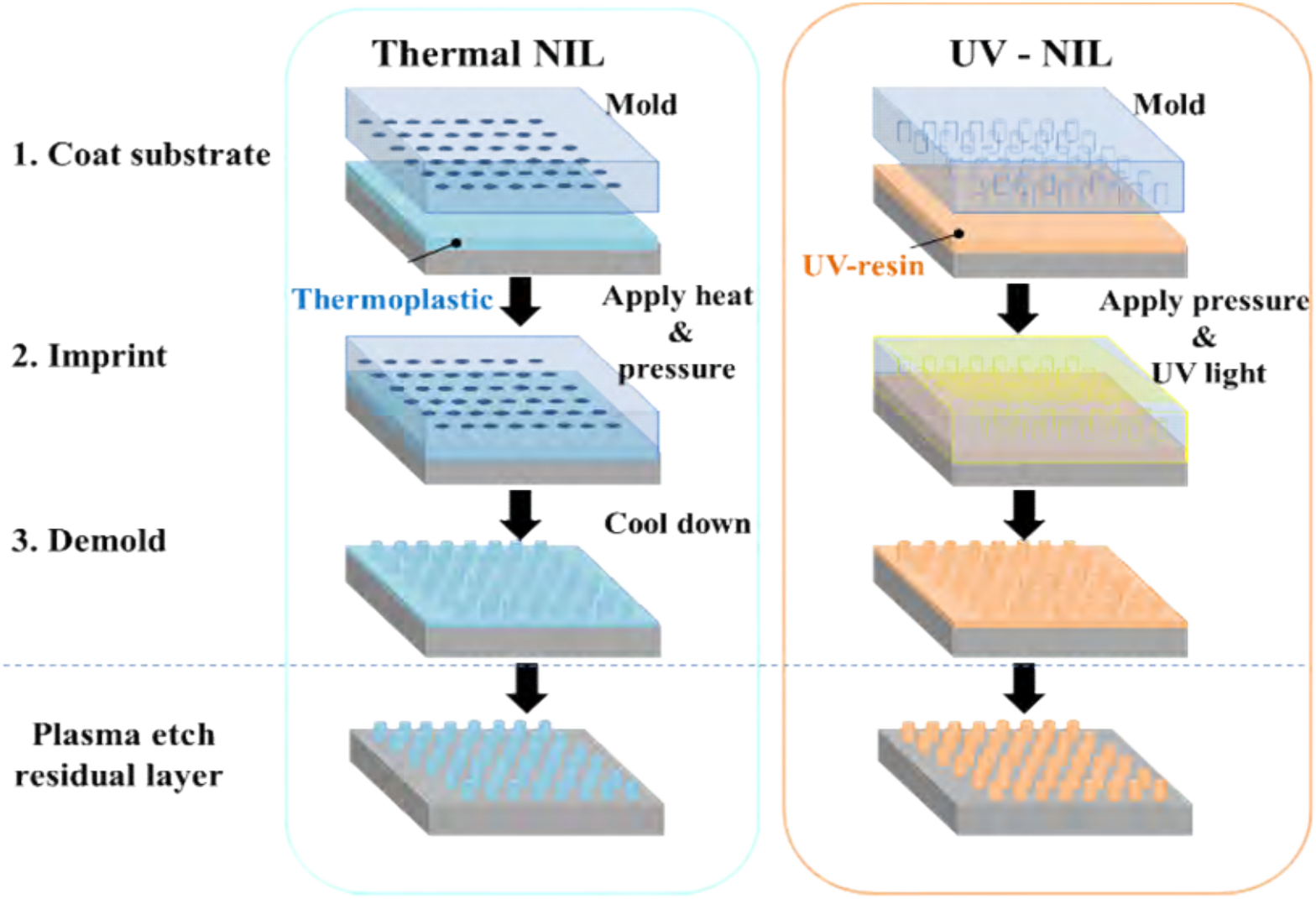
Nanoimprint lithography and hybrid processes

to produce complex nanostructures

Isabel Rodríguez
i.rodriguez@imdea.org

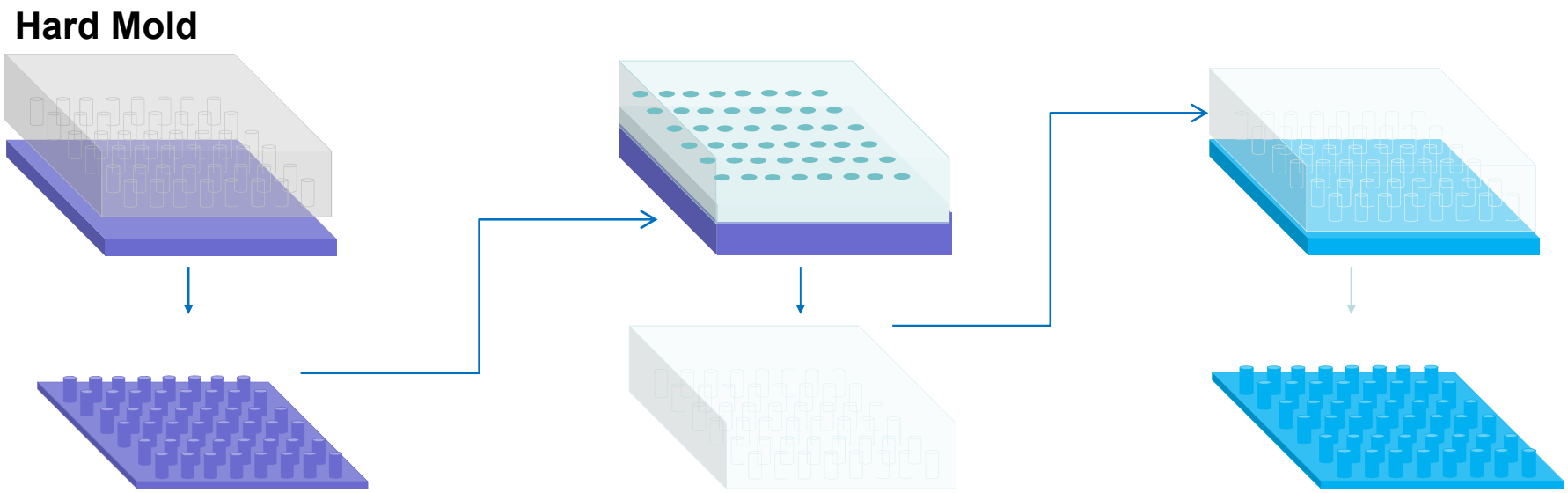
Nano Imprint Lithography - NIL

A replication process : Pattern transfer by mechanical deformation of a flowing resist material



Soft –NIL

Thermal-NIL | **Soft lithography** | **Soft NIL**



IPS
Intermediate polymer stamp

Soft Mold
PDMS
PFPE

Patterned polymer

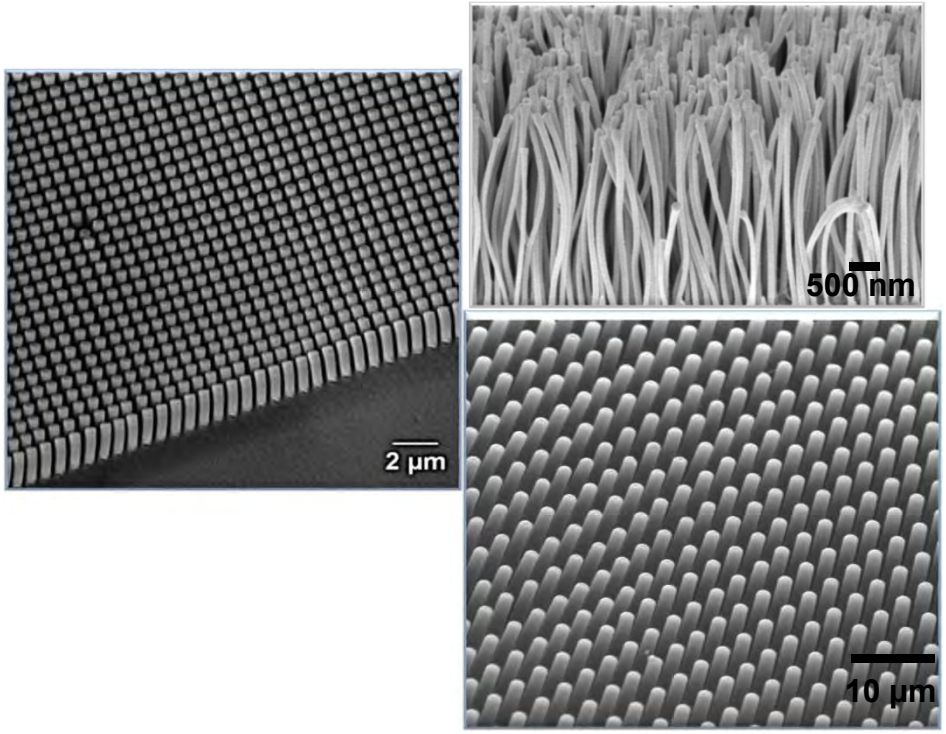
Soft –NIL:

- Sequential action of peeling the mold from substrate
- High gas permeability
- Conformal contact to substrate
- Low surface energy

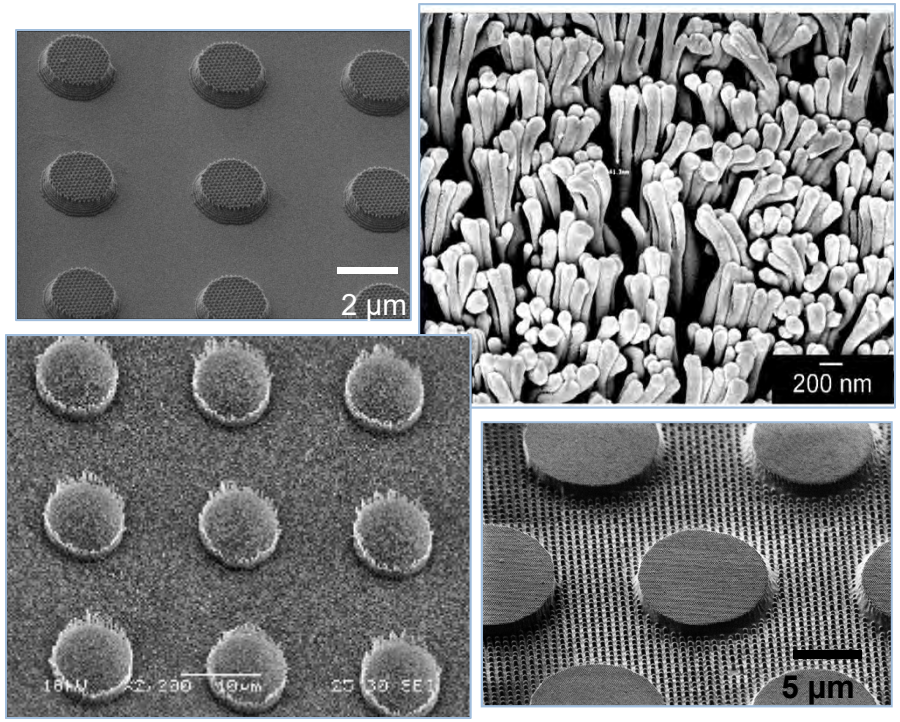
PDMS: Polydimetilsiloxane
PFPE: Polyurethane based on perfluoropolyether

Key Technological Expertise

High Aspect Ratio Topographies



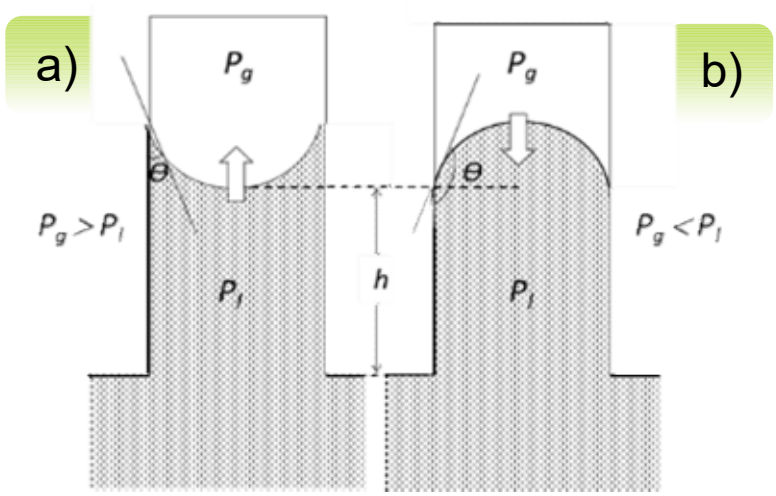
Complex Hierarchical Topographies

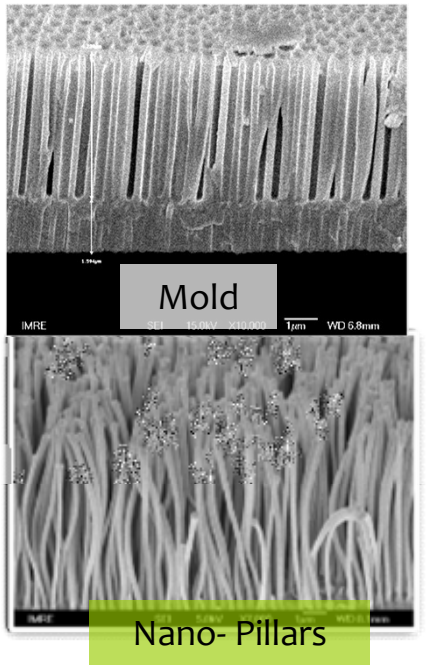


High Aspect Ratio NIL

Laplace pressure - Capillary forces

$$\Delta P_c = P_g - P_l = \frac{2\,\gamma cos\theta}{r}$$





a) polymer wets the capillary (θ < 90°)

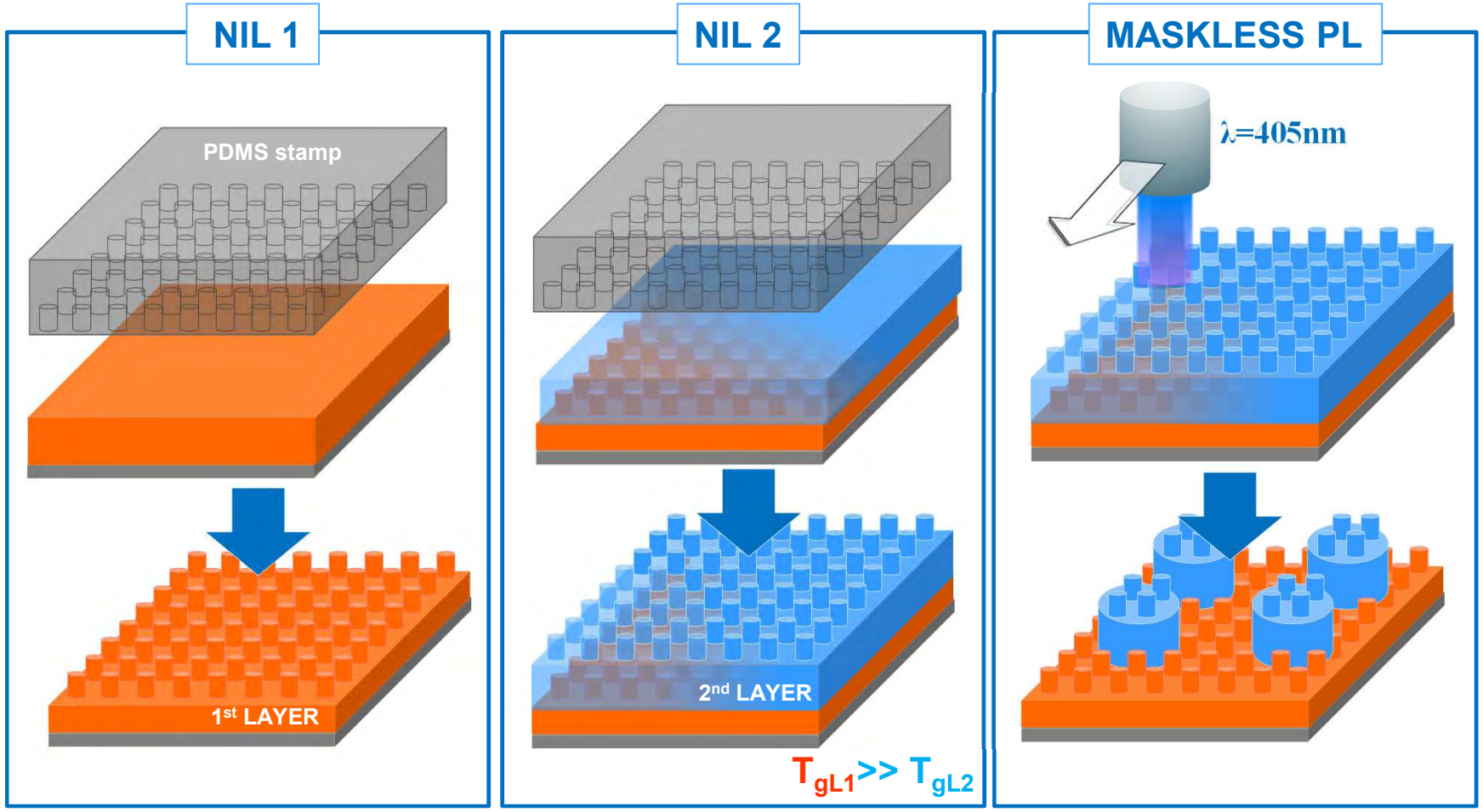
b) polymer does not wet the capillary (θ > 90°)

Lucas-Washburn equation:

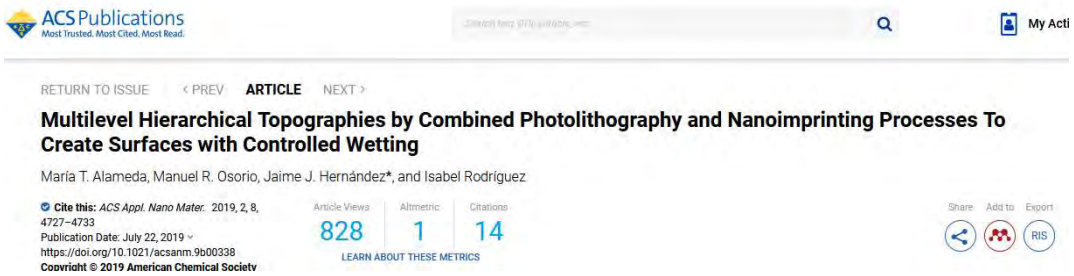
$$\frac{dh}{dt} = \frac{r\,\gamma cos\theta}{4\eta h} \qquad t = \frac{2\,\eta\,h^2}{r\,\gamma\,cos\theta}$$

γ_p - surface tension of the viscous polymer
η - the viscosity
θ - the solid-liquid contact angle
r - the capillary radius.

Hybrid fabrication proccess: NIL + PL



NIL: Nanoimprint Lithography ; PL: Photolithography


ACS Publications
Most Trusted. Most Cited. Most Read.

RETURN TO ISSUE ‹ PREV ARTICLE NEXT ›

Multilevel Hierarchical Topographies by Combined Photolithography and Nanoimprinting Processes To Create Surfaces with Controlled Wetting

María T. Alameda, Manuel R. Osorio, Jaime J. Hernández*, and Isabel Rodríguez

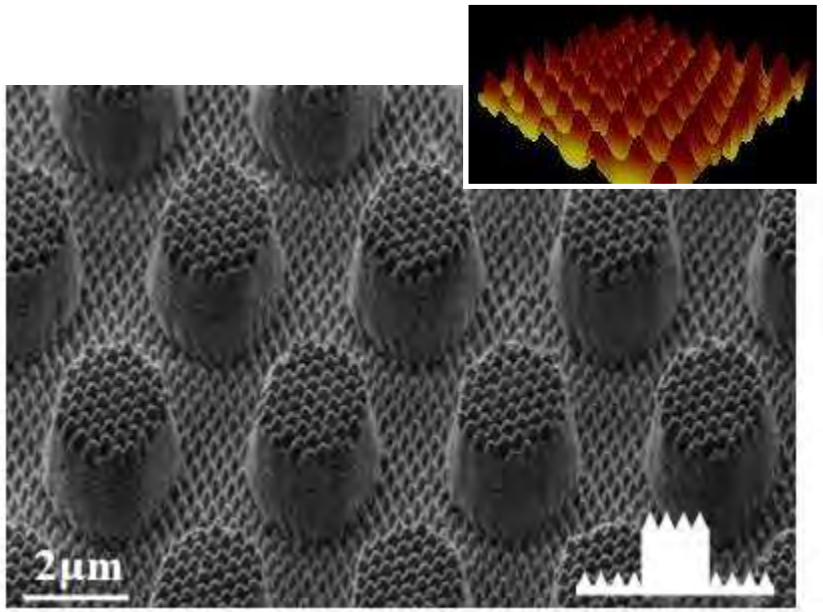
Cite this: *ACS Appl. Nano Mater.* 2019, 2, 8, 4727−4733
Publication Date: July 22, 2019
https://doi.org/10.1021/acsanm.9b00338
Copyright © 2019 American Chemical Society

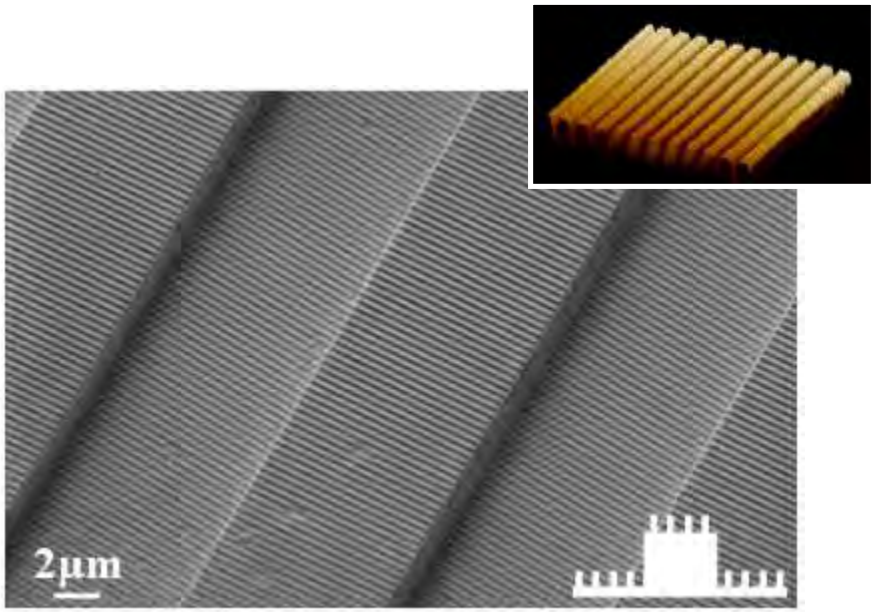
Article Views 828 | Altmetric 1 | Citations 14
LEARN ABOUT THESE METRICS

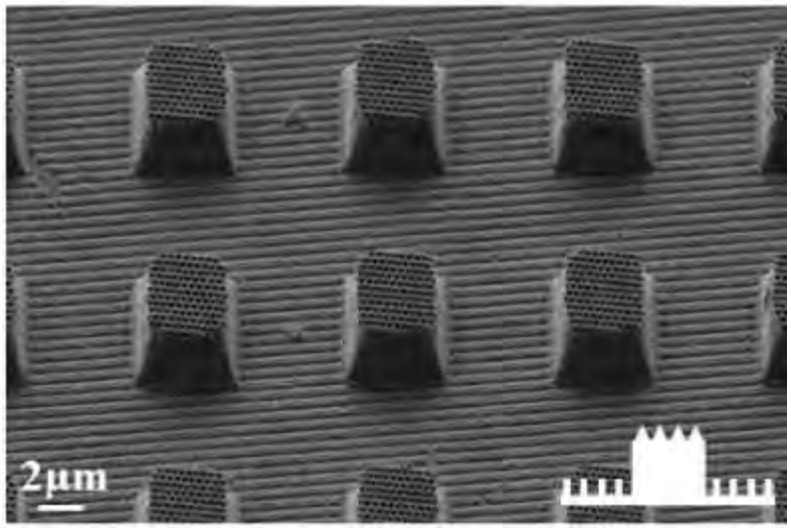
Share Add to Export RIS

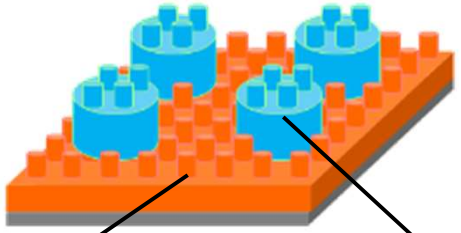
Micro & Nano Hierarchical Structures

1ST LAYER: THERMOPLASTIC







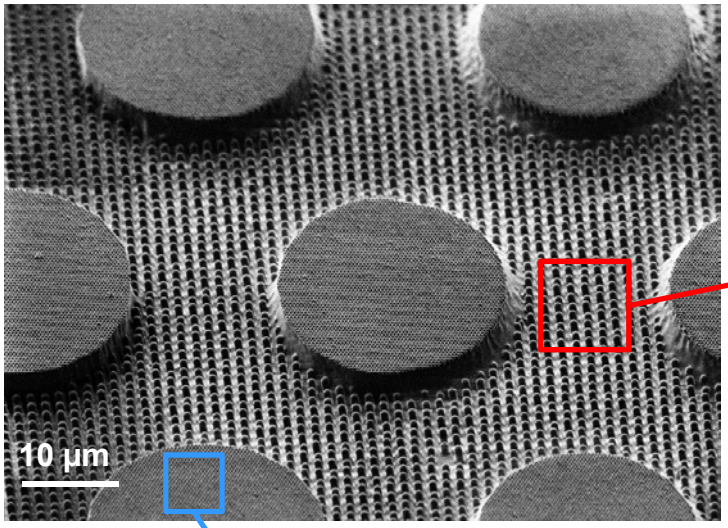


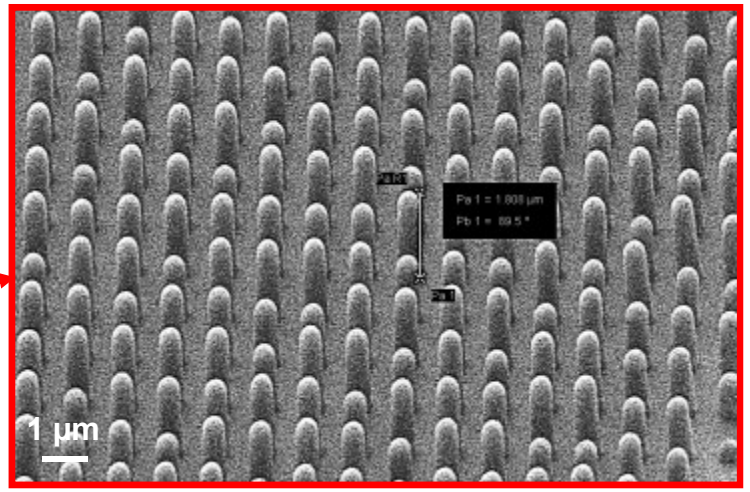
PMMA-A4
T_g=98-106ºC
T_{NIL}=170ºC
P_{NIL}=30bar
t=5min

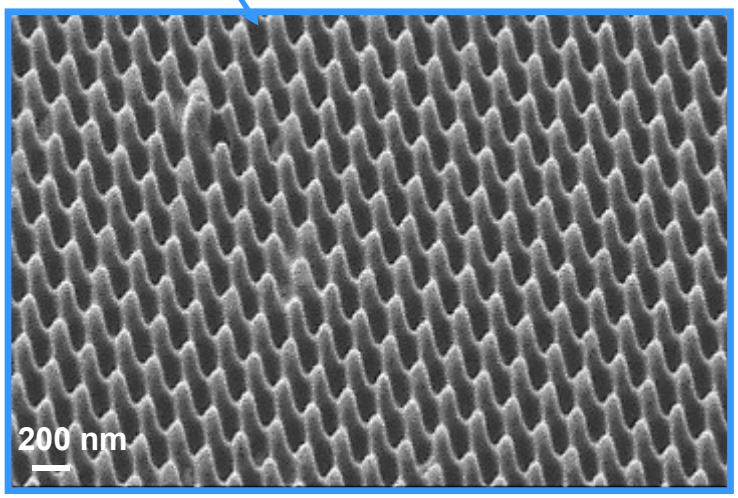
AZ1512
S.C: 2000rpm, 1min
T_{NIL}=100ºC
P_{NIL}=30bar
t=5min

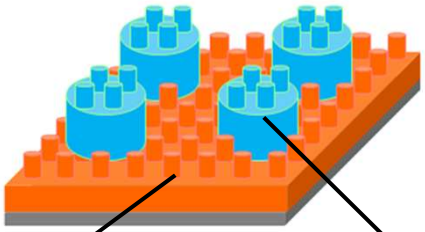
Micro & Nano Hierarchical Structures

1ST LAYER: THERMOSET





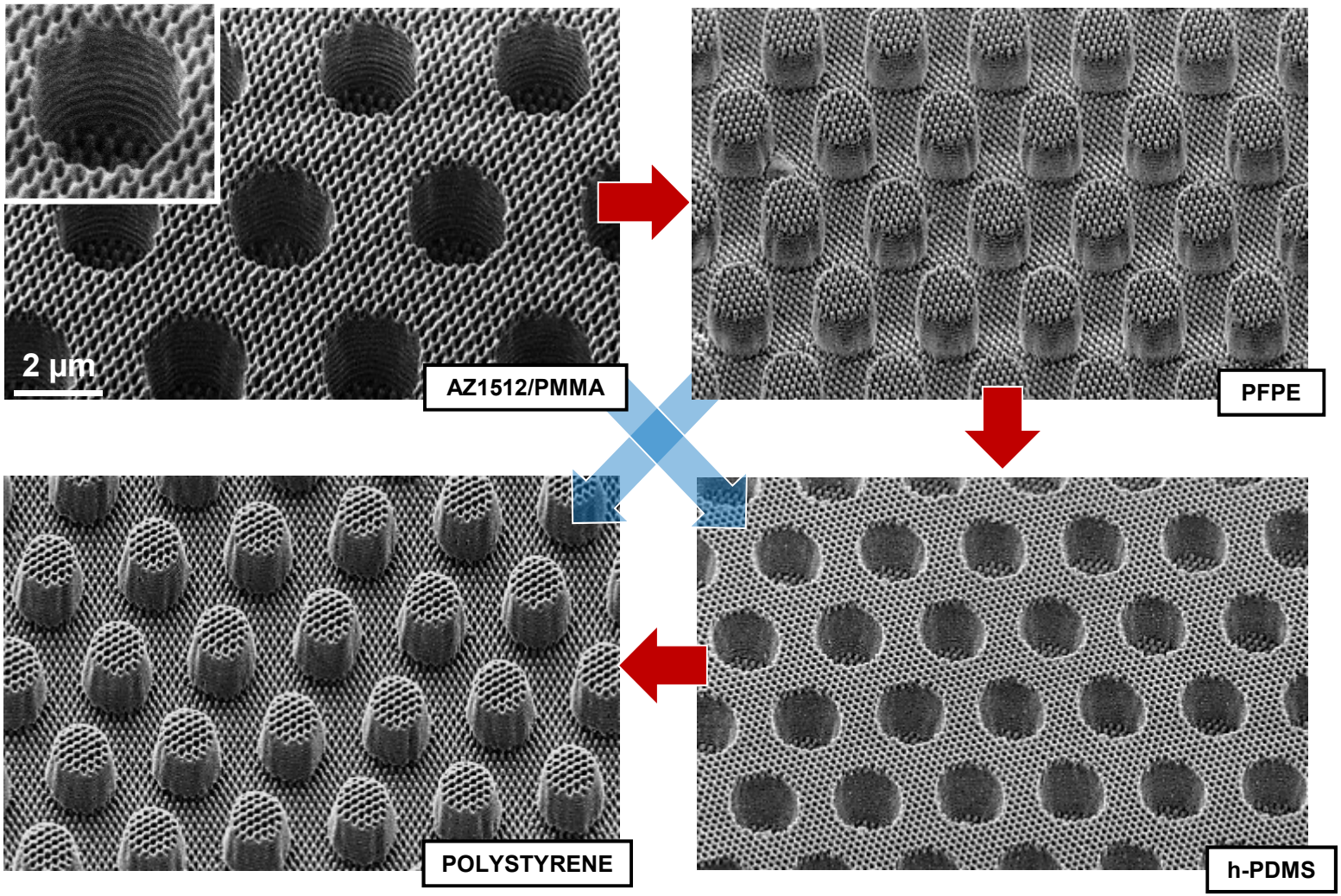




EpoTek
$T_{UV\text{-}NIL}$=60ºC
P_{NIL}=30bar
t=5min

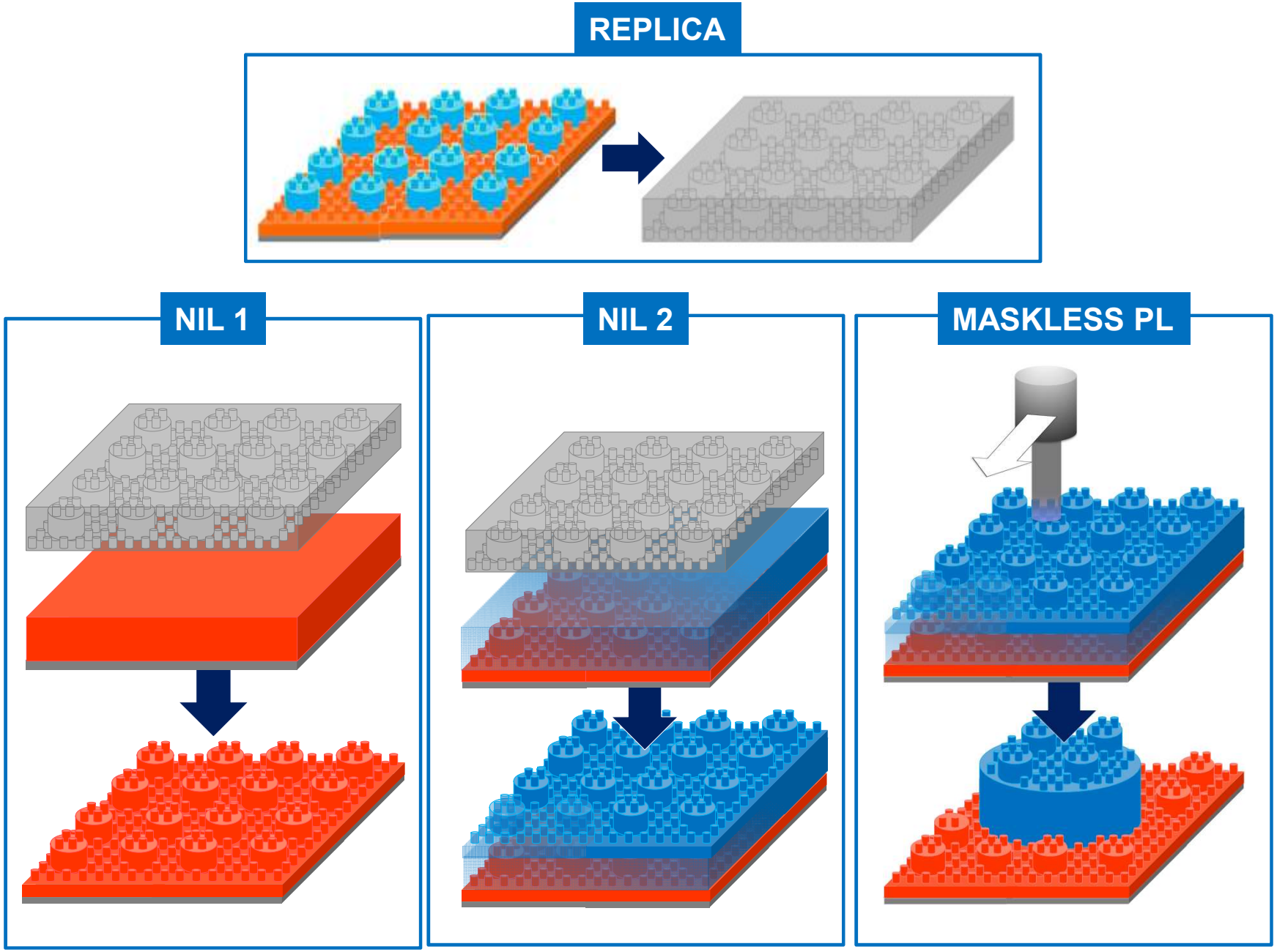
AZ1512
S.C: 2000rpm, 1min
T_{NIL}=100ºC
P_{NIL}=30bar
t=5min

Soft-NIL - Polymer replication

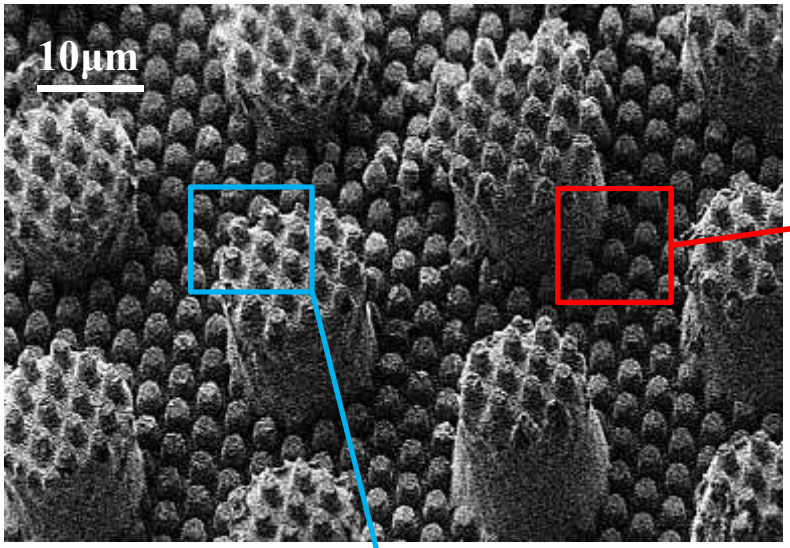


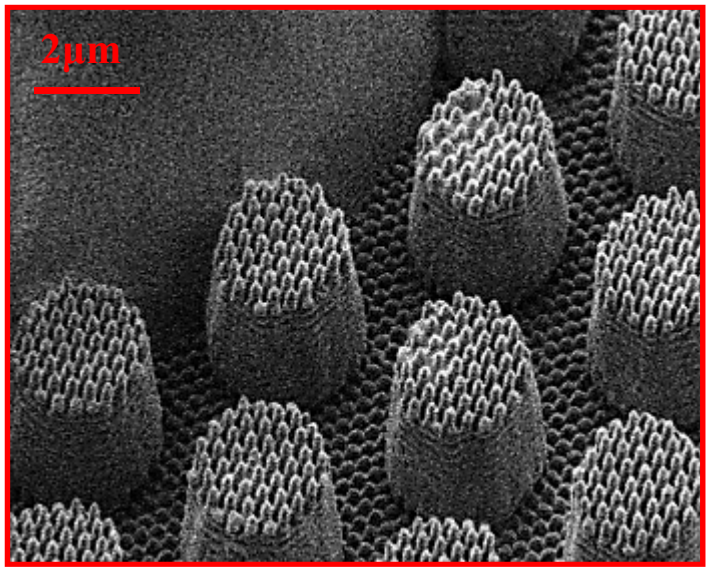
PFPE - Perfluoropolyether
PMMA - Poly(methyl methacrylate)
PDMS - Polydimethylsiloxane

Multilevel Hierarchical Structures

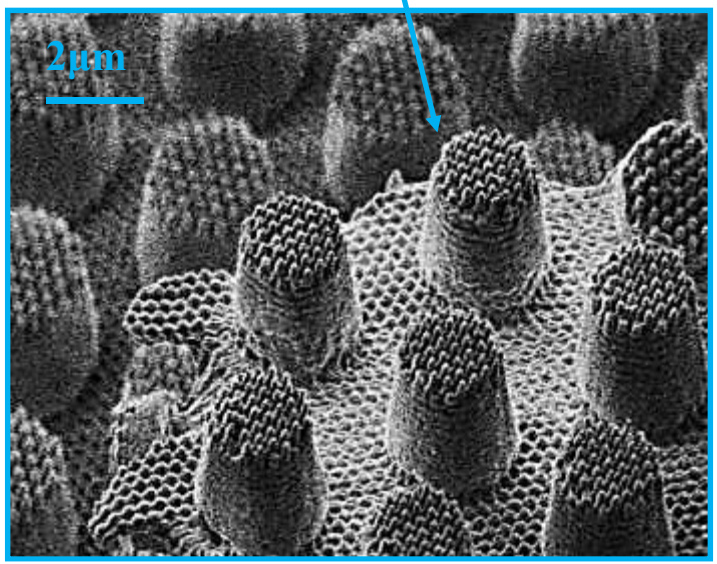


Multilevel Hierarchical Structures

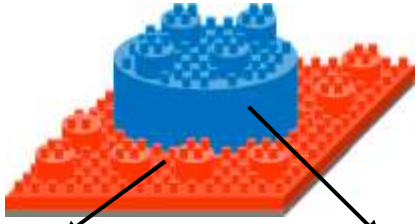




BOTTOM



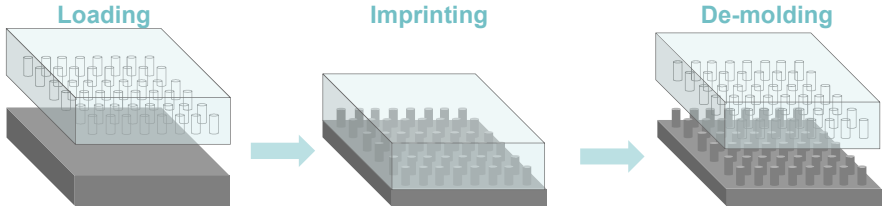
TOP



EpoTek
$T_{UV\text{-}NIL}$=60ºC
P_{NIL}=30bar
t=5min

AZ 9260
S.C: 2000rpm, 1min
T_{NIL}=110ºC
P_{NIL}=30bar
t=5min

Nanoimprint Lithography (NIL) Tools



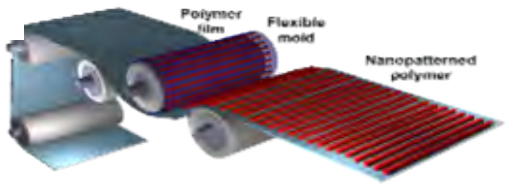
3” wafers - UV & Thermal NIL
Thermosets & thermoplastic materials

Obducat Eitre® E3

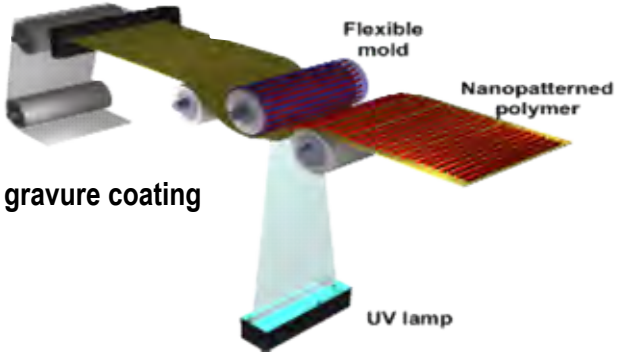
rla red de laboratorios Sistema madriod

N° registro: 432

Thermal -NIL



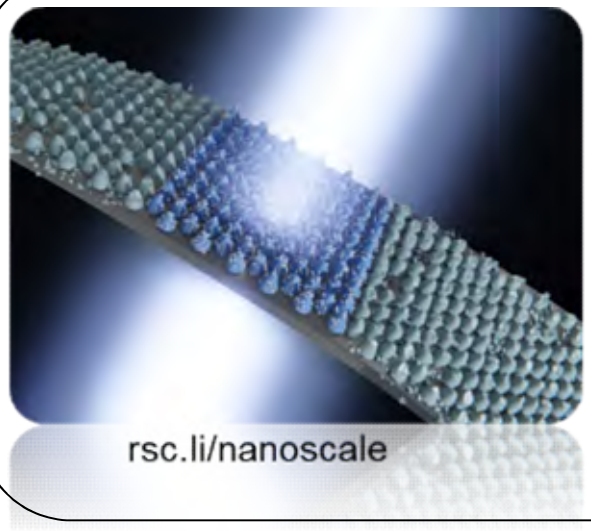
UV-NIL



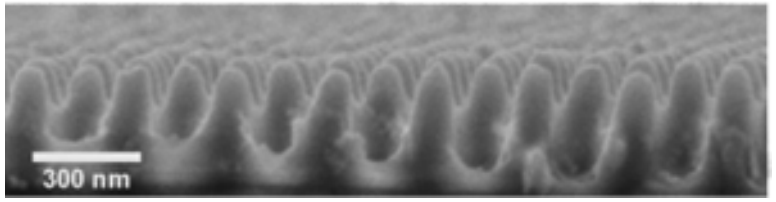
Reverse gravure coating

Roll to Roll NIL - Pilot facility for scale-up processing (5 m/min)

Moth-eye biomimetic anti- reflective surfaces



Moth-eye TiO_2 reinforced surface nanocomposite nano patterns



Nanoscale

PAPER

View Article Online

Check for updates

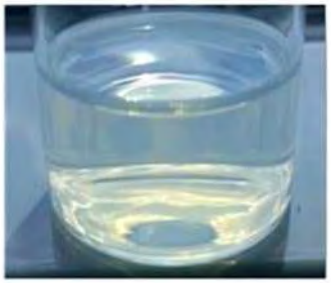
Single-imprint moth-eye anti-reflective and self-cleaning film with enhanced resistance†

Iván Navarro-Baena, Alejandra Jacobo-Martín, Jaime J. Hernández, Jose R. Castro Smirnov, Felipe Viela, Miguel A. Monclús, Manuel R. Osorio, Jon M. Molina-Aldareguia and Isabel Rodriguez

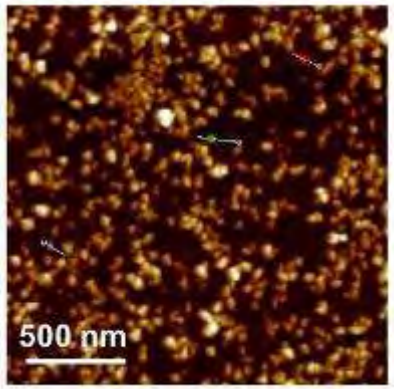
TiO_2 Surface Nanocomposite

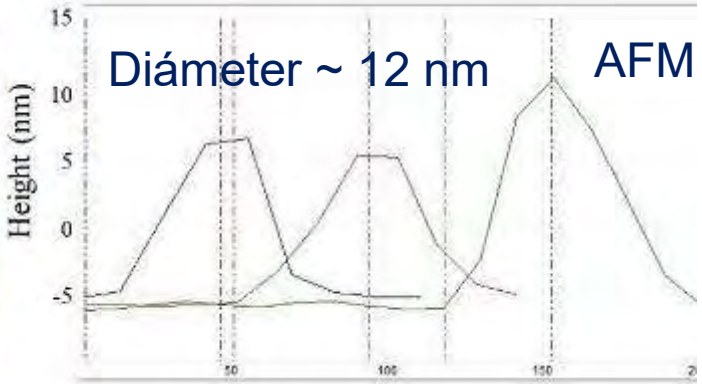
Preparation of polymer nanocomposite

TiO_2 nanoparticles: Hydrothermal synthesis

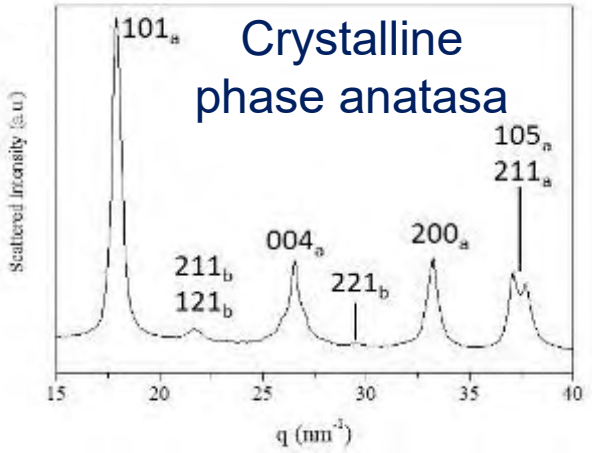


Coloidal suspensión

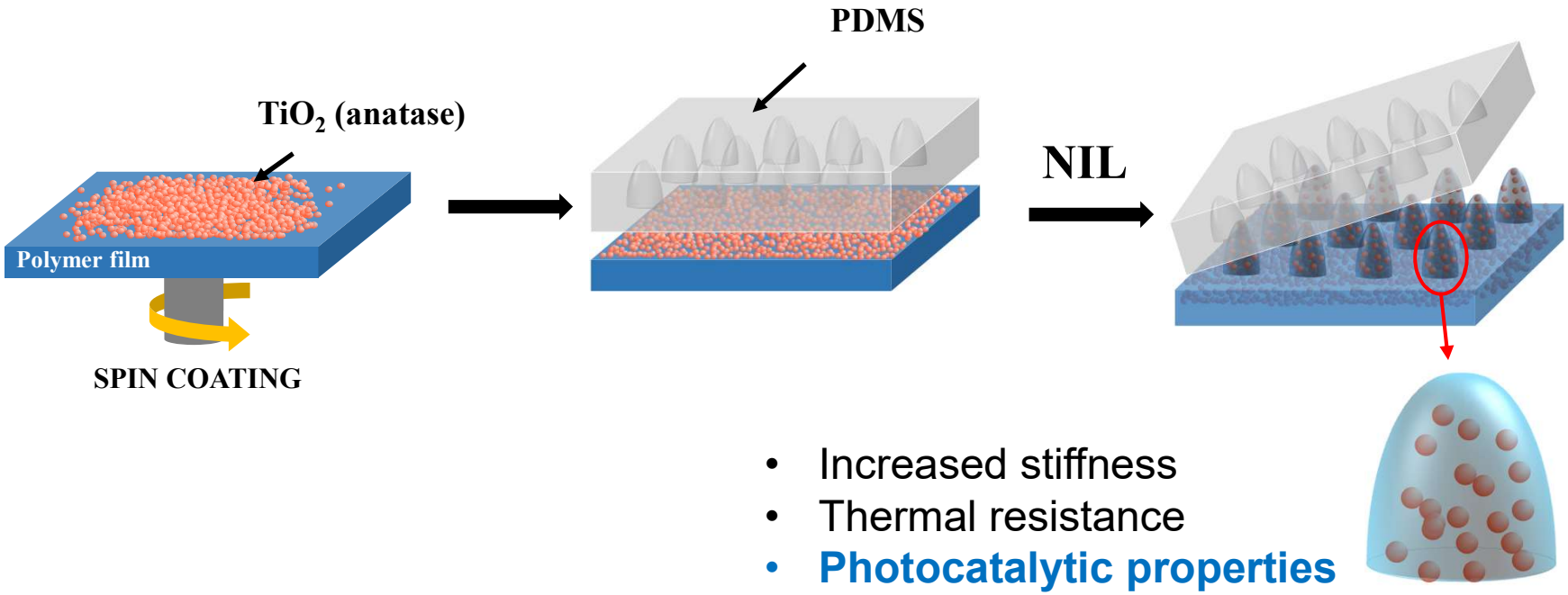




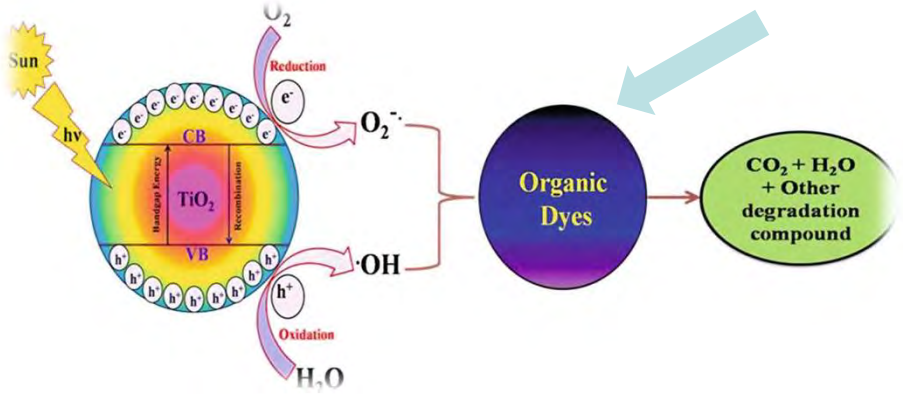
WAXS



Anti-reflective surface nanocomposite

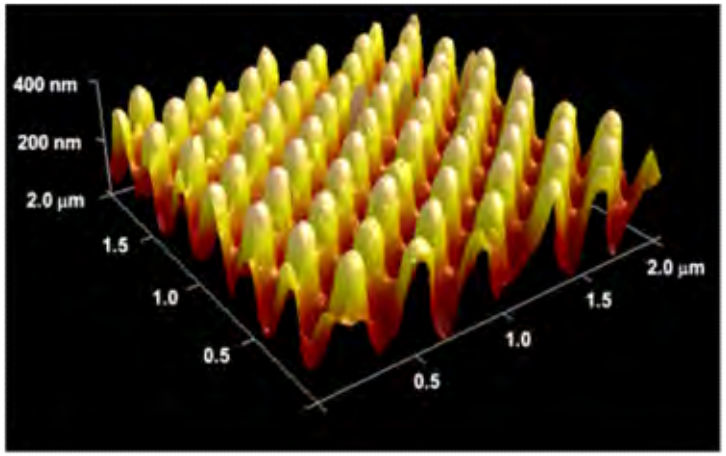


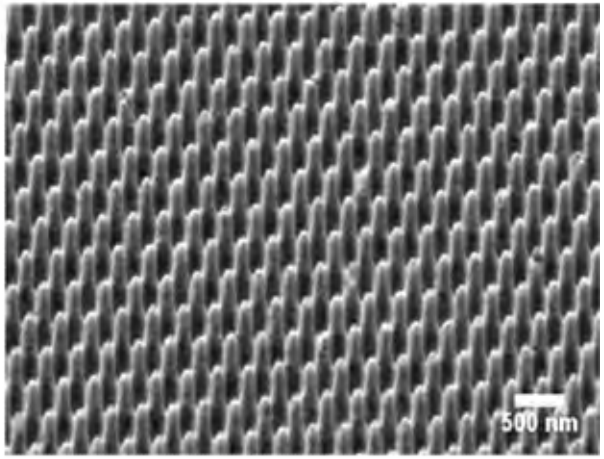
- Increased stiffness
- Thermal resistance
- **Photocatalytic properties**



Moth-eye imprinted topography

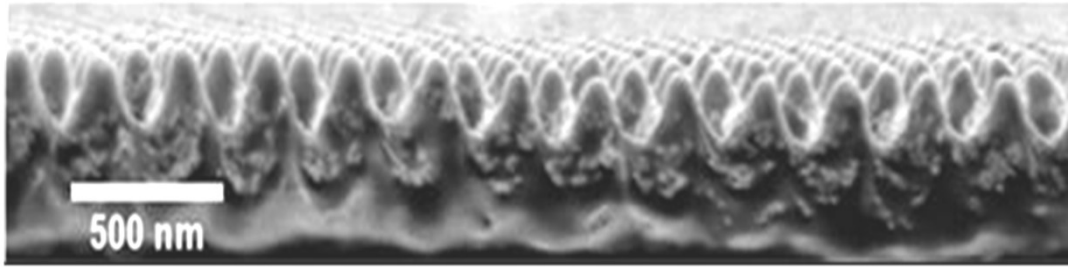
Morphology: SEM & AFM images





Moth-eye Nano-patterns →

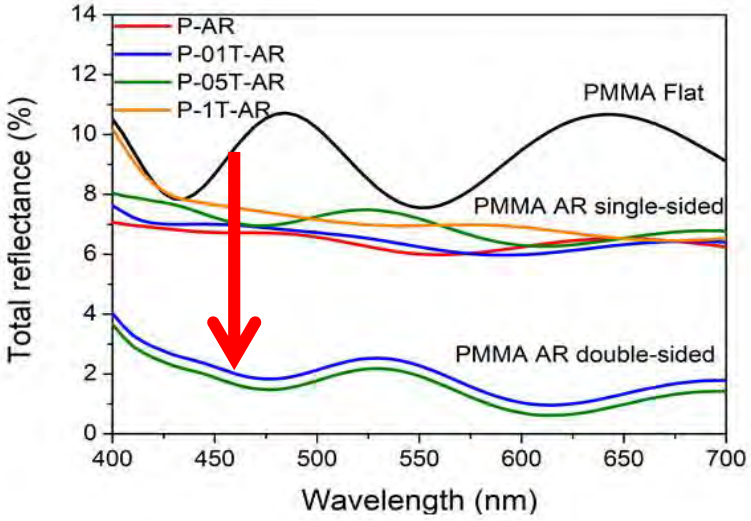
Nano-particles →



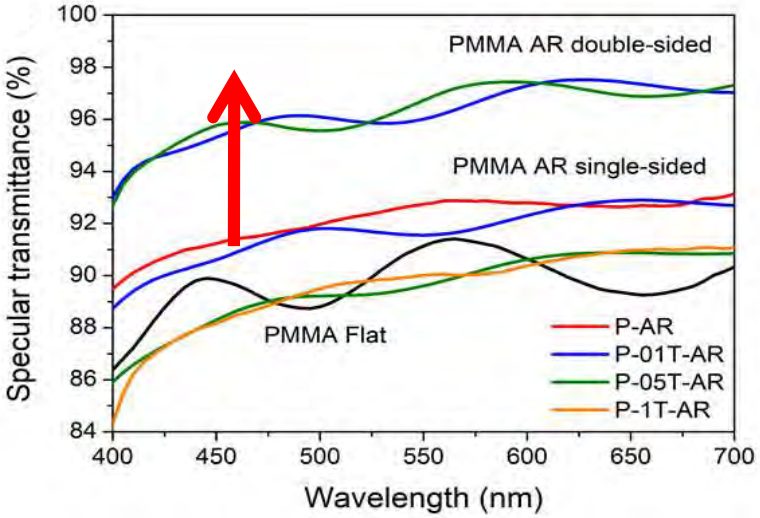
- High fidelity replication of the master mold on PMMA Nanocomposites
- Good nanoparticles dispersion
- Embedded particles within the polymer

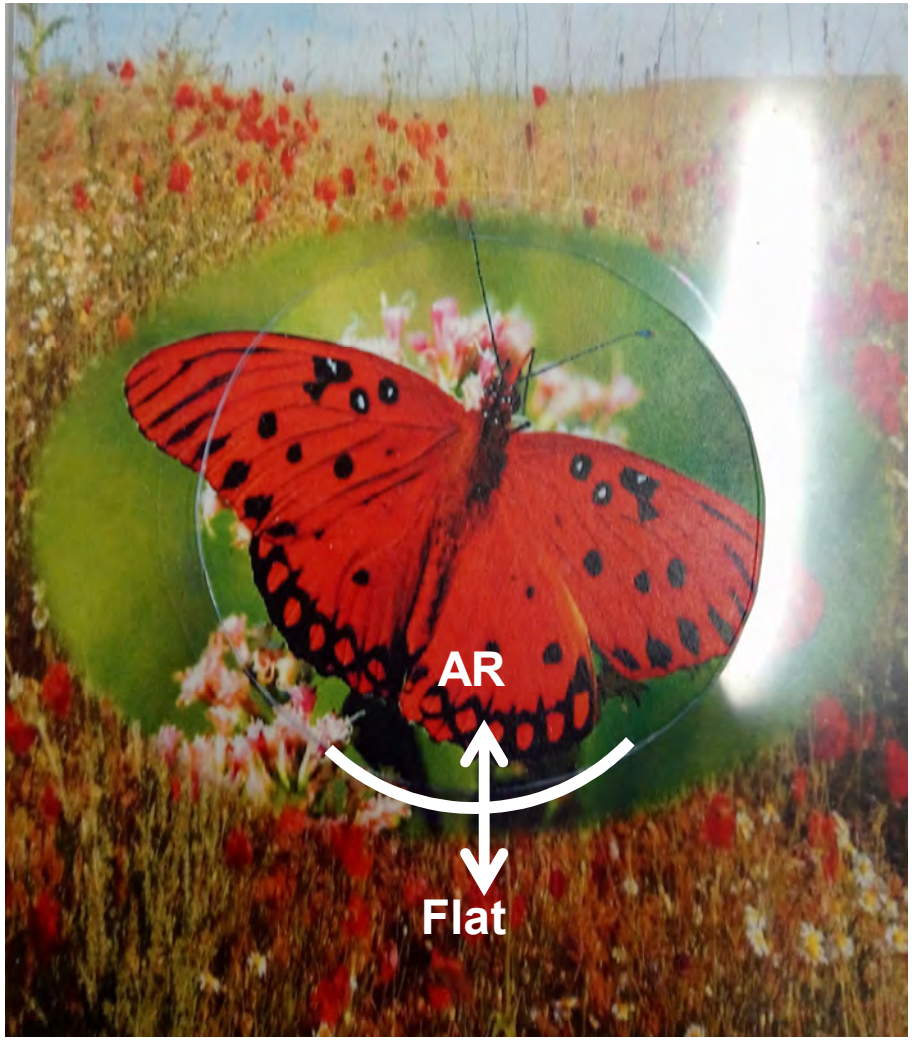
Moth-eye optical characterization

Total Reflectance

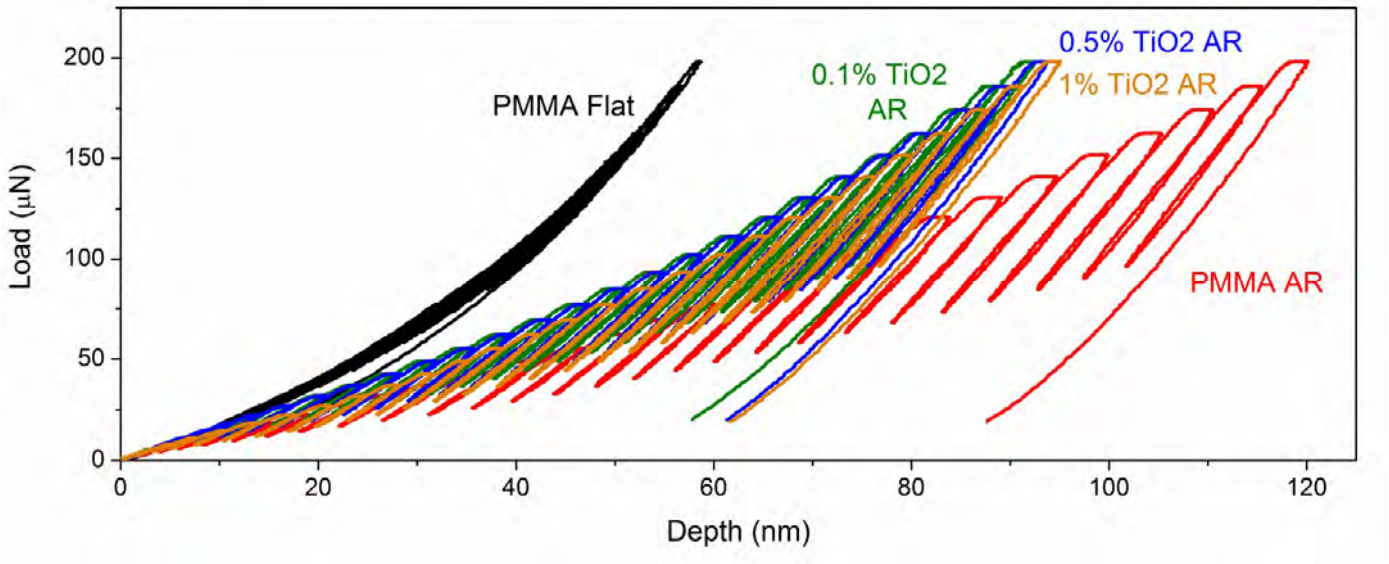


Transmittance





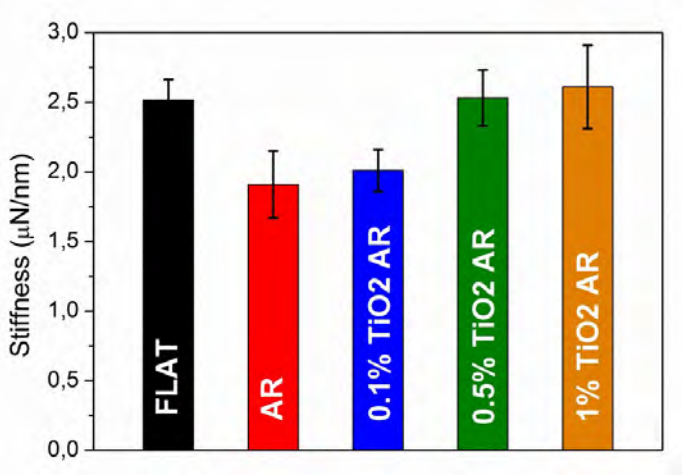
Mechanical behavior:
Nanoindentation

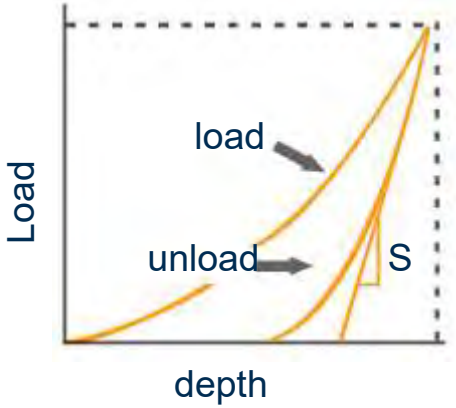


20 load/unload cycles until maximum load of 200 µN

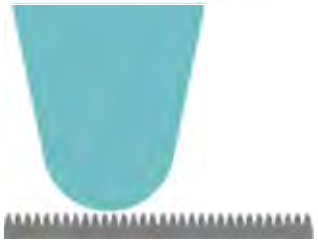
Stiffness

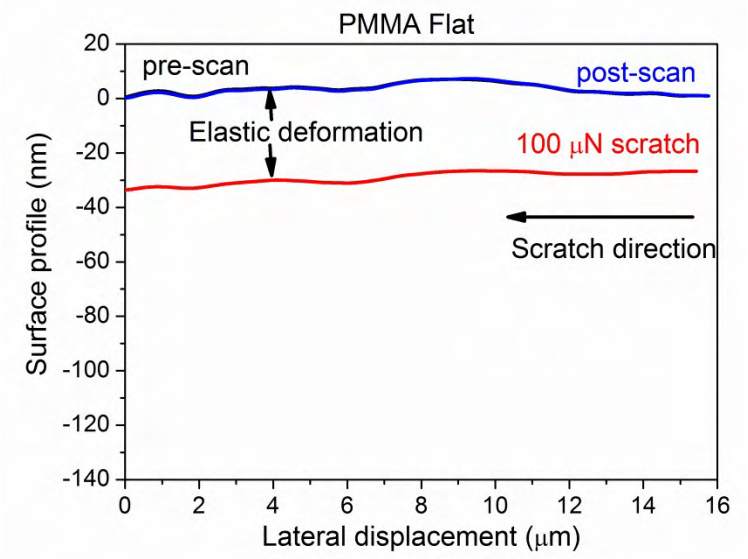
Slope of the curves in the elastic region (maximum of 10 nm)



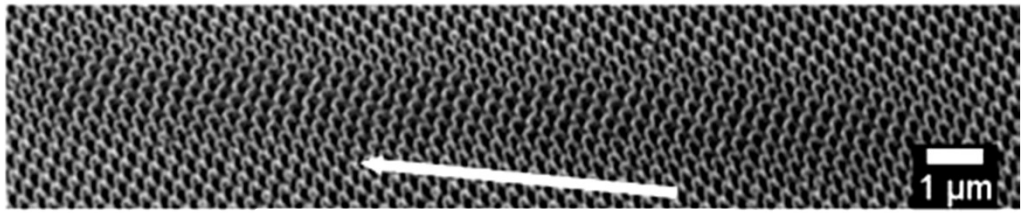


Mechanical resistance : Nanoscratch

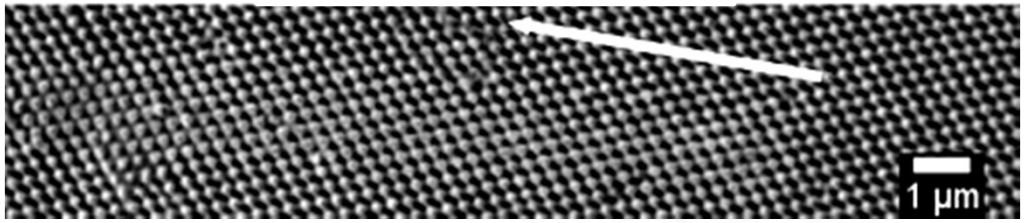


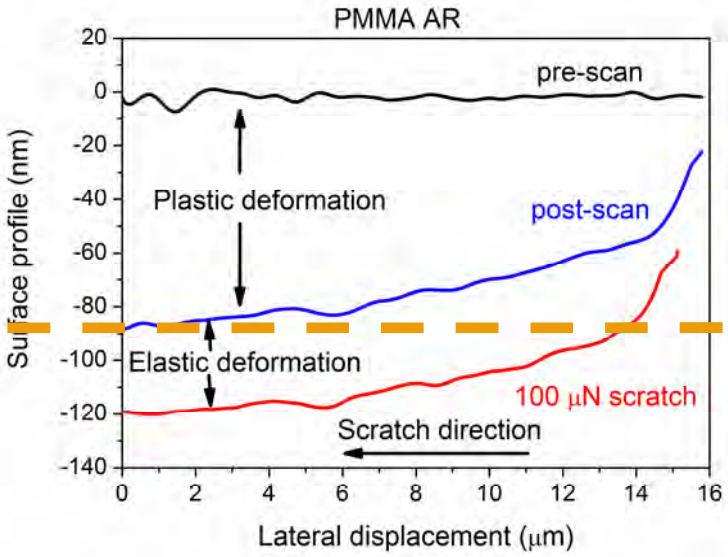


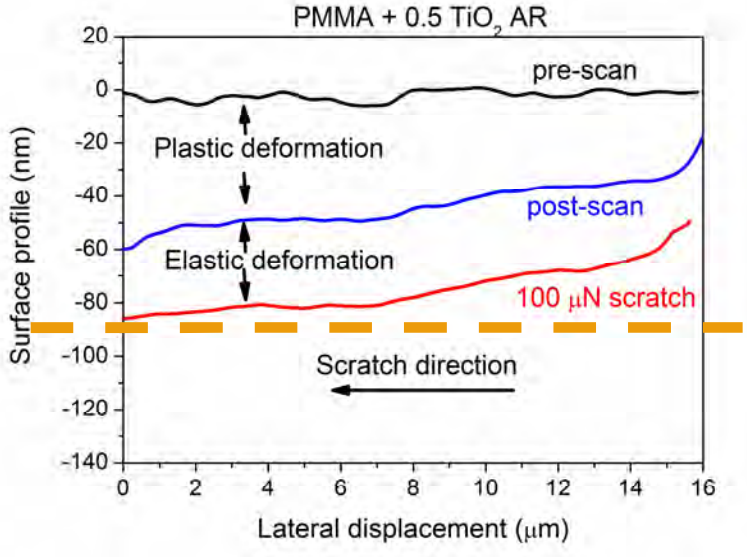
PMMA



PMMA + 0.1 wt% TiO_2

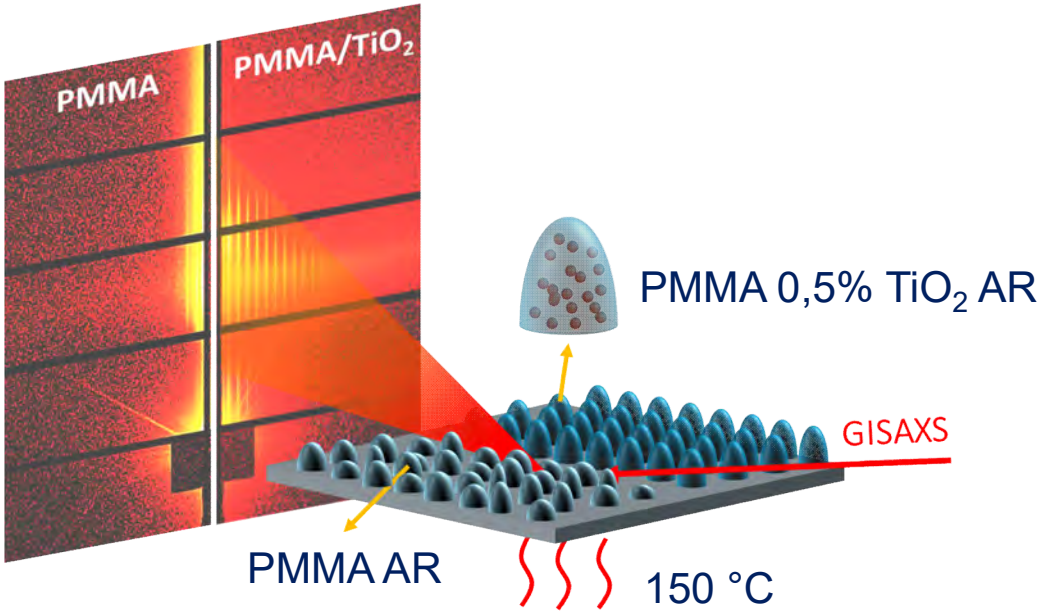






Thermal stability of AR patterns

Grazing Incidence Small Angle X-ray Scattering: GISAXS



IOP Publishing Nanotechnology
Nanotechnology 32 (2021) 385302 (9pp)

Improved thermal stability of antireflective moth-eye topography imprinted on PMMA/TiO_2 surface nanocomposites

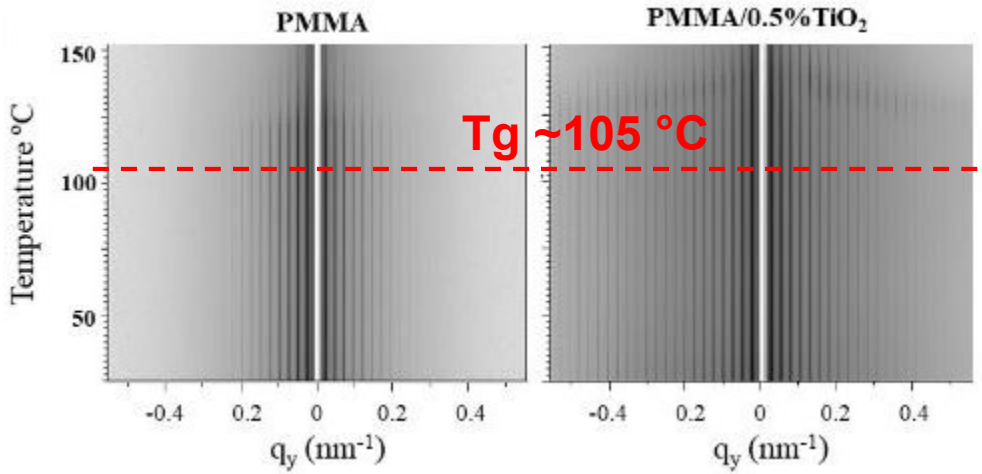
Alejandra Jacobo-Martín, Jaime J Hernández, Patricia Pedraz, Eduardo Solano, Iván Navarro-Baena and Isabel Rodríguez

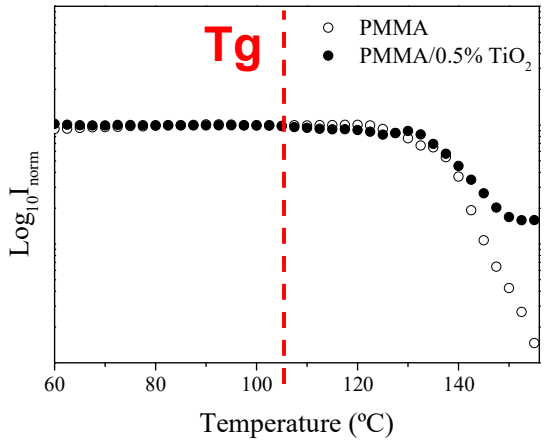
Distortions on the AR pattern

↓

Changes on the diffraction pattern

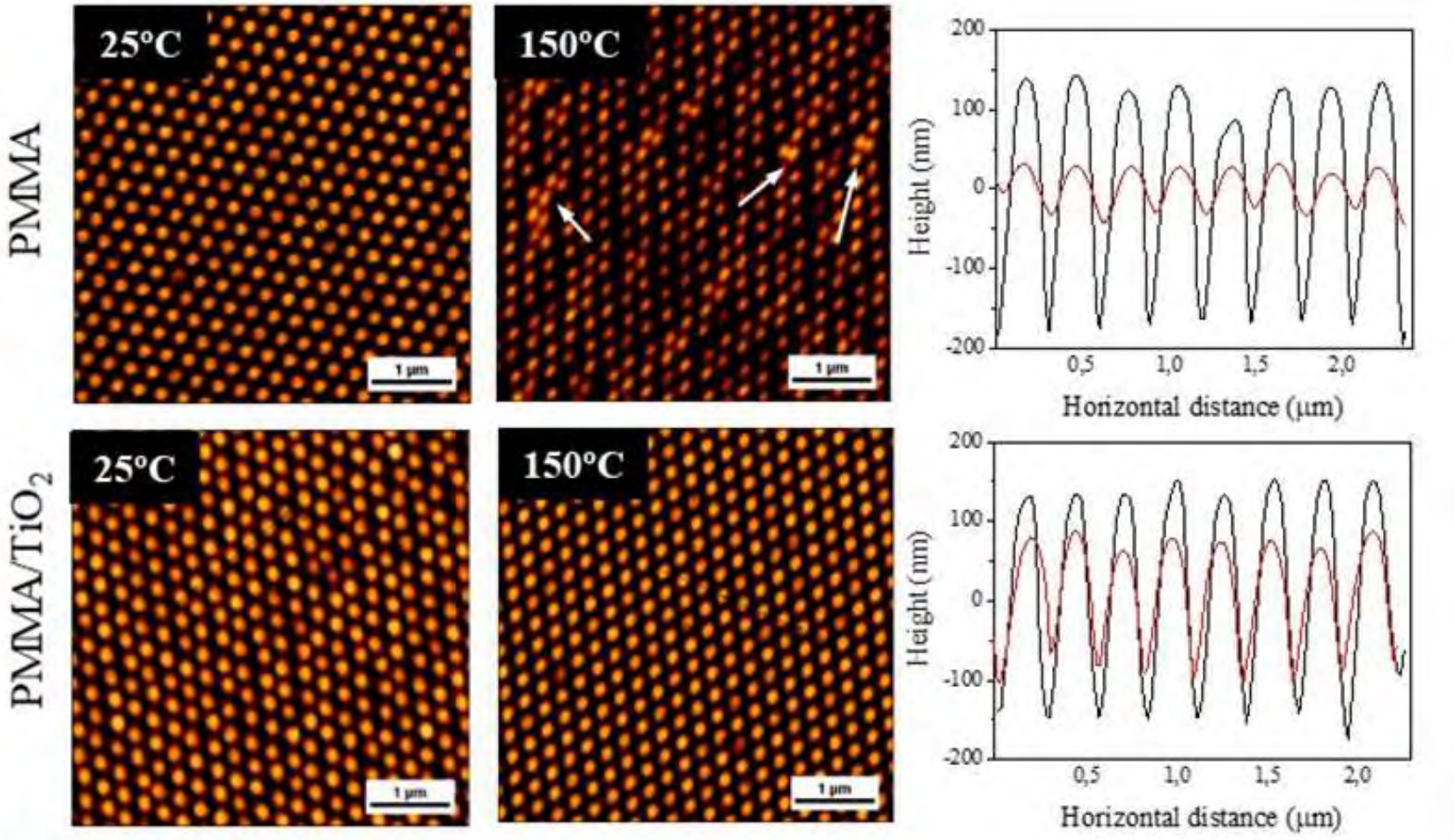
Integrated scattered intensity plots





Improved thermal stability

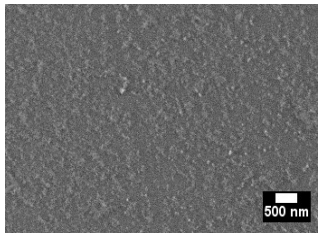
Moth-eye PMMA/TiO2 surface nanocomposites

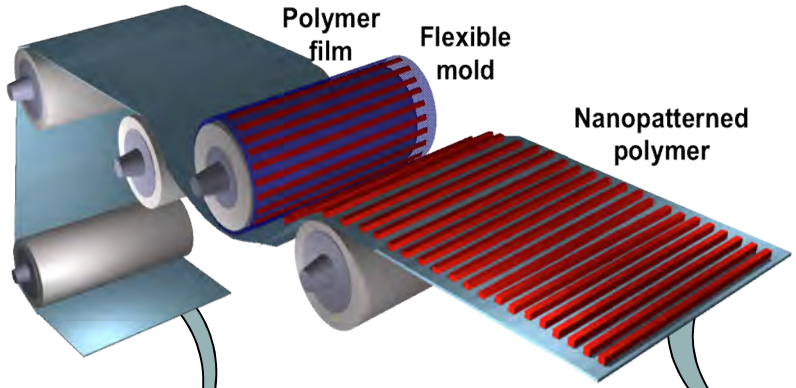


"anchoring effect of the TiO_2 NP to the polymer chain mobility" – pattern stability

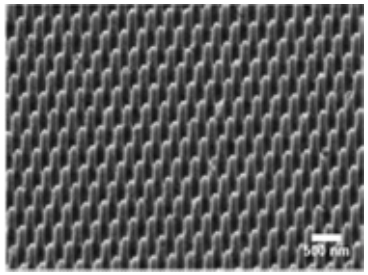
Continuous R2R process

2. Surface nanoimprinting



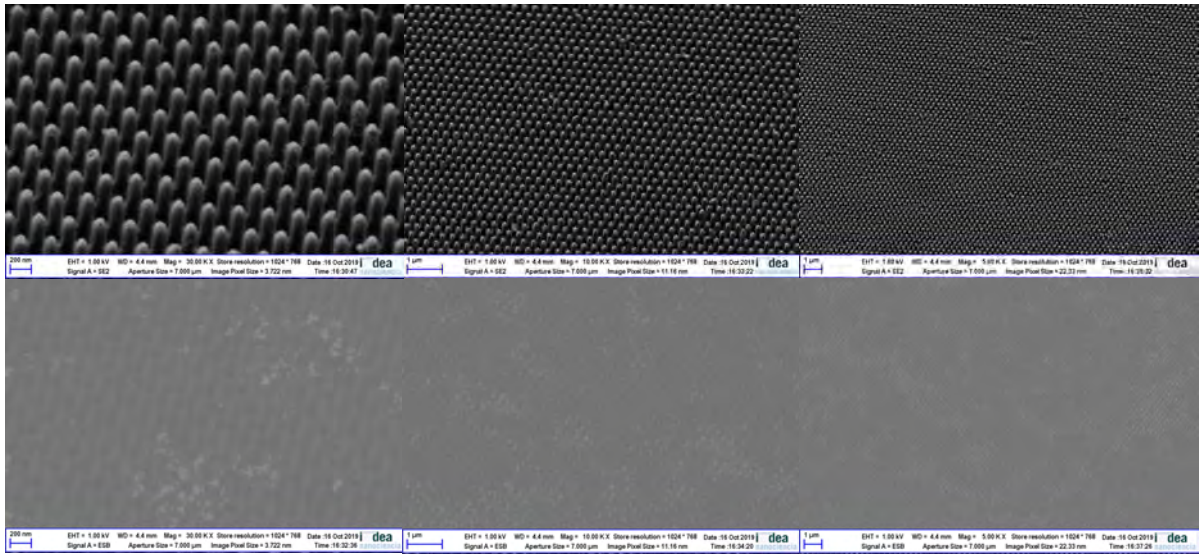


➢ Nanopatterned nanocomposite



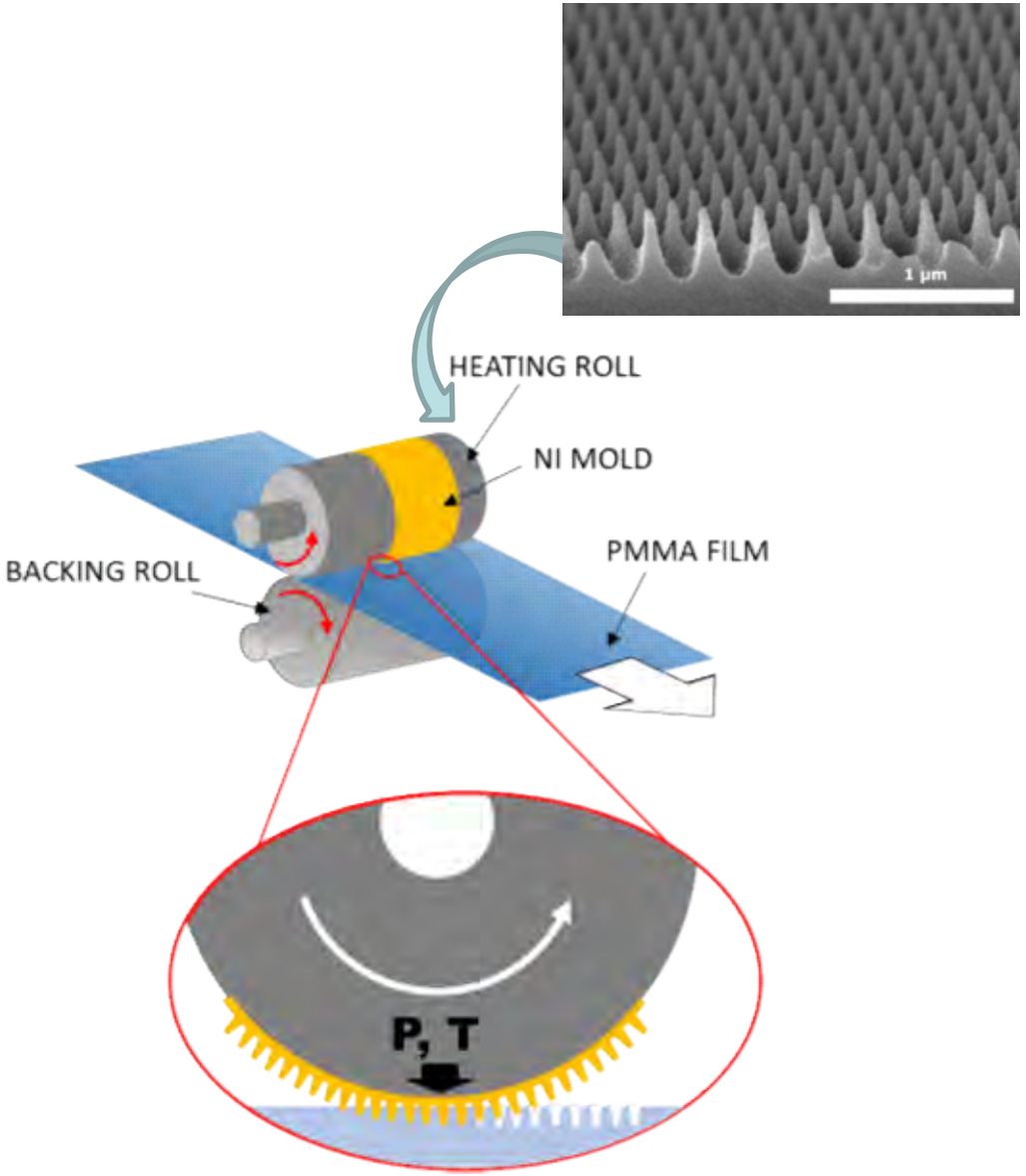
1. Nanoparticle coating

PET + PMMA + 025 % TIO2 ARC (R2R)



Patent : Polymeric composites with functional surfaces EP3436233B1 0000000

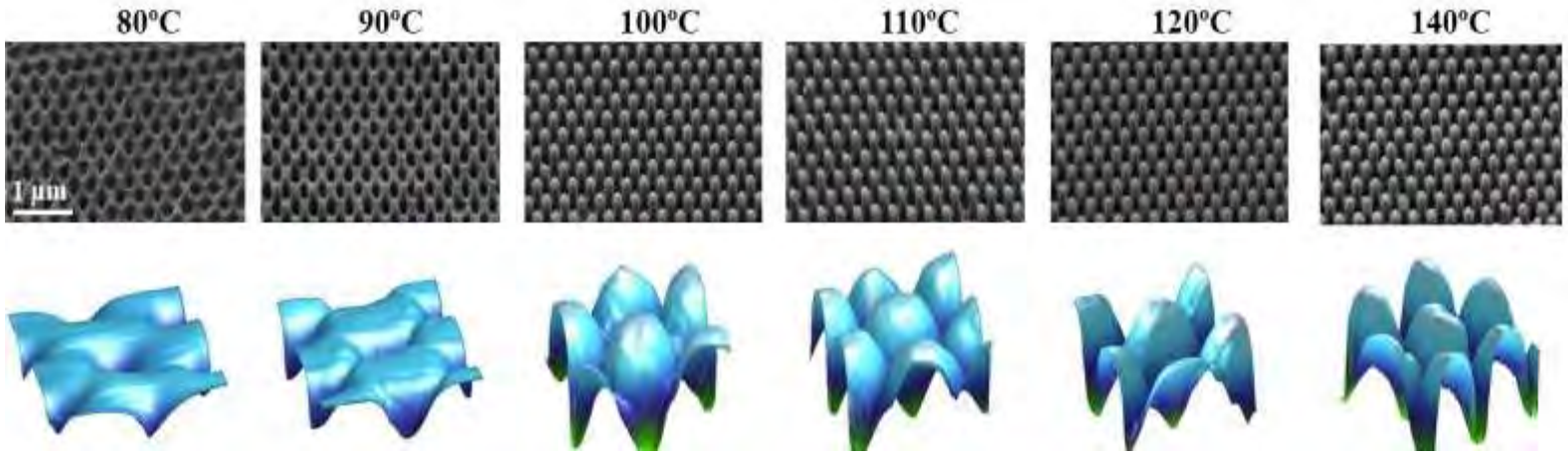
Thermal R2R imprinting of moth-eye non-reflective films



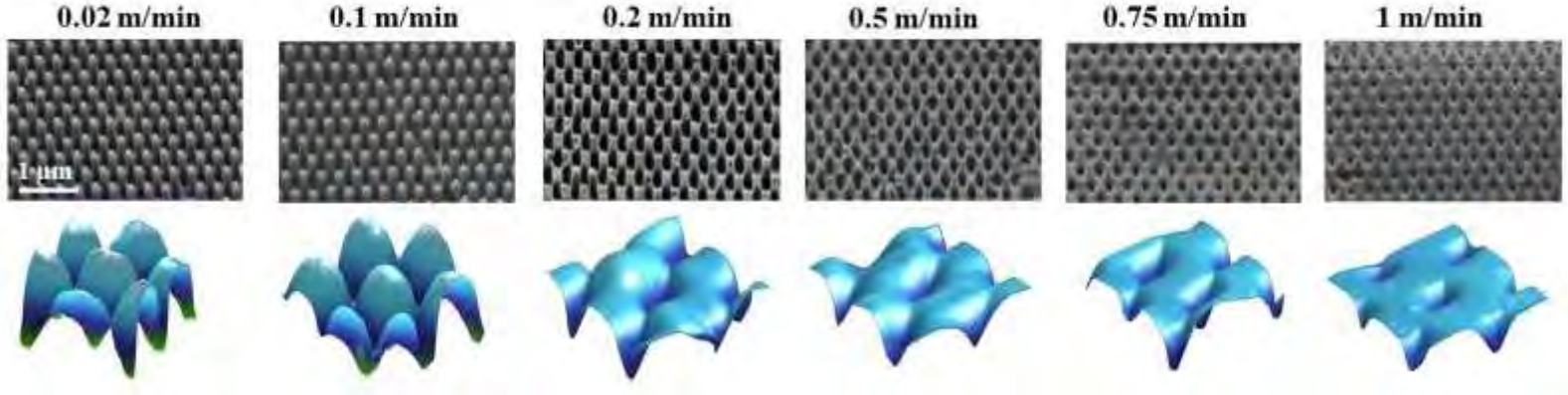
Scientific Reports, 2021 , 11(1), 1-15.

Thermal R2R imprinting of moth-eye non-reflective films

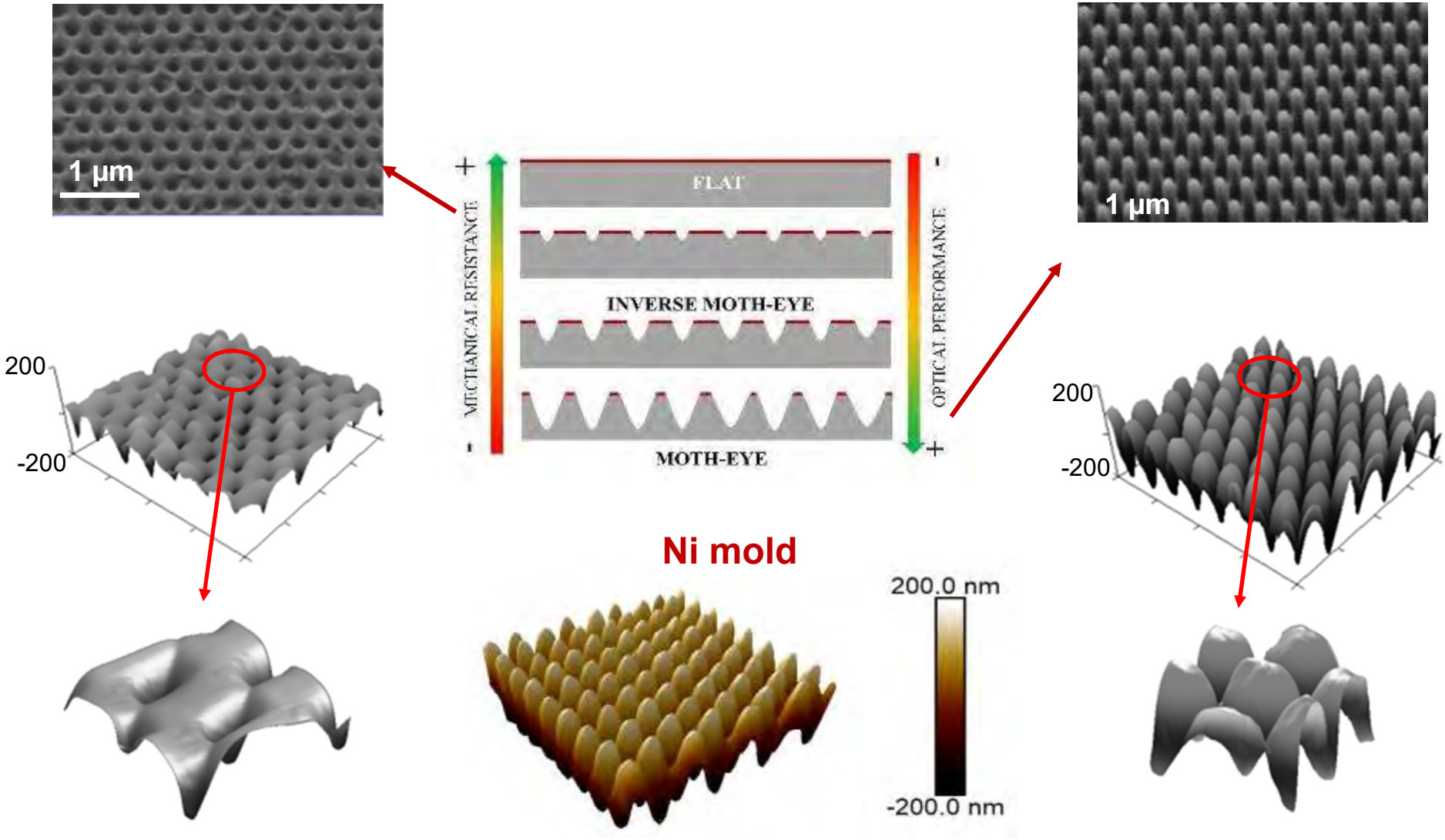
@ Variable temperature



@ Variable speed



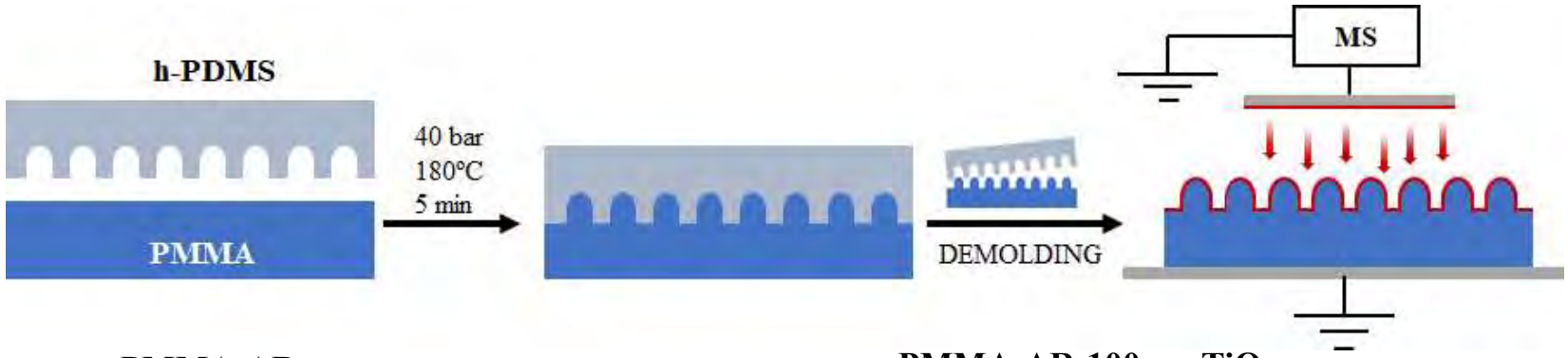
Thermal R2R imprinting of moth-eye non-reflective films



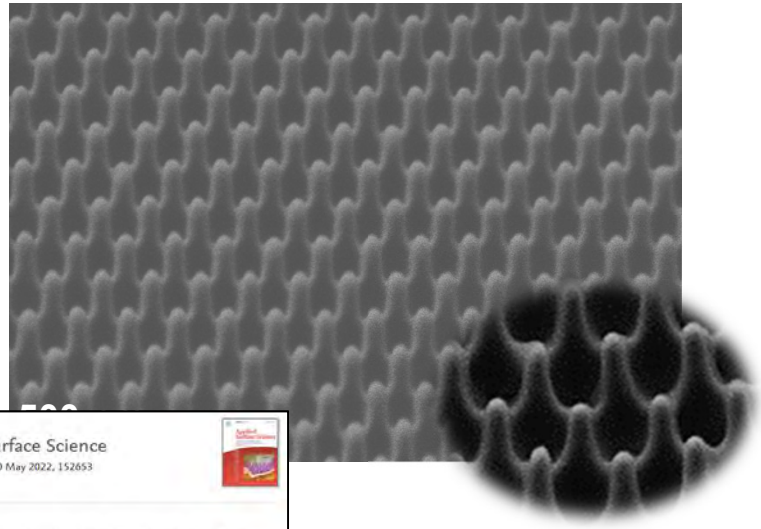
TiO_2-PMMA Moth-eye MS coating

NANOIMPRINT LITHOGRAPHY

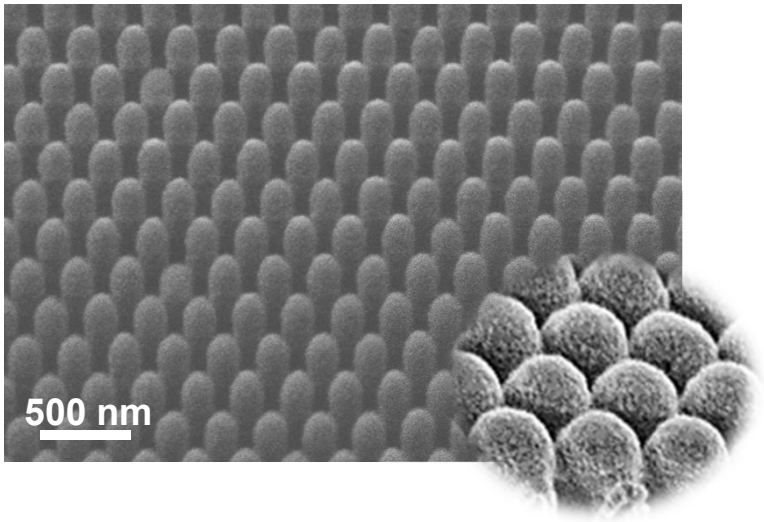
MAGNETRON SPUTTERING

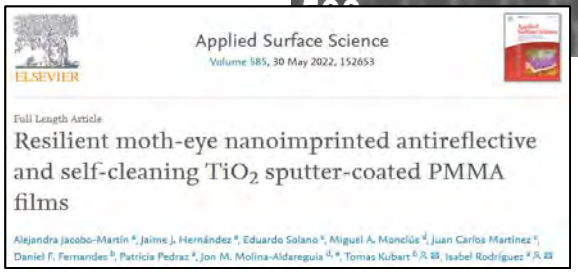


PMMA-AR



PMMA-AR-100nm-TiO_2





Applied Surface Science
Volume 585, 30 May 2022, 152653

Full Length Article

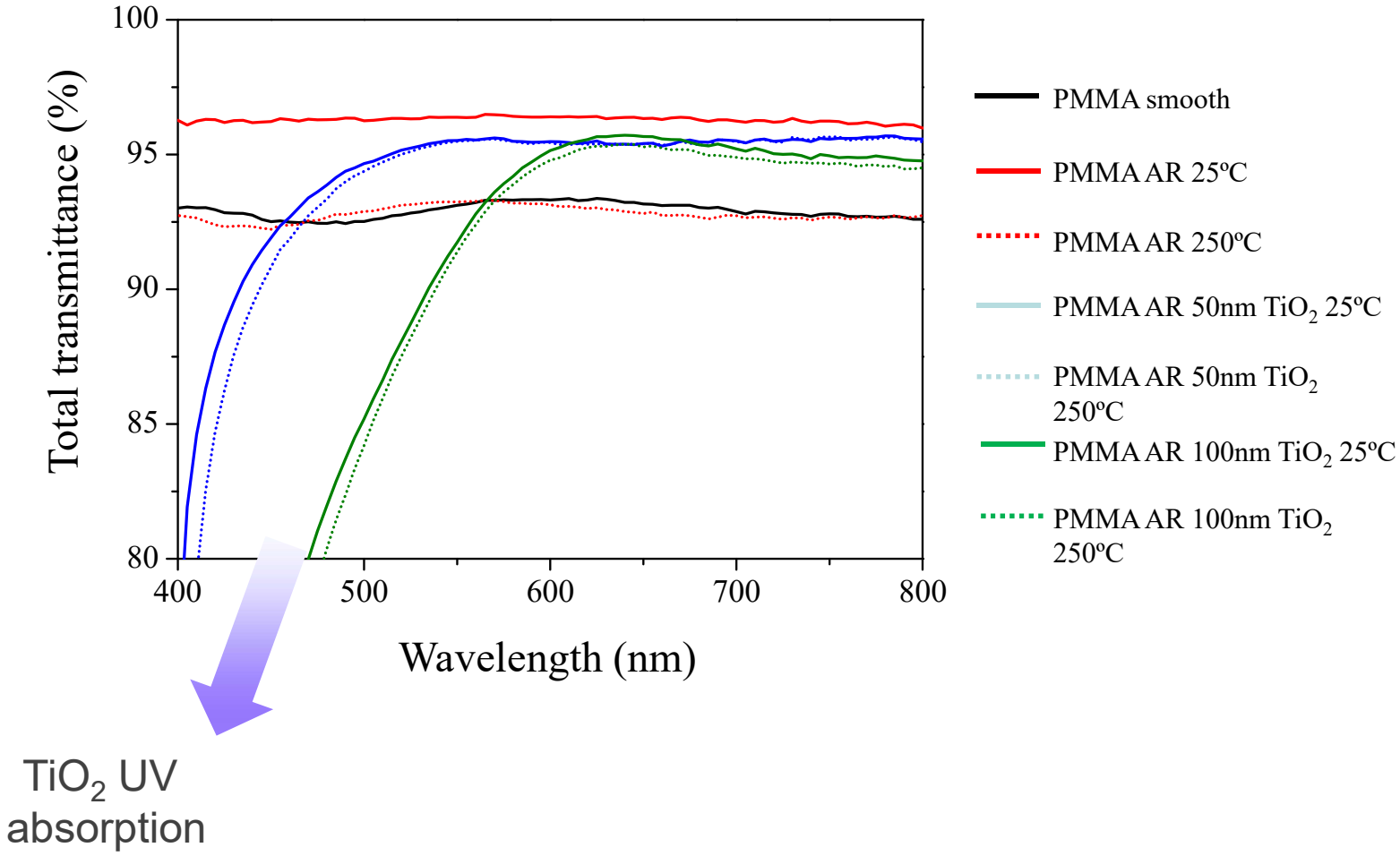
Resilient moth-eye nanoimprinted antireflective and self-cleaning TiO_2 sputter-coated PMMA films

Alejandra Jacobo-Martín [a], Jaime J. Hernández [a], Eduardo Solano [b], Miguel A. Monclús [d], Juan Carlos Martínez [c], Daniel F. Fernandes [b], Patricia Pedraz [a], Jon M. Molina-Aldareguía [d, *], Tomas Kubart [b, **], Isabel Rodríguez [a, **]

UPPSALA UNIVERSITET

Daniel Fernandes
Tomas Kubart

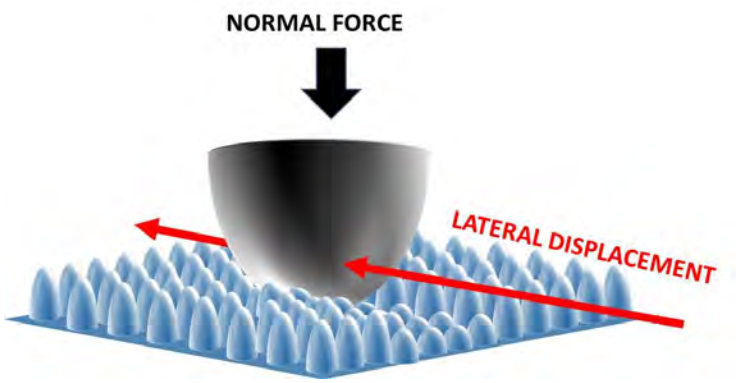
Optical transmittance

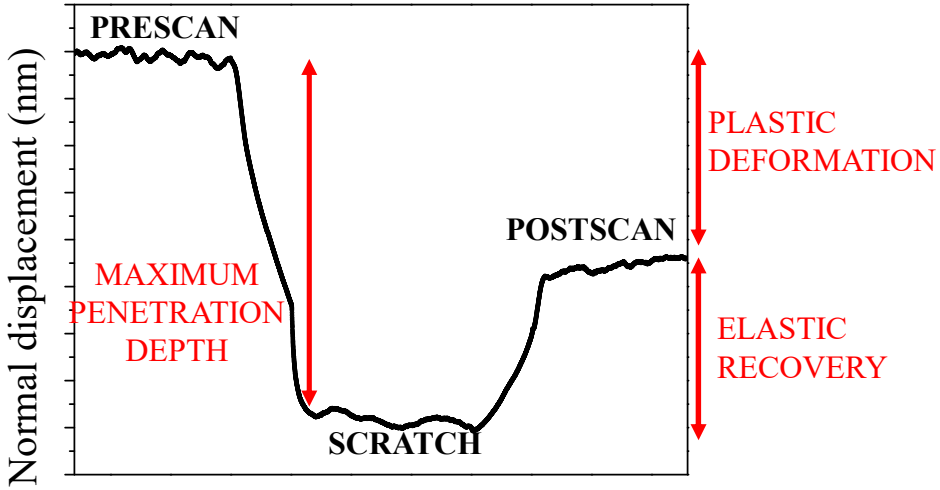


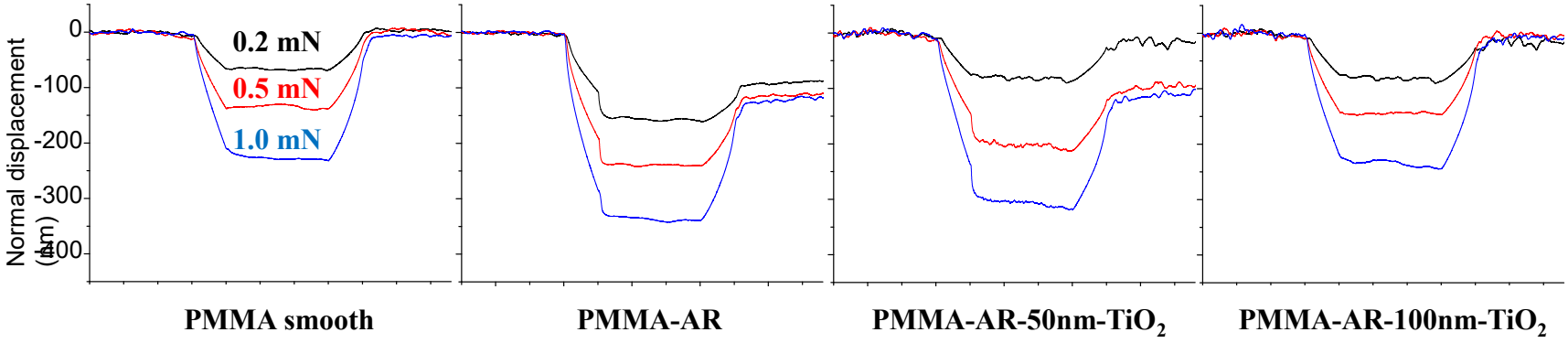
ANTIREFLECTIVE FUNCTIONALITY IS PRESERVED AT T>>Tg

Mechanical resistance

NANOSCRATCH TEST

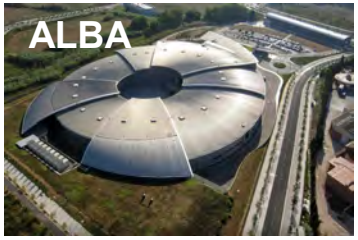




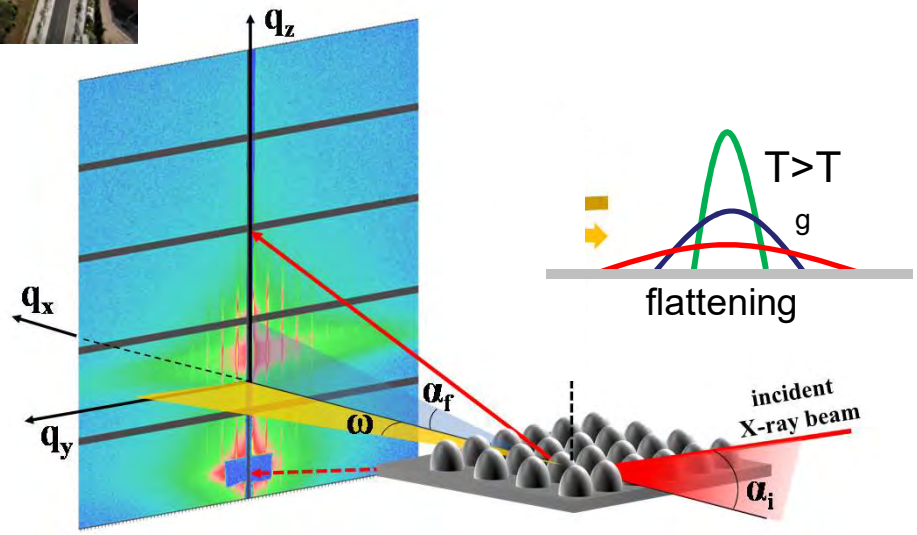


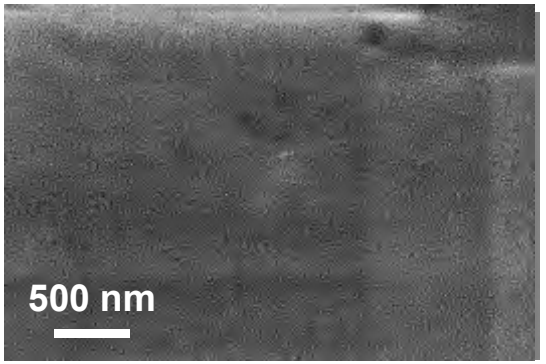
TIO_2 ENCAPSULATION IMPROVES SCRATCH RESISTANCE OF AR NANOSTRUCTURES

Thermal resistance

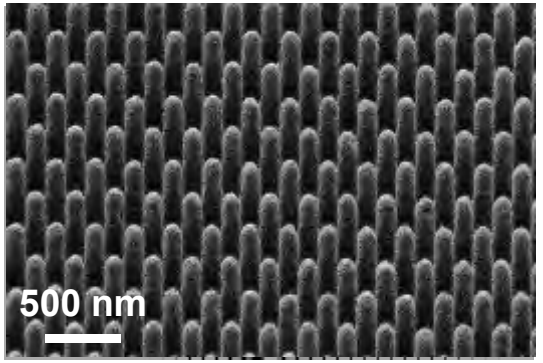


Grazing Incidence Small Angle X-ray Scattering (GISAXS)

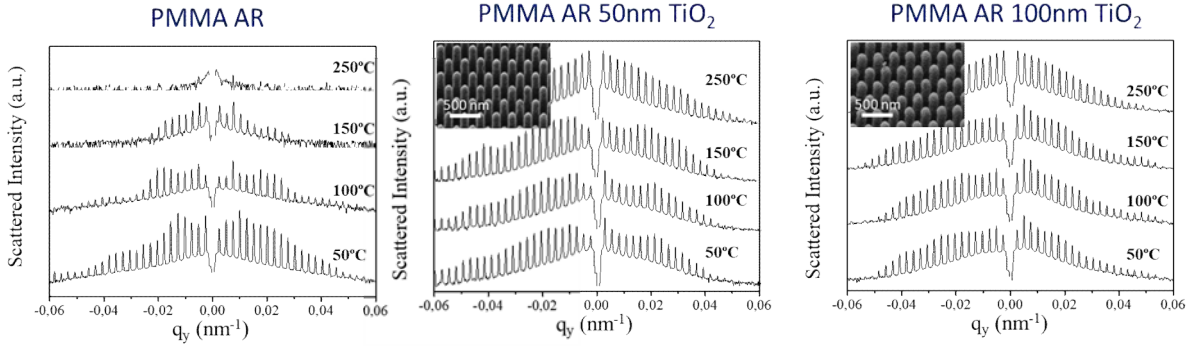




PMMA-AR



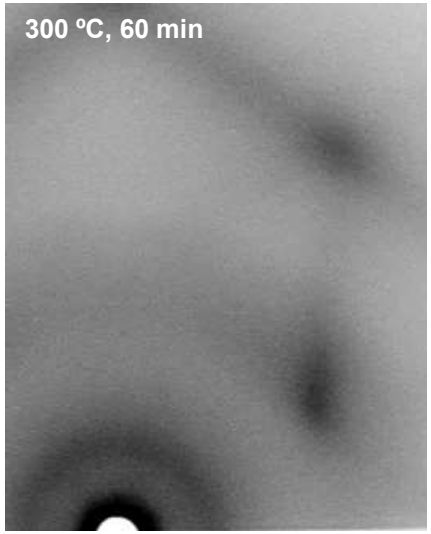
PMMA-50nm TiO_2-AR



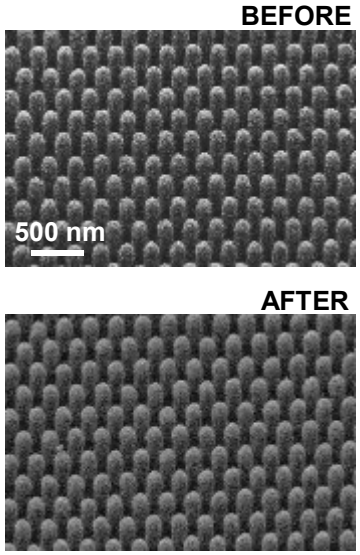
TIO_2 ENCAPSULATION PREVENTS REFLOW AND DISTORTION EFFECTS up to 250 C

Photoinduced self-cleaning

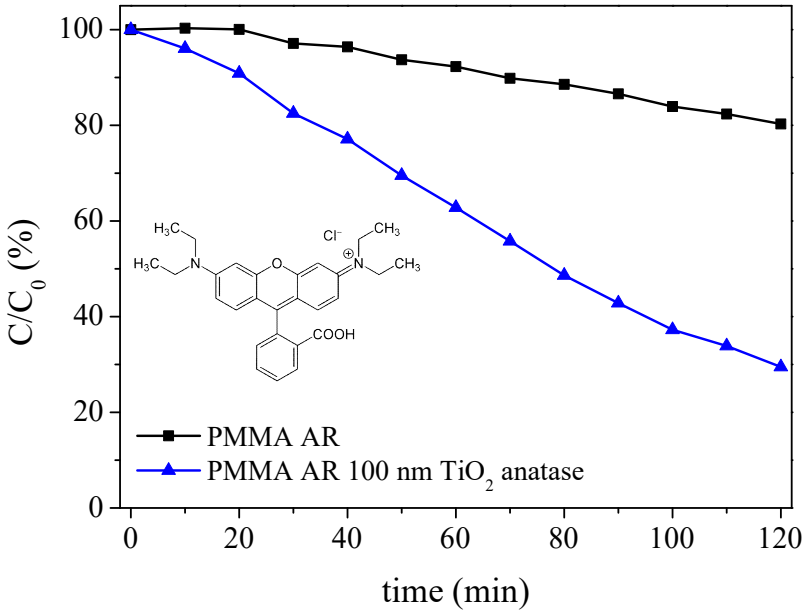
Amorphous TiO_2 → anatase

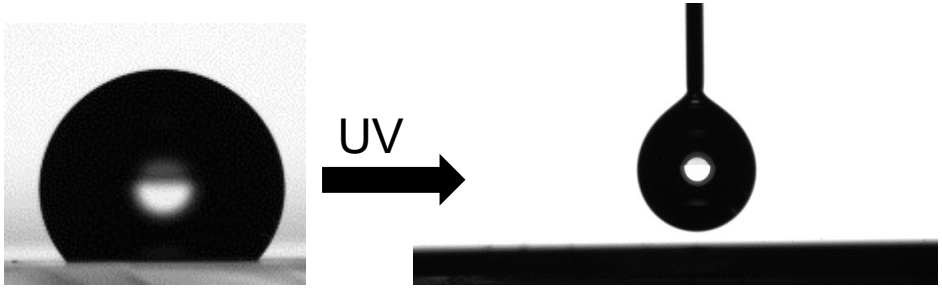


GIWAXS



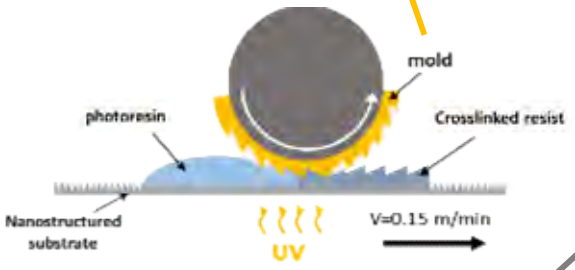
RhB UV degradation assay

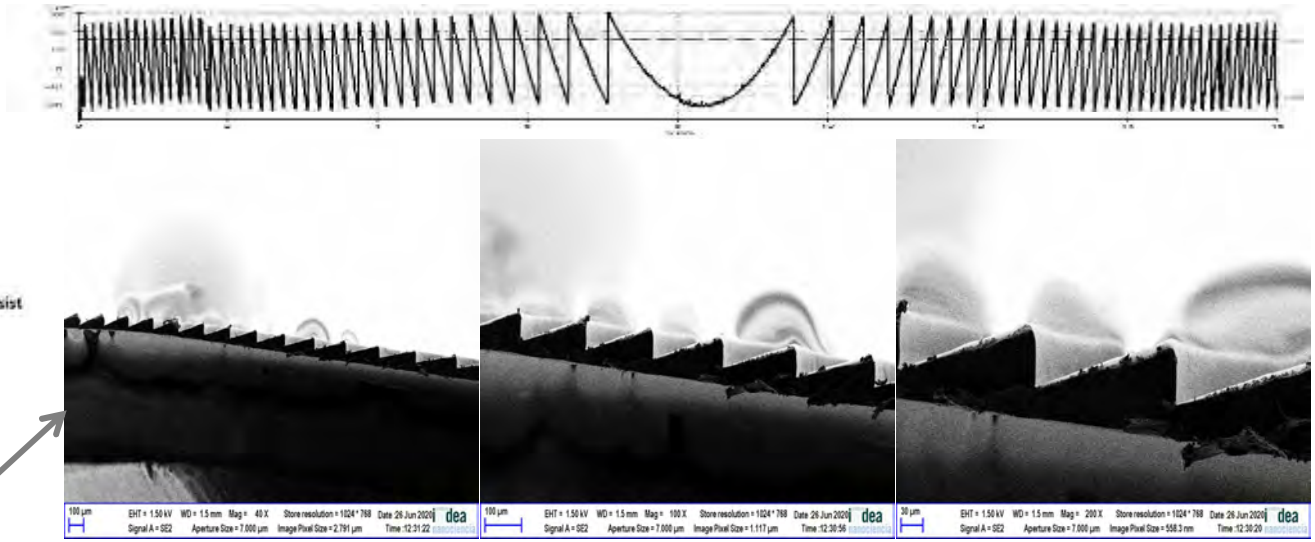


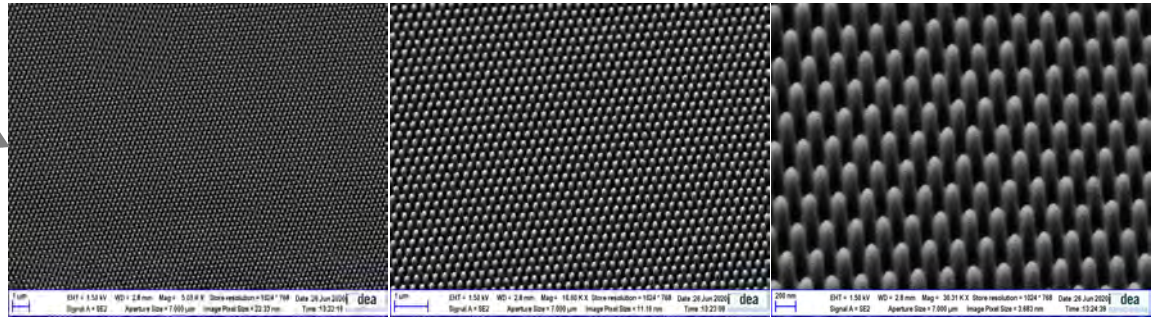


POLLUTANT DEGRADATION + SUPERHYDROPHYLICITY = SELF-CLEANING

UV R2R NIL Fresnel lens with anti- reflective moth eye







Acknowledgements

Group members

Jaime Hernandez
Alberto Martín Asensio
Miguel Esteban Lucía
Sergio Dávila
Maria Teresa Alameda

Alejandra Jacobo
Jean Cacheux
Ivan Navarro Baena

Collaborators

Daniel Fernandes
Tomas Kubart

Manuel R Osorio
Daniel Granados

Miguel Monclus
Jon Molina

César Domínguez
Ignacio Antón

Eduardo Solano
Juan Carlos Martínez

Thank you for you attention !