3 mask remaining after resist removal
OR
L=400 nm
R=120 nm
Resulting disc or ring square arrays after Ar^+ milling through Al_2O_3 mask
R_{in} R_{out}=120 nm
L=400 nm

Characterization

- Scanning electron microscopy (SEM)
- Optical transmission measurements
- Spectroscopic Faraday rotation measurements

Scanning electron microscopy (SEM)

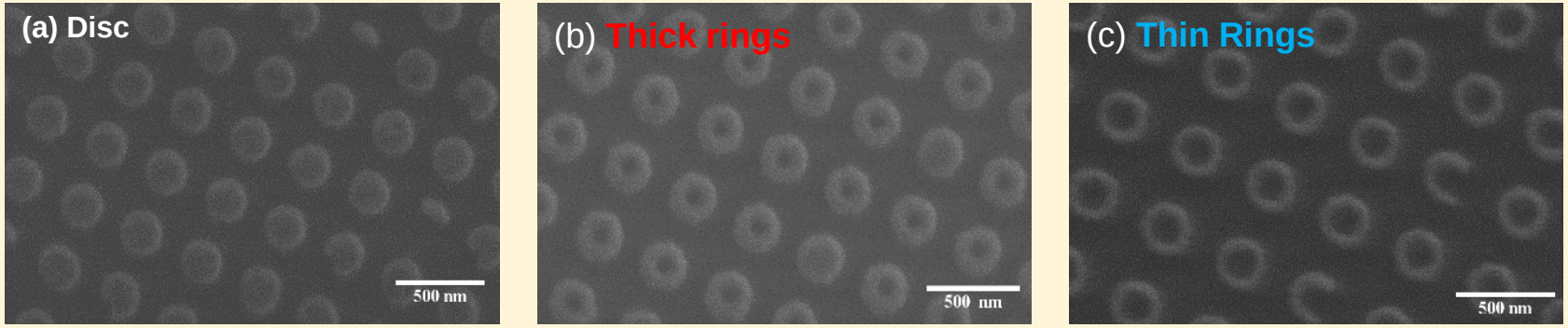


Figure 2. SEM micrographs of EBL patterned (a) disc, (b) donut and (c) ring arrays.

Sample	Nominal radius*		Actual radius**	
	R_{out}, nm	R_{in}, nm	R_{out}, nm	R_{in}, nm
a	120	40	125±5	0
b		60	126±5	30±5
c		80	123±5	60±5
Broken rings***		100	"Broken"	"Broken"

*Nominal radius → from the patterning file
**Actual radius → dimensions measured from SEM micrographs
***Not shown, can be found in Additional information

Optical transmission measurements

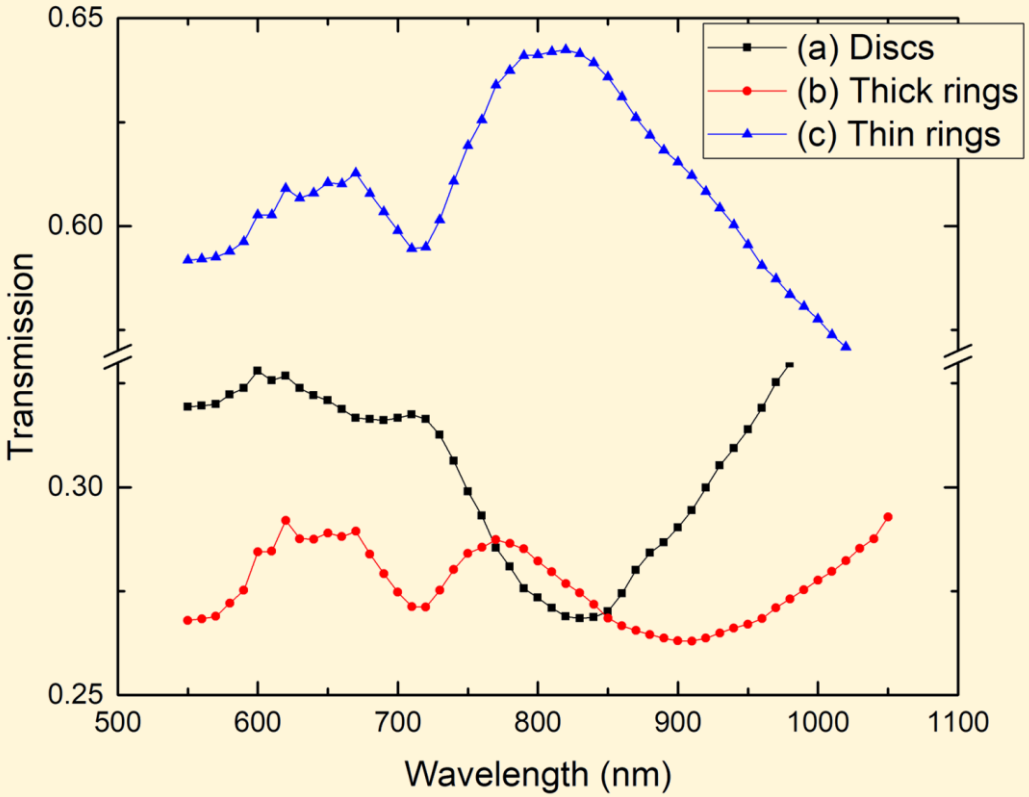


Figure 3. Optical transmission measurements of nano-arrays shown in Fig.2.

Spectroscopic Faraday rotation measurements: Schematics

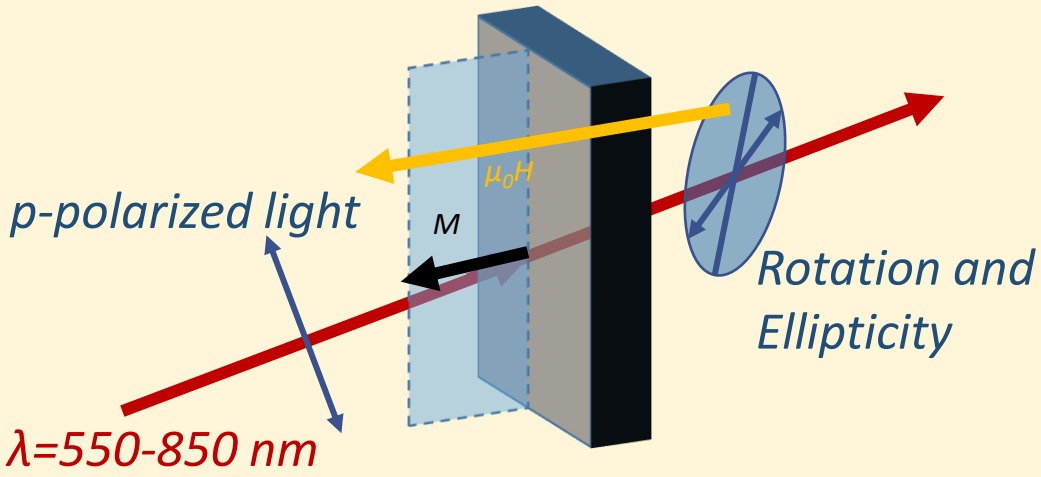


Figure 4. Schematic of polar MOKE measurement geometry. Measured arrays fabricated from $Tb_{18}Co_{82}$ alloy, exhibit out-of-plane magnetization *M*. External field magnetic field $\mu_0 H$ was applied out-of-plane.

Spectroscopic Faraday rotation measurements: Results

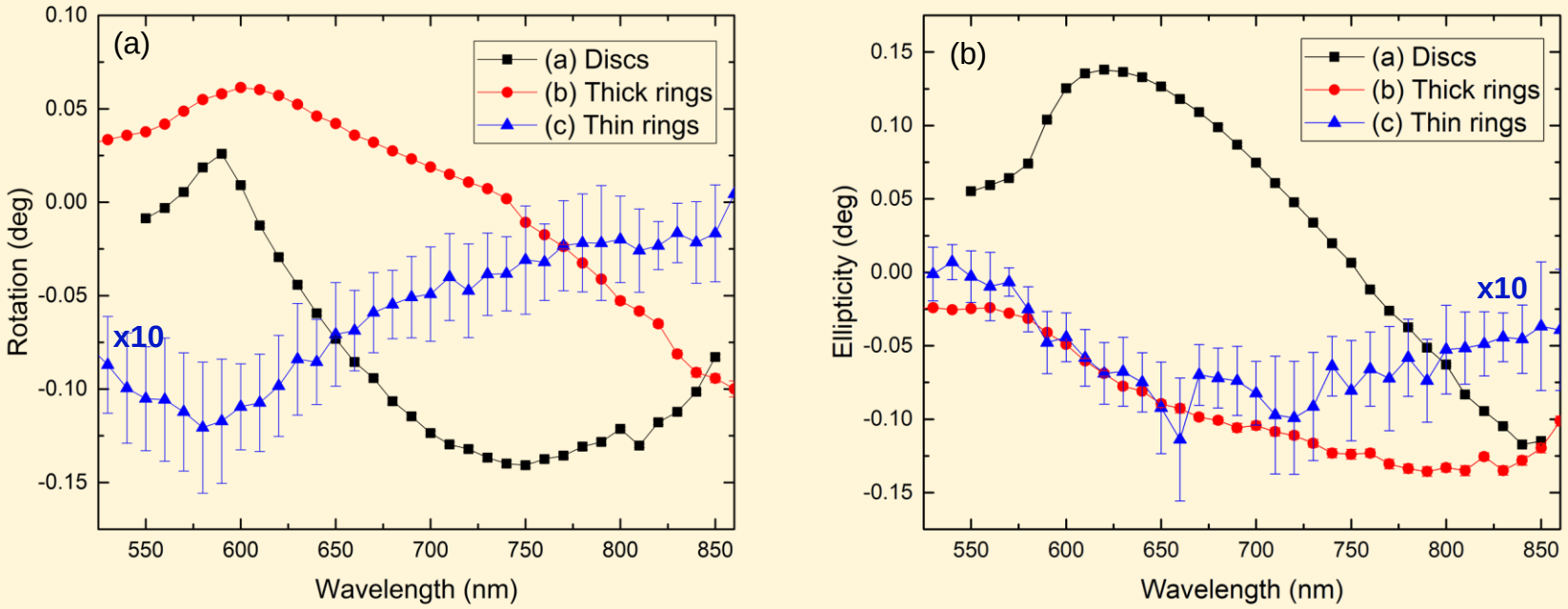


Figure 5. Spectroscopic magneto-optical measurements of nano-arrays shown in Fig. 2: (a) Faraday rotation and (b) ellipticity.

Magneto-Optic measurements

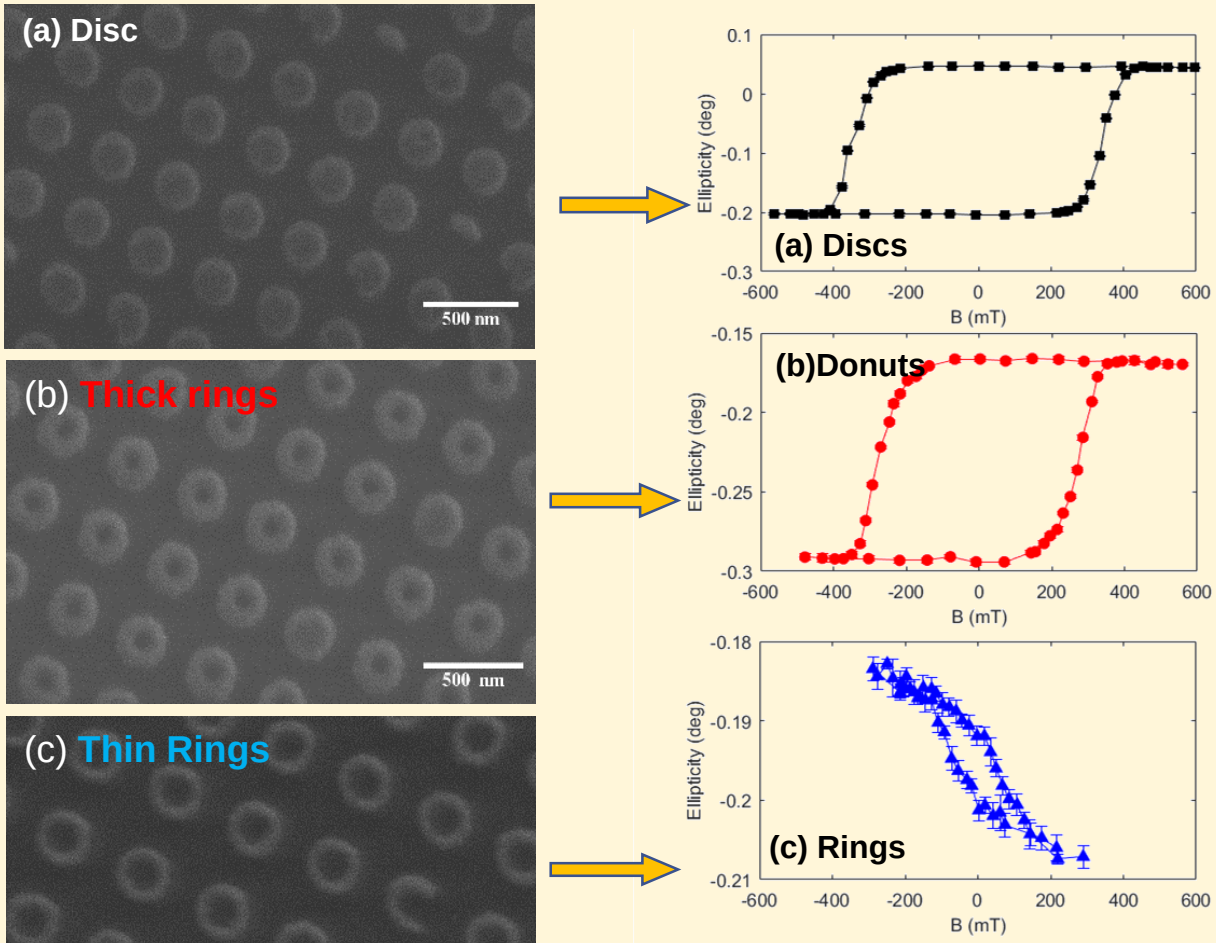


Figure 6. Magnetic Faraday rotation measurements at 600 nm wavelength of nano-arrays.

Compare to:

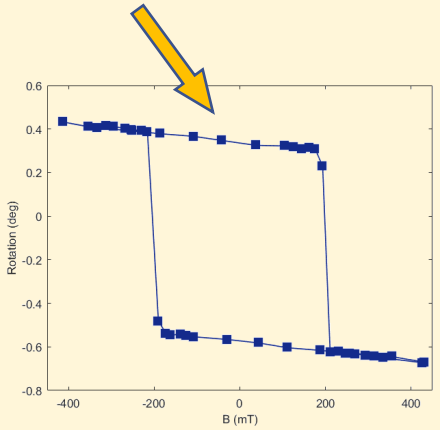


Figure 1. Faraday rotation measured at 600 nm wavelength of incident light for the hybrid structure film

Summary

- Patterning ring structures via EBL and Ar^+ milling results in expansion of structures, namely, outer diameter becomes slightly larger while the inner – smaller, resulting in thicker rings than expected from the design.
- Aiming for 80 nm thick rings with 120 nm outer radius resulted into what appears as closed discs;
- Aiming for 20 nm thick rings with 120 nm outer radius, resulted into broken rings and lost magnetization of the sample;
- Pattern appears to be uniform throughout the entire area of 3x3 mm^2
- Spectroscopic Faraday effect measurements show broad resonances extending to IR region for three magnetic arrays of discs, thick and thin rings.

Outlook

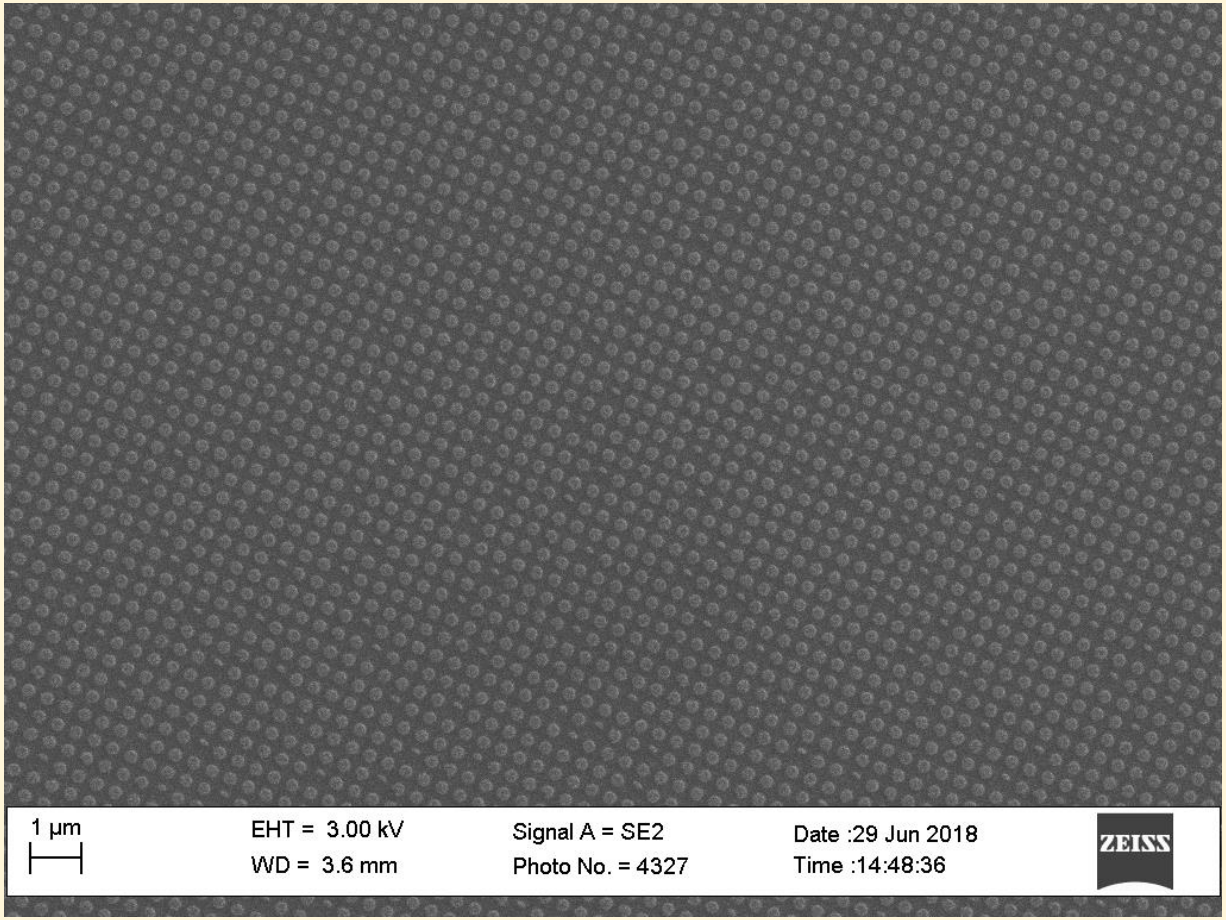
- Modify the EBL designs in order to shift resonances to a visible range → reduce dimensions from 120 nm outer radius to …
- Fabricate identical structures using the following stuctures:
  - Au(40nm)/AlOx(20nm)/Au(40nm) (cap structure with AlOx since EBL worked on Au/AlOx/TbCo/AlOx multilayer);
  - AlOx/TbCo;
  - Au/AlOx/TbCo/AlOx;
  - ...

Additional information

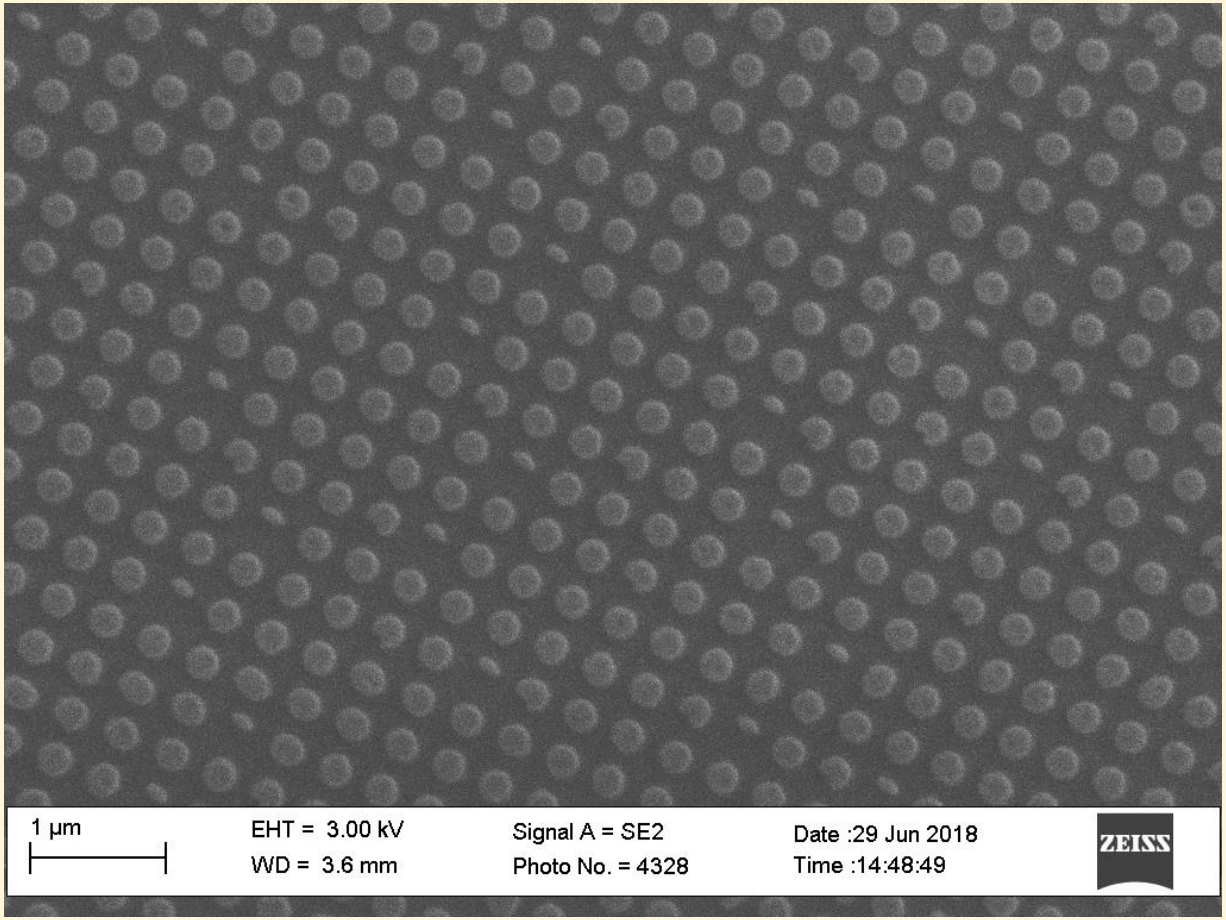
SEM images, optical transmission measurements

SEM

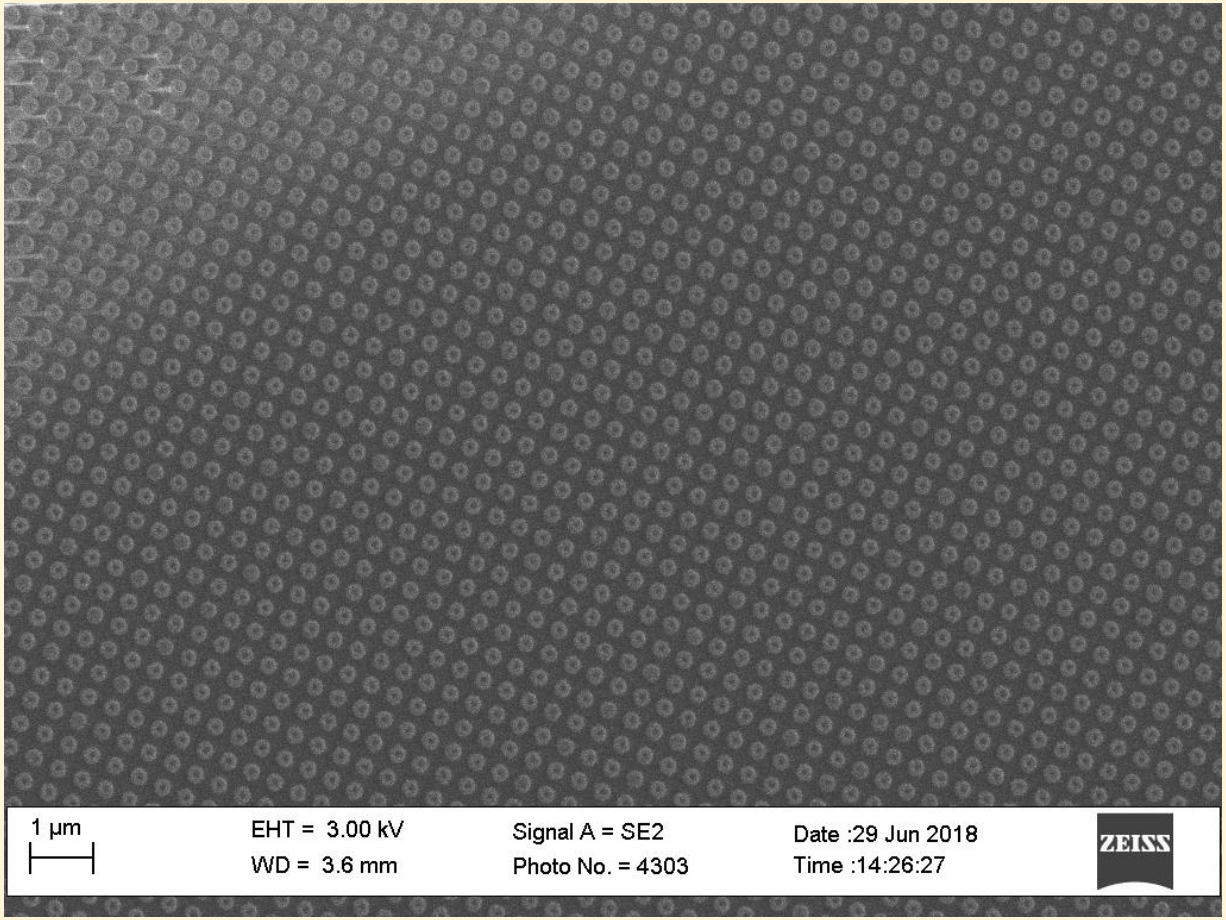
Array 1: Discs



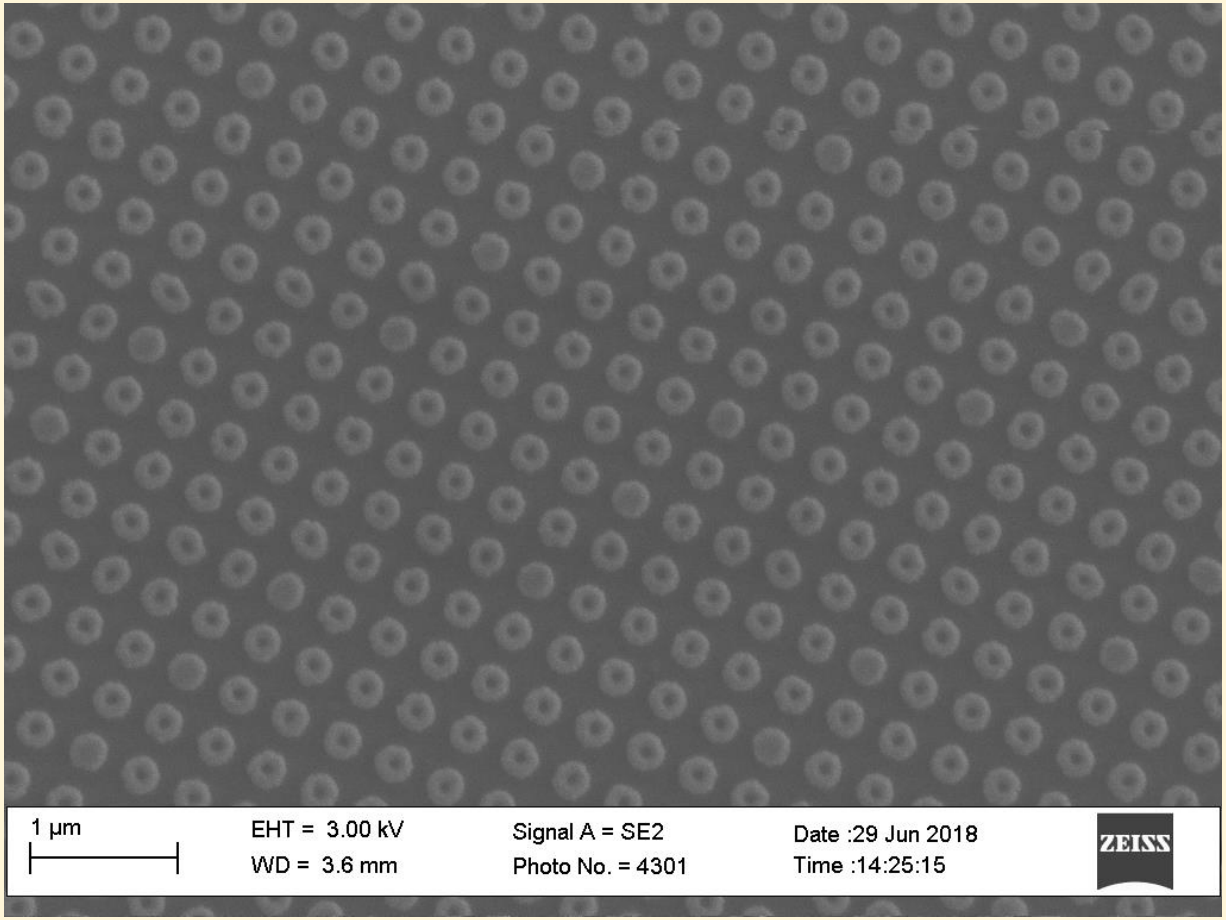
Array 1: Discs



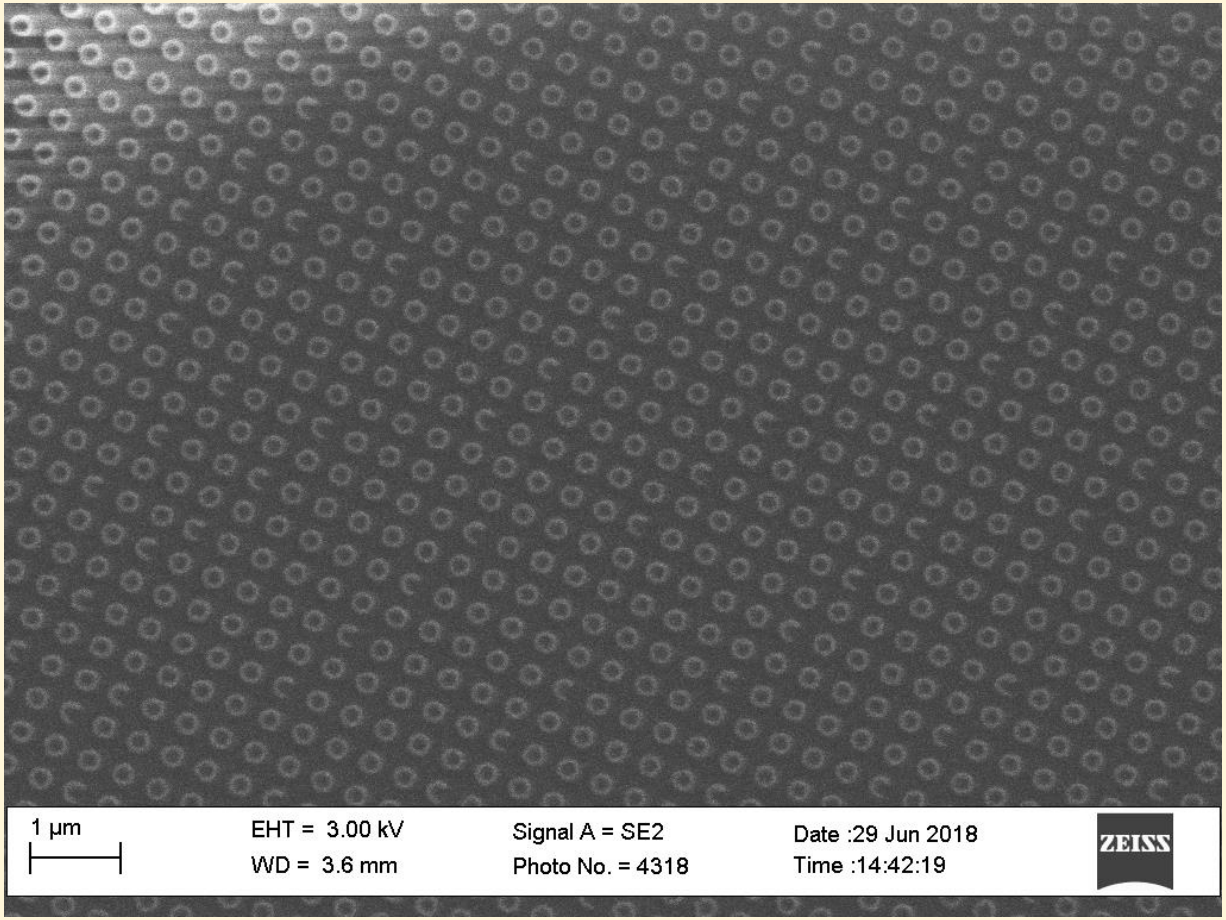
Array 2: Thick rings



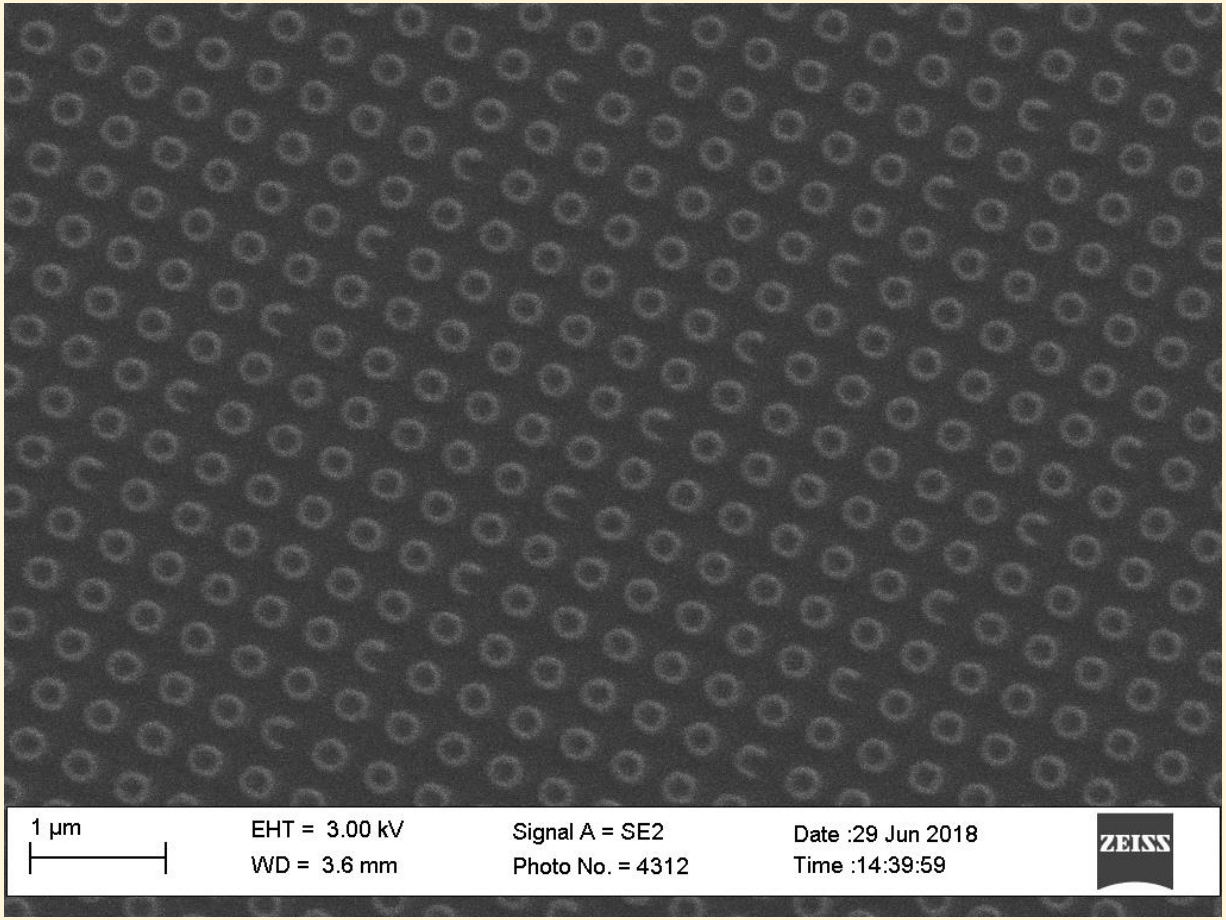
Array 2: Thick rings



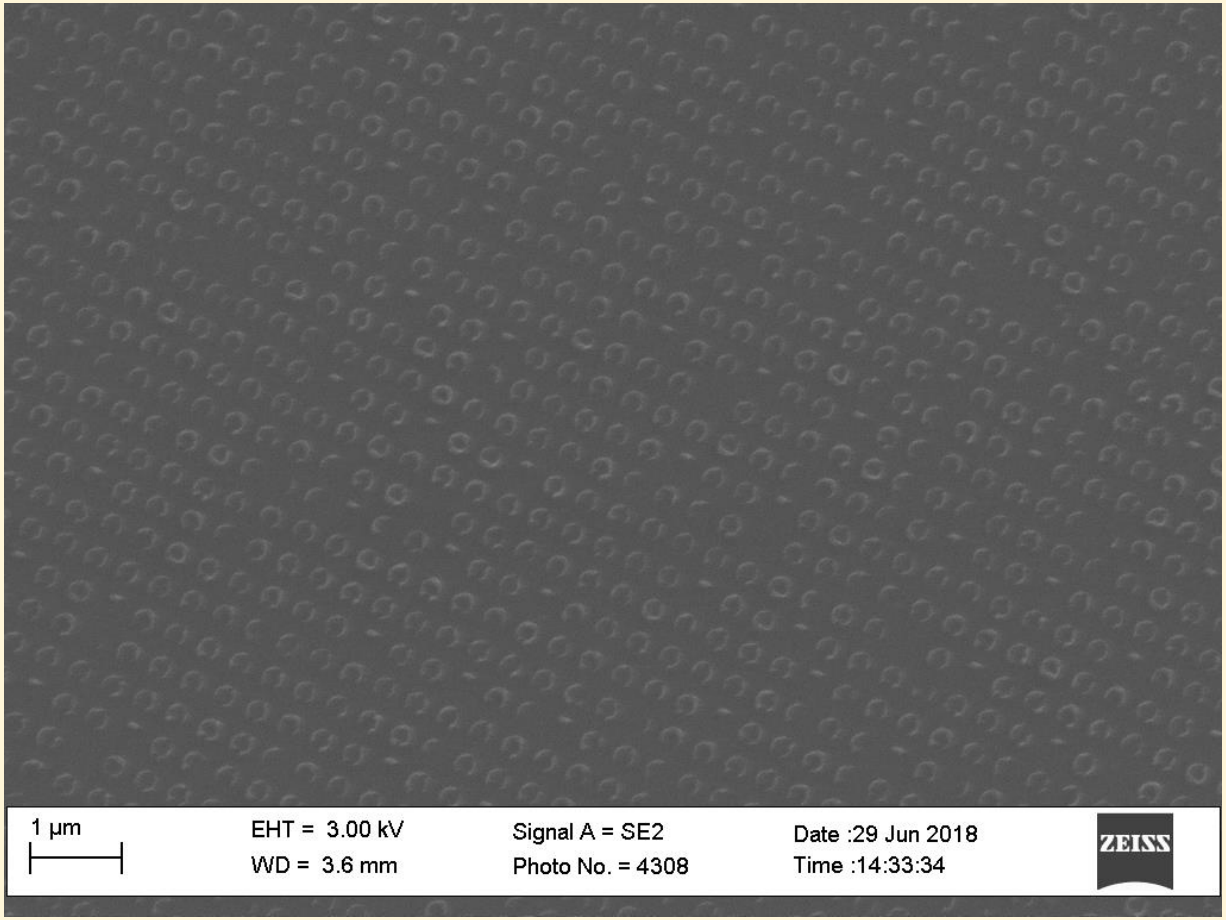
Array 3: Thin rings



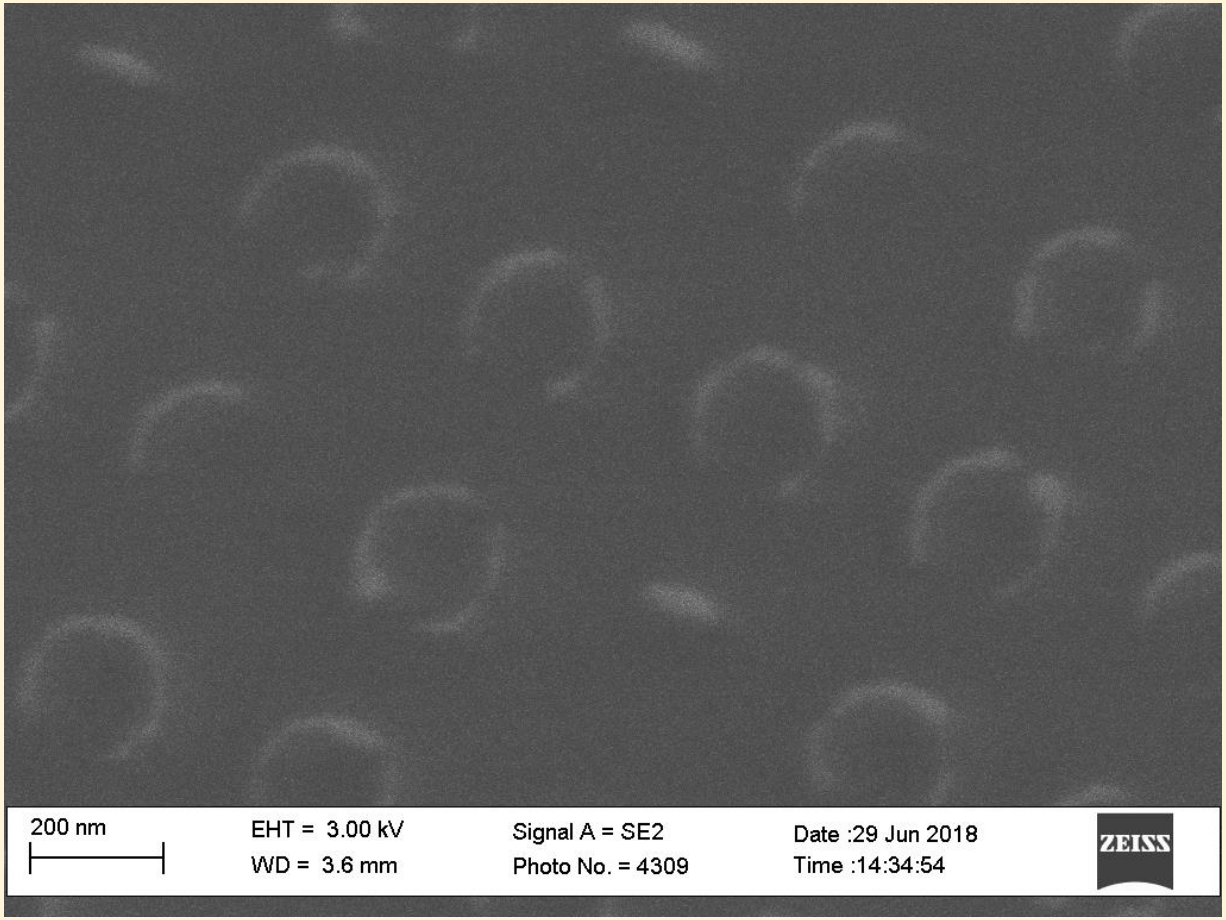
Array 3: Thin rings



Array 4: Broken rings

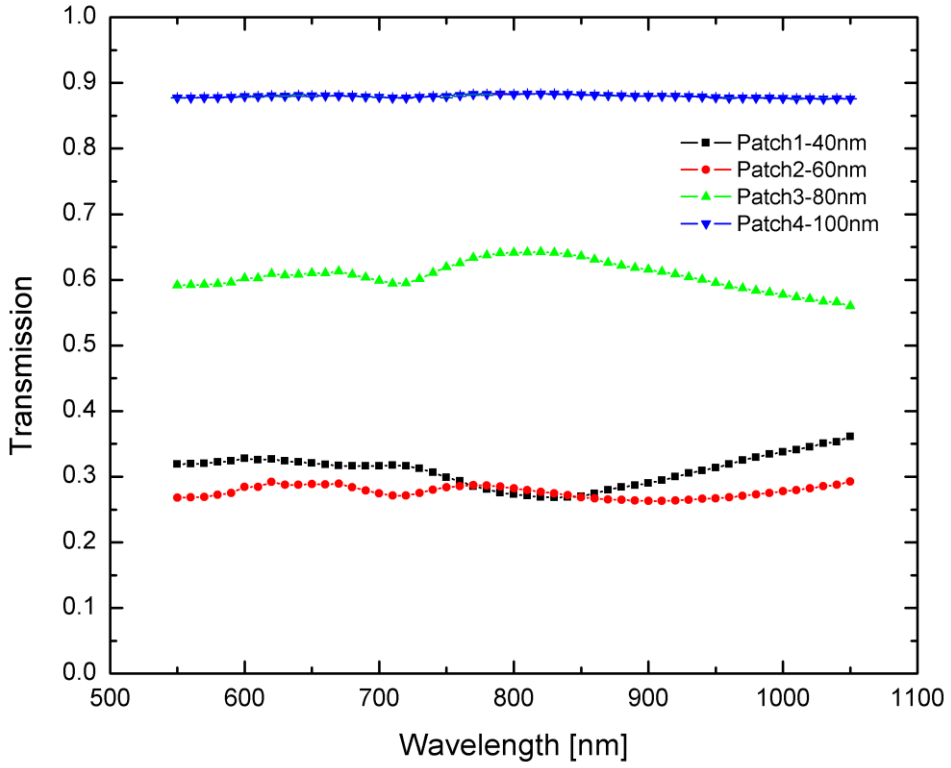


Array 4: Broken rings



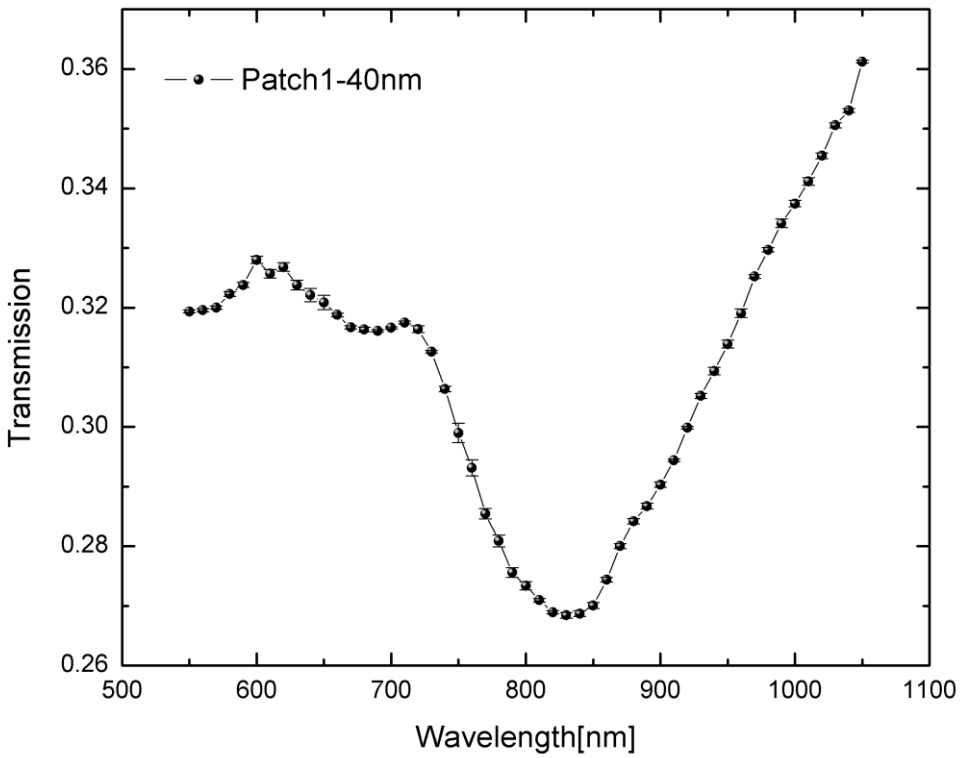
Optical transmission

Optical transmission: comparison of all arrays

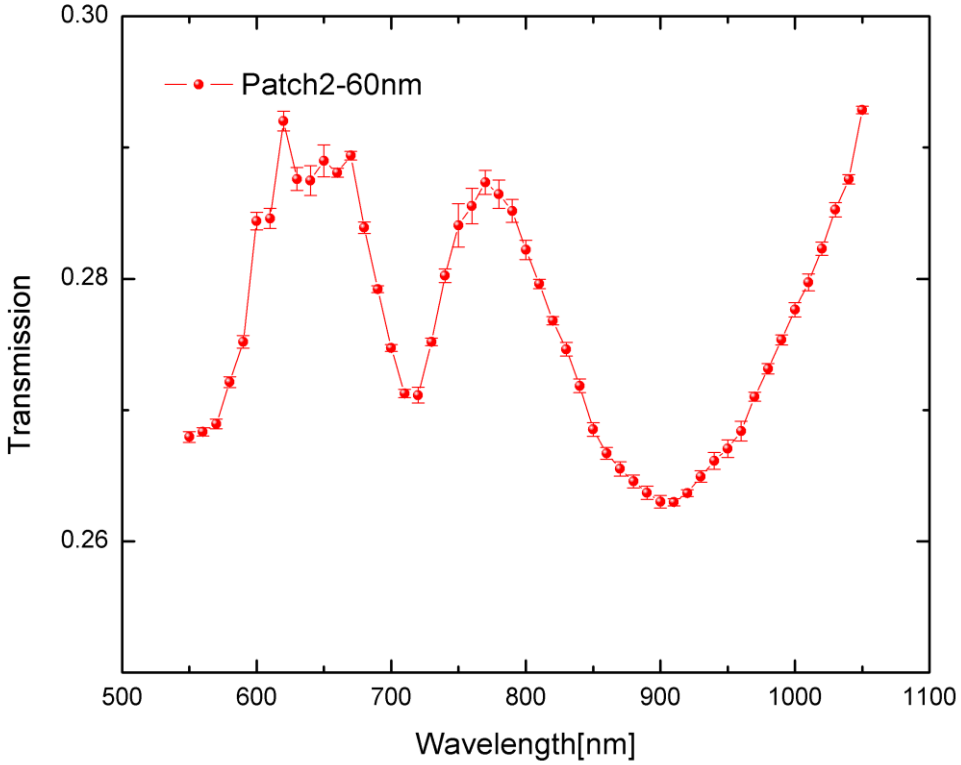


Patch 1 – 40 nm: **Discs**
Patch 2 – 60 nm: **Thick rings**
Patch 3 – 80 nm: **Thin rings**
Patch 4 – 100 nm: **Broken rings**

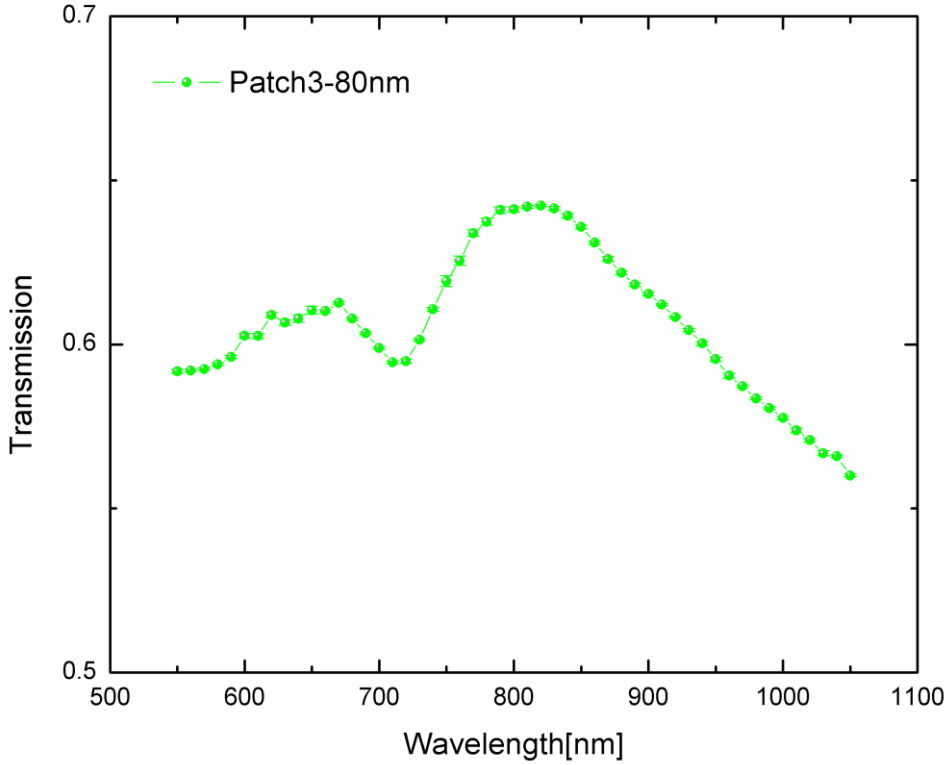
Optical transmission: Discs



Optical transmission: Thick rings



Optical transmission: Thin rings



Optical transmission: Broken rings