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Fabrication of nanostructured microarrays by combining nanoimprint-assisted microcontact stripping and colloidal lithography techniques

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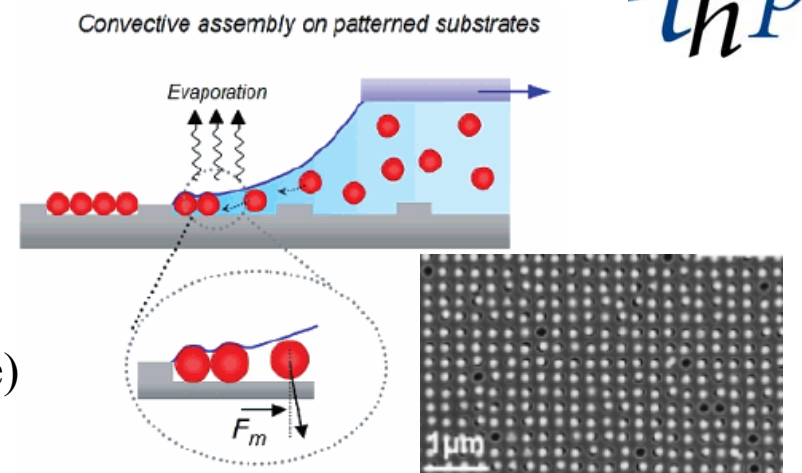
- **Purpose of the work:** fabrication of ordered microstructures of colloidal crystals over large areas

- **Table of contents**

1. Introduction

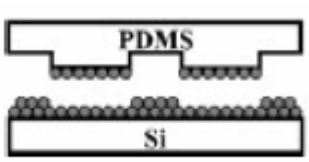
Bead patterning methods

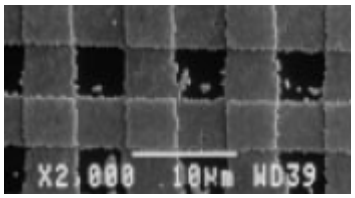
- Directed self-assembly of nanoparticles
  - Chemical modification
  - Topographic modification (SAPI, Delamarche)



* Malaquin et al. *Langmuir*, 200

- Methods for patterning the colloidal film after it has been formed:
  - Soft lithography lift-off processes (PDMS)





* Yao et al. *Adv. Mater.*, 2004, 16(1)

Nanoimprint-assisted contact stripping

- Top-down, fine control over the microstructure of the colloidal film
- Control of pressure and temperature during the removal of the nanoparticles
- PMMA stamps are harder than PDMS and less deformable

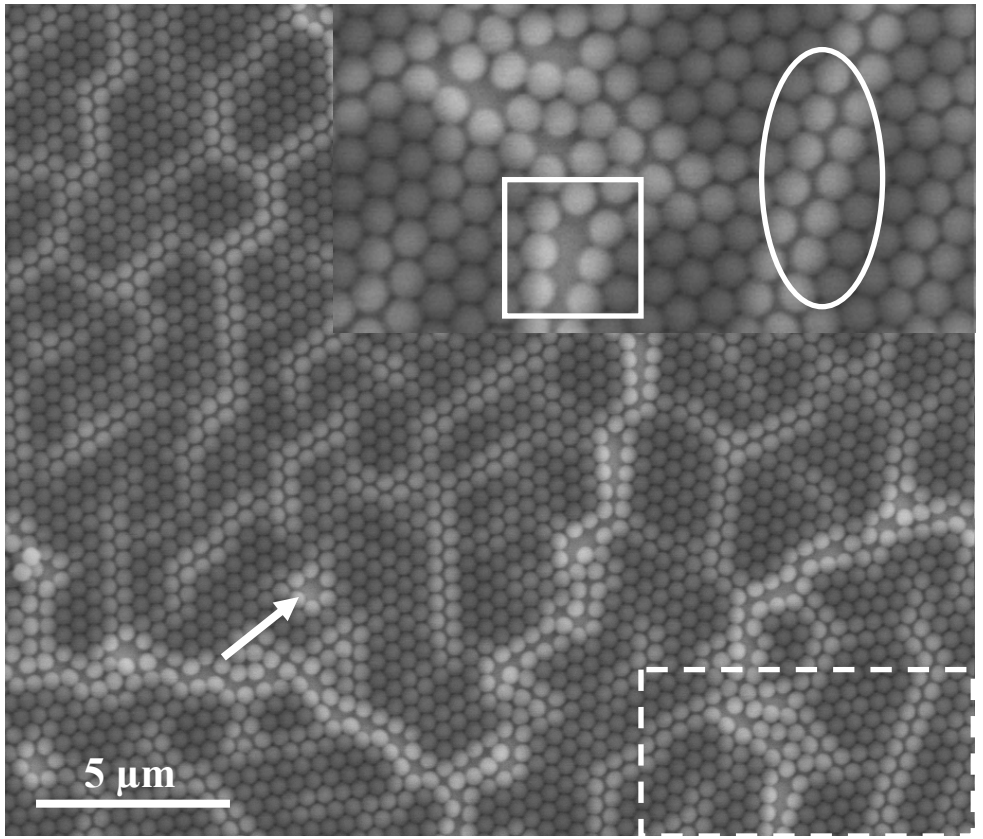
Applications

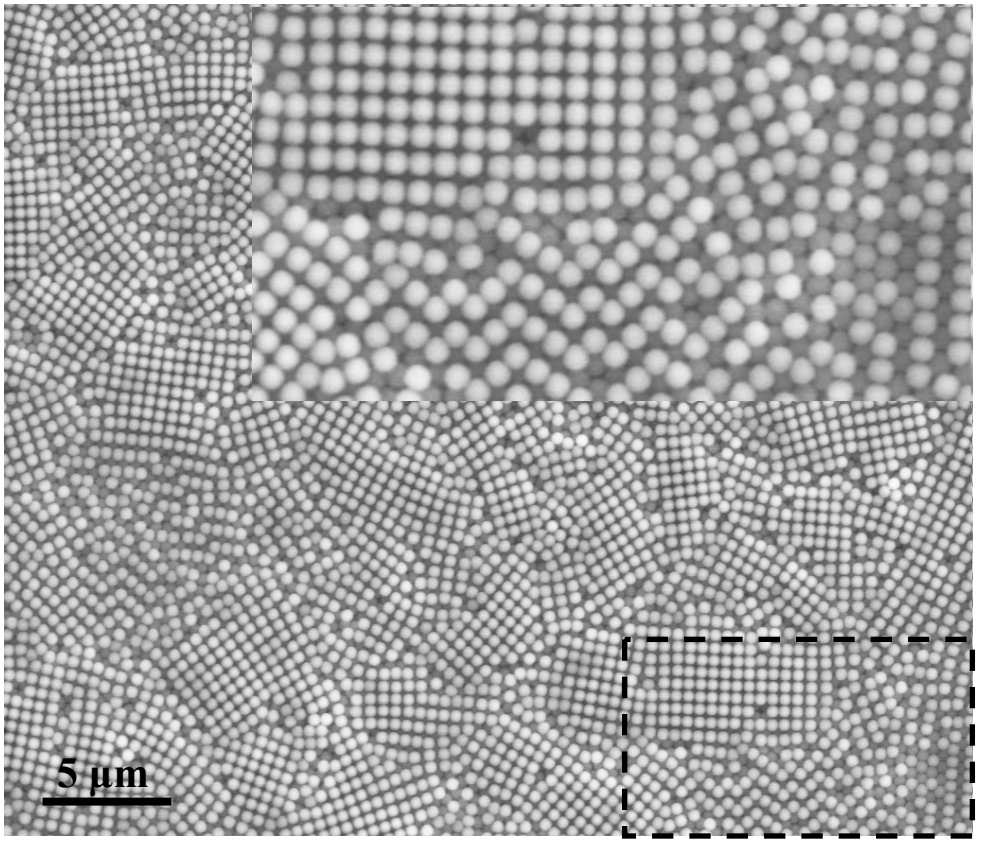
- Cell culture platforms to examine cell-surface interactions
- Sensing platforms for parallel detection

2. Poly(styrene) bead deposition

Spin-coating

PS 500nm → Monolayer and bilayer formation



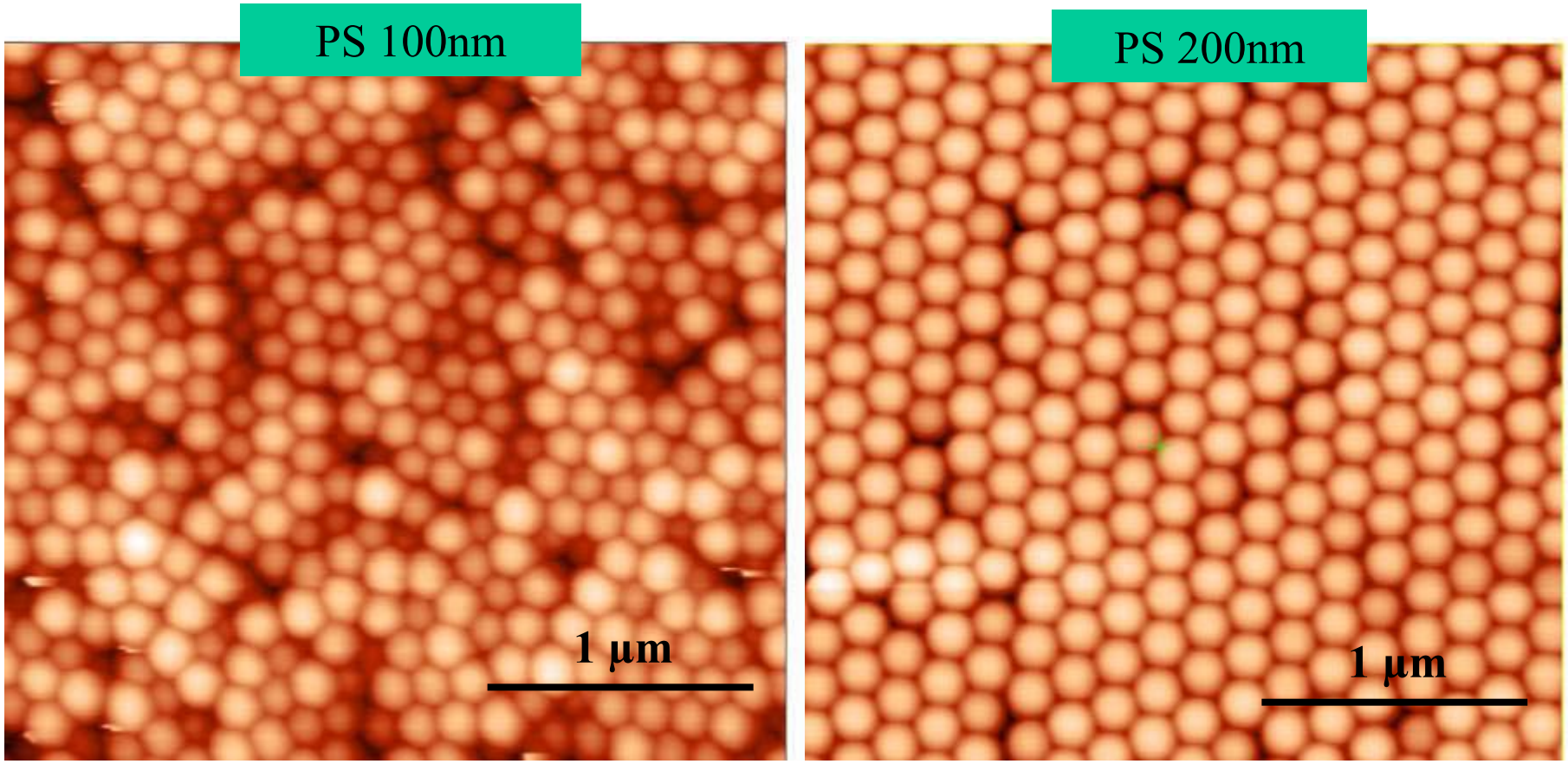


2. Poly(styrene) bead deposition

Spin-coating

PS 100nm → disordered multilayer

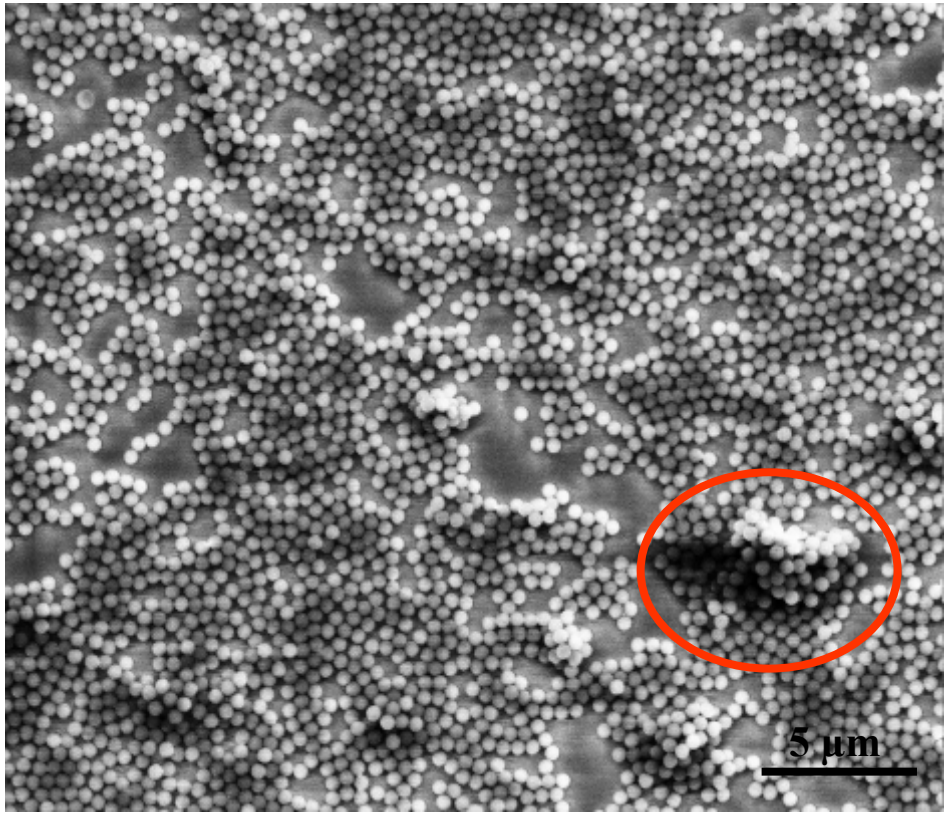
PS 200nm →ordered packing of nanoparticles

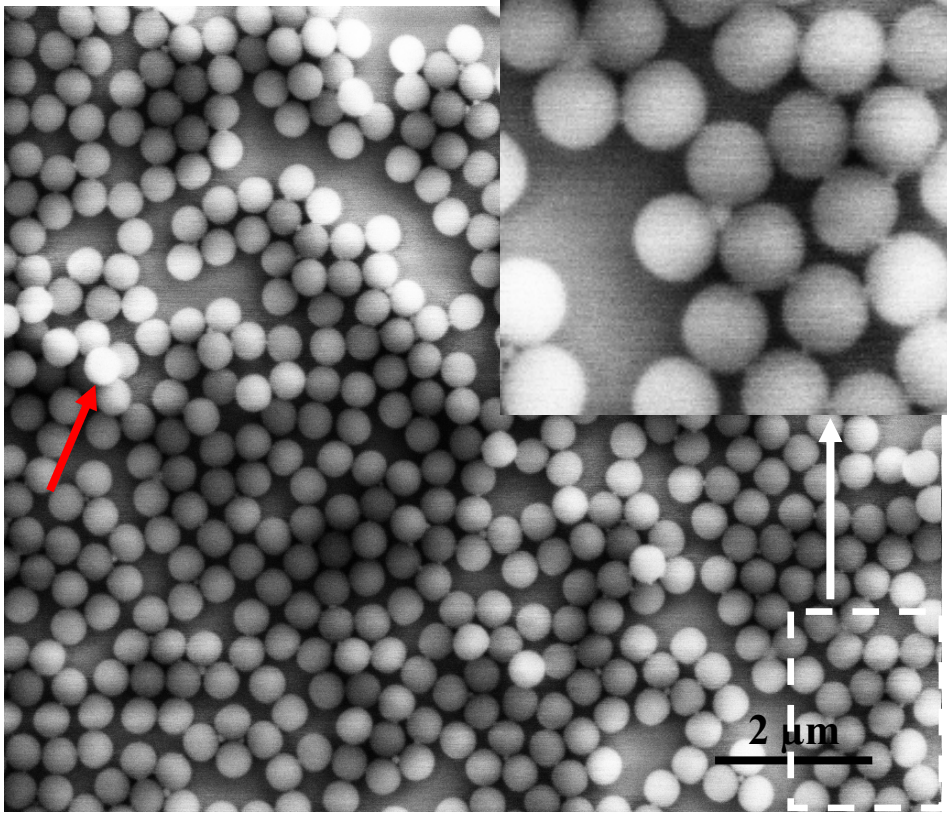


2. Poly(styrene) bead deposition

Langmuir-Blodgett films

Ionic assembly → inhomogeneous layers, high adhesion to the substrate





3. Nanoimprint-assisted contact stripping

Nanoimprint Lithography (NIL) – parallel technique

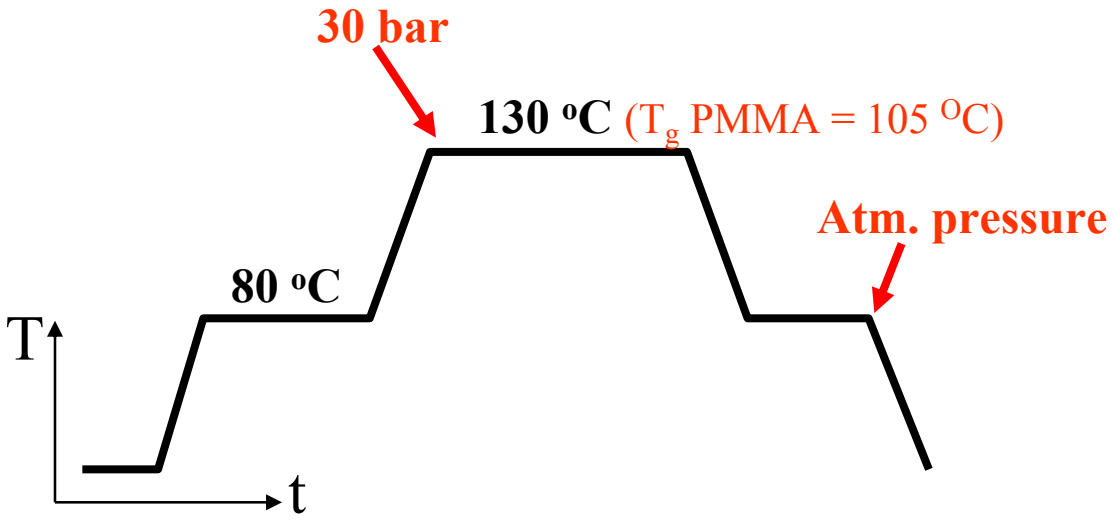
Imprinting: a mould that includes the nanostructures is pressed into a thermoplastic polymer (T, P)

Lateral resolution: 30 nm.

Working temperature: up to 250ºC

Working pressure: from 5 to 70 bar

Typical sequence for imprinting PMMA:



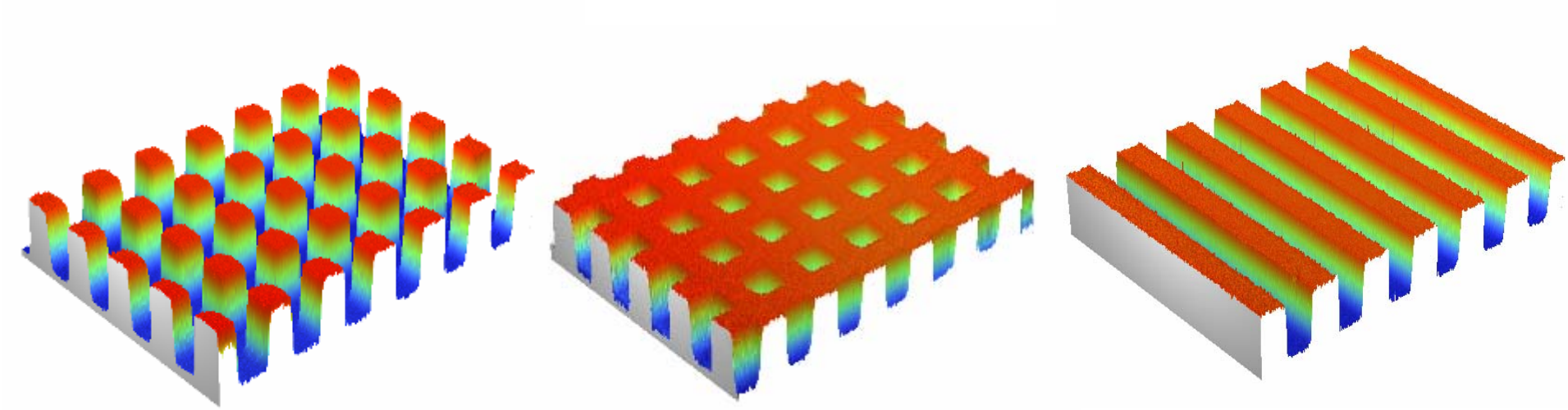
We have used the NIL for nanostructuring polymer surfaces (fabrication of PMMA stamps) and for patterning nanoparticles

3.1 Stamp production

PMMA moulds by NIL

	$T_{(Imprint)}$ / K	P / Nm^{-2}	t / s	$T_{(Release)}$ / K
PMMA stamp production	403	$3x10^6$	600	353

Size of structures: 20 µm - 2 µm

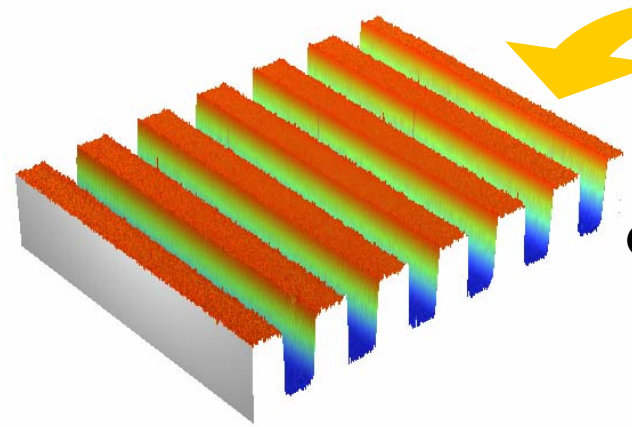


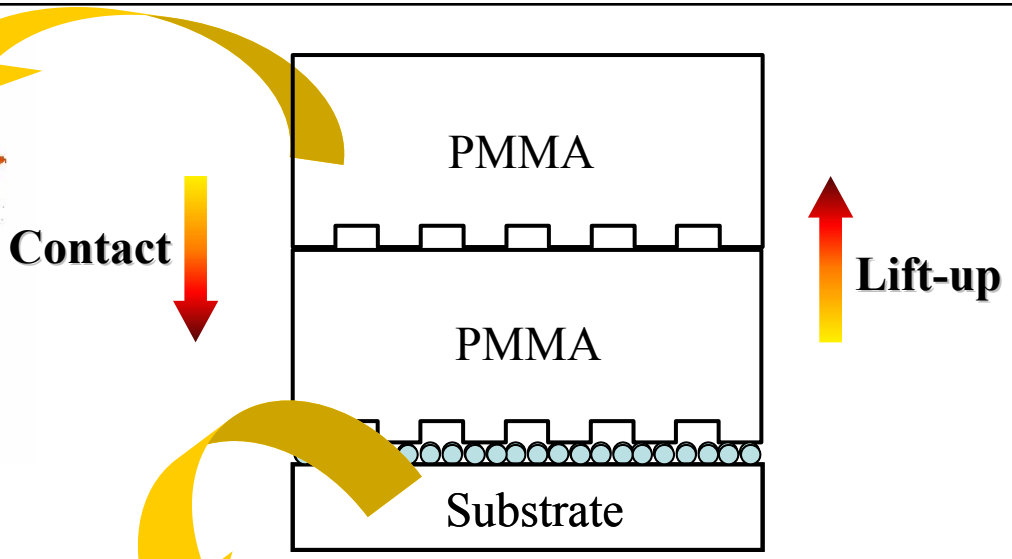
Optical interferometer images of the PMMA replicas

3.2. Patterning of nanoparticles

Microcontact Stripping (MCS)

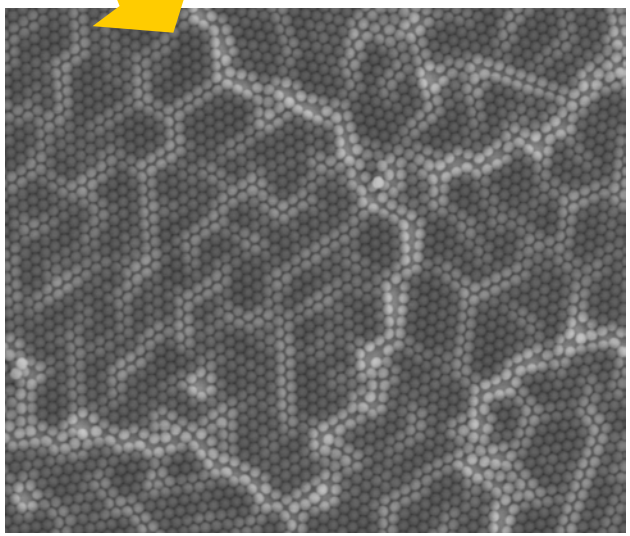
	$T_{(Imprint)}$ / K	P / Nm^{-2}	t / s	$T_{(Release)}$ / K
PS contact stripping	323	$5x10^6$	200	303





PMMA stamps

Produced by imprinting silicon masters using the nanoimprinter



Substrate with nanoparticles

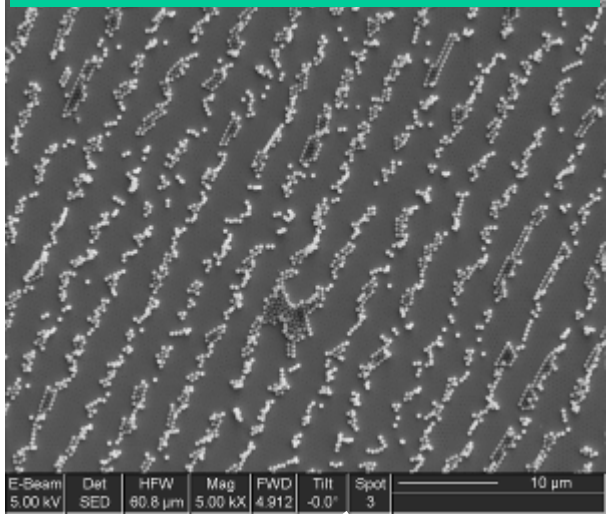
PS beads 100nm ~ 500nm spin coated on silicon or self-assembled by Langmuir-Blodgett technique

3.2. Patterning of nanoparticles

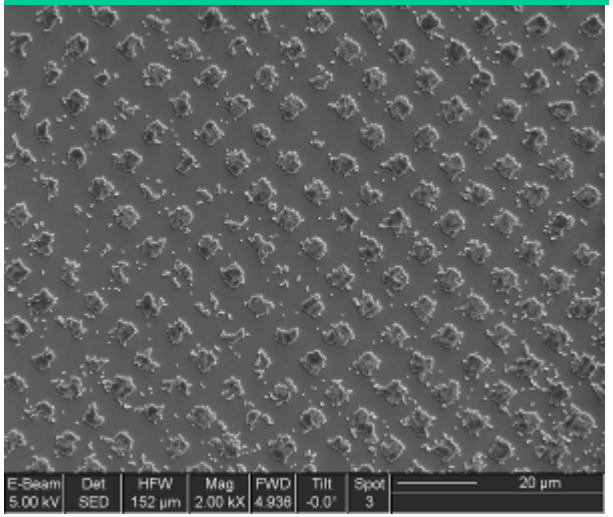
Microcontact Stripping (MCS)

PDMS stamps

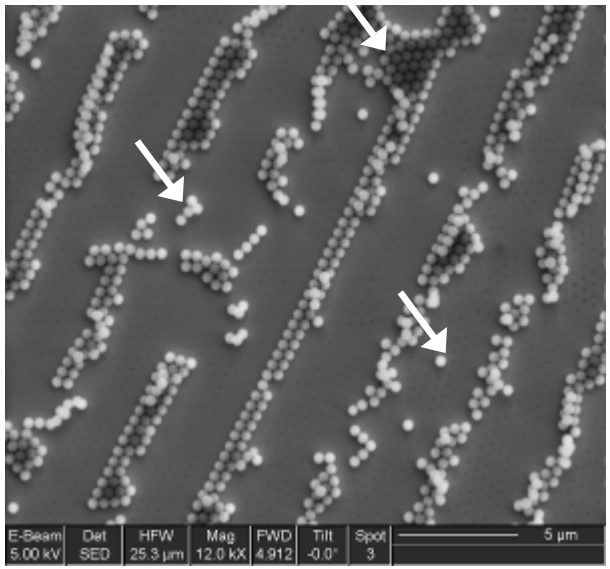
PDMS with 2 µm lines

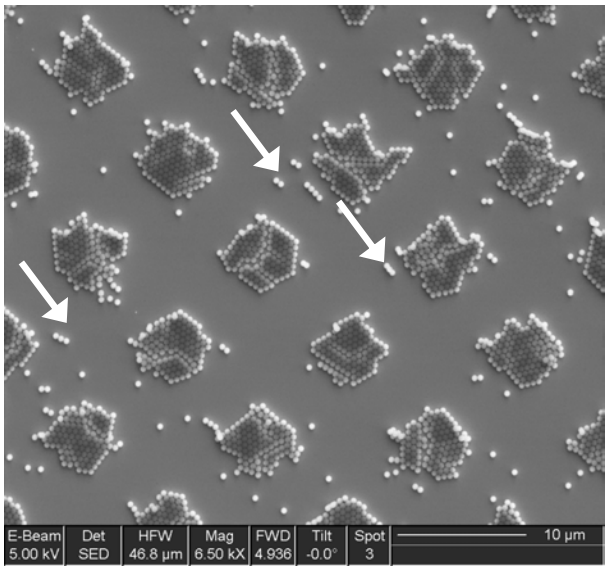


PDMS with 5 µm holes



Bead "contamination" between the patterns



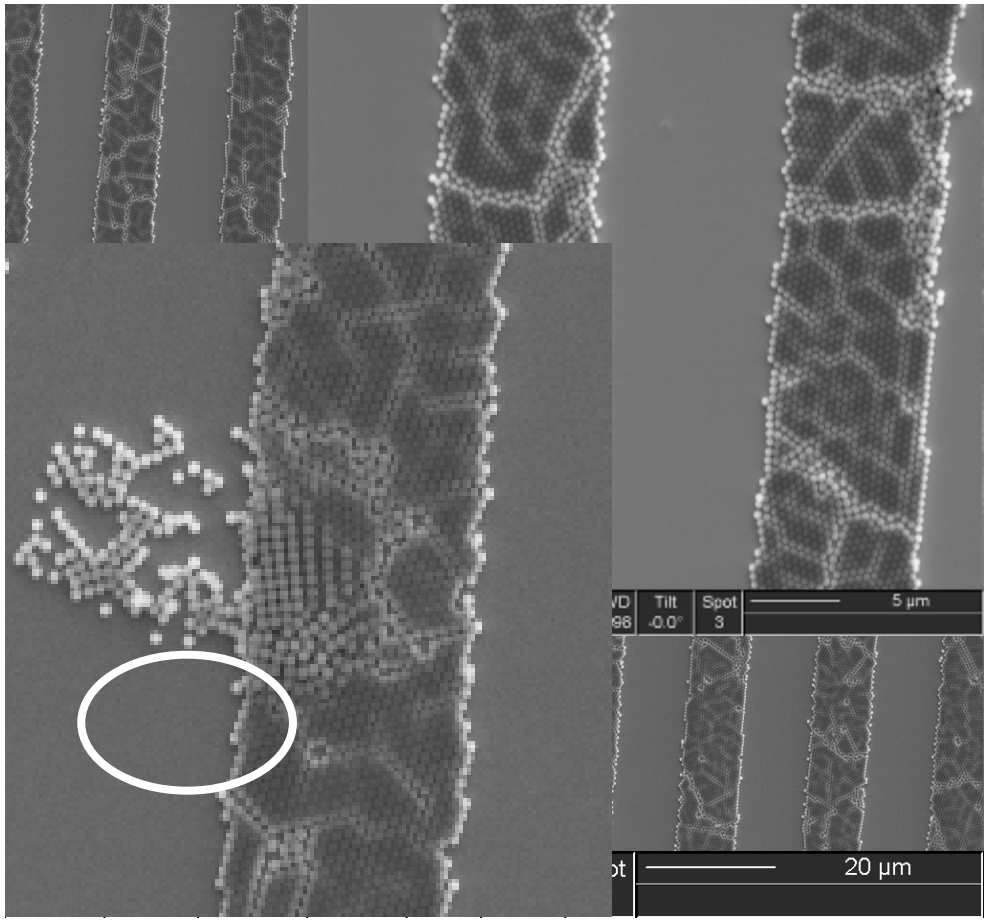


3.2. Patterning of nanoparticles

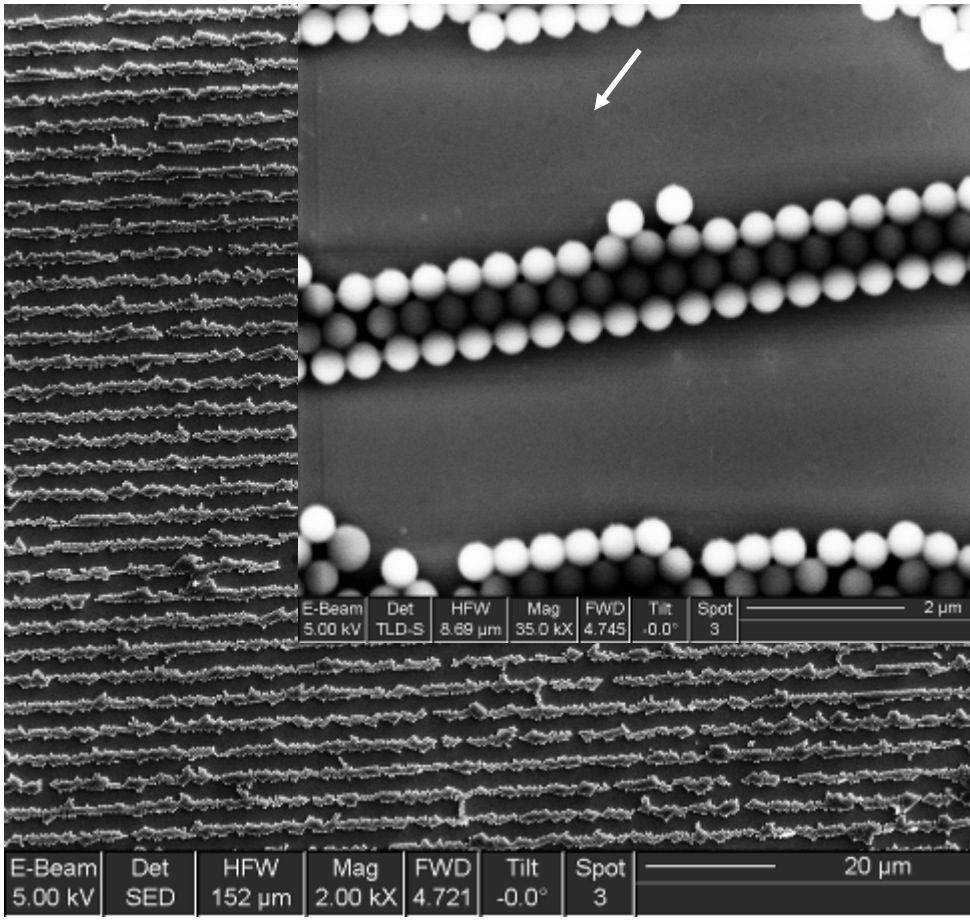
NIL-assisted Microcontact Stripping

PMMA stamps Stripping routine: 50bar 50 °C

10 µm lines



~2 µm lines

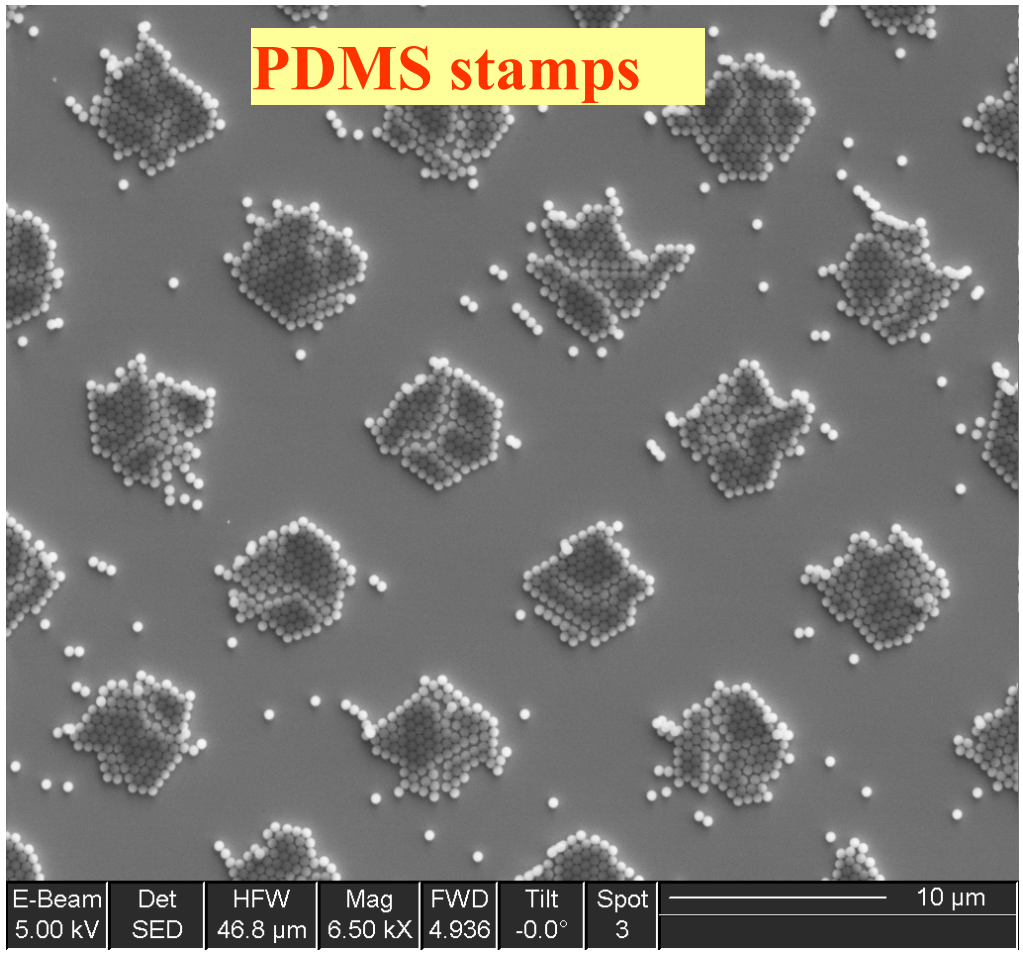


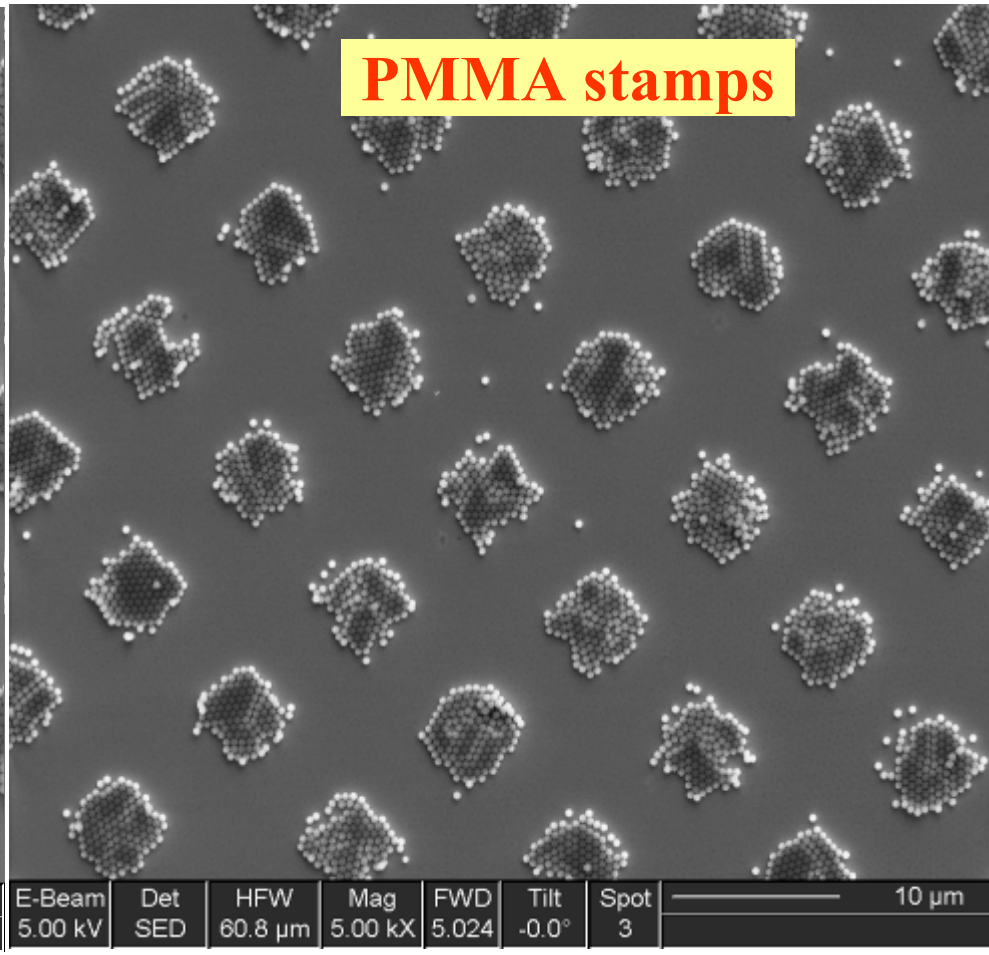
Advantage: larger areas, more homogeneous stripping

3.2. Patterning of nanoparticles

Conventional PDMS vs NIL-assisted Microcontact Stripping

Stamps with 5 µm holes

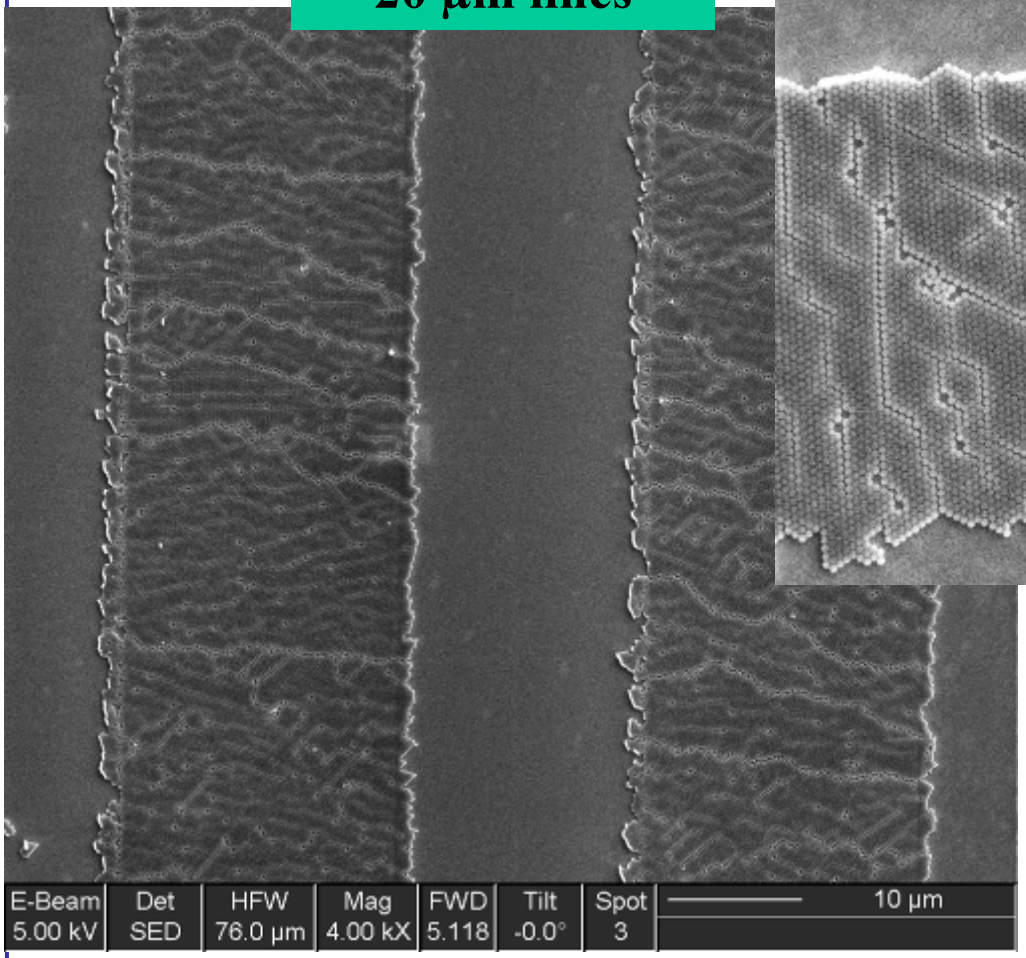




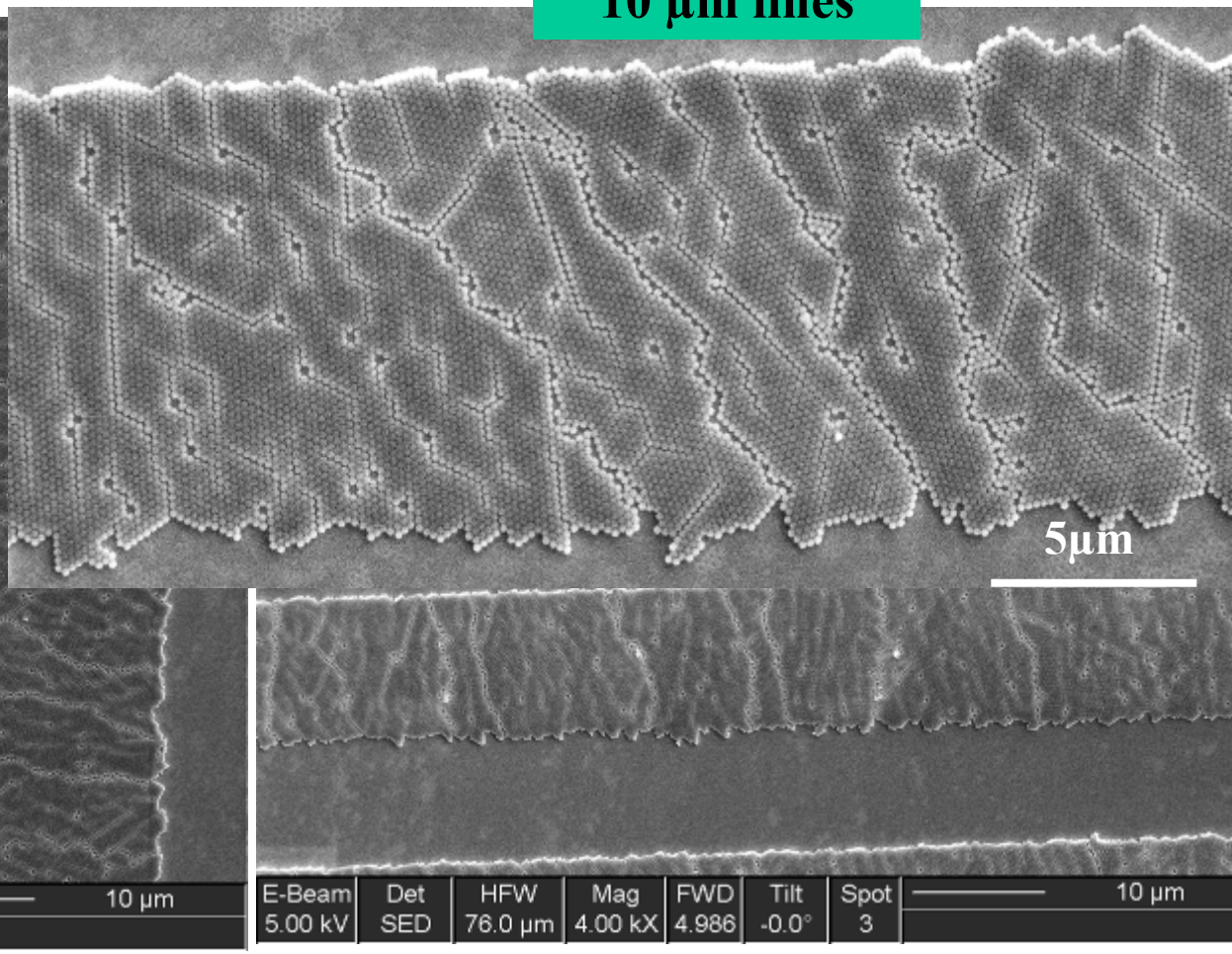
3.2. Patterning of nanoparticles

PMMA stamps – 200nm diameter PS beads

20 µm lines

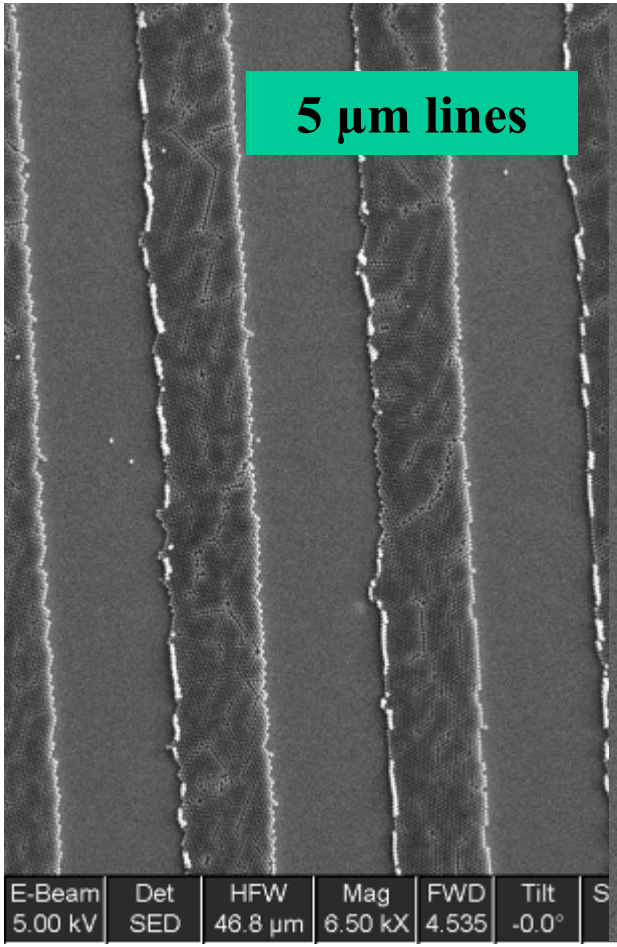


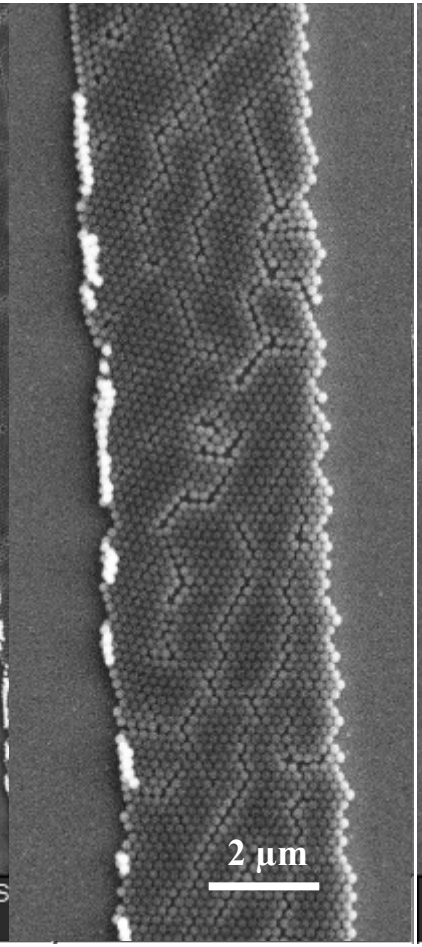
10 µm lines

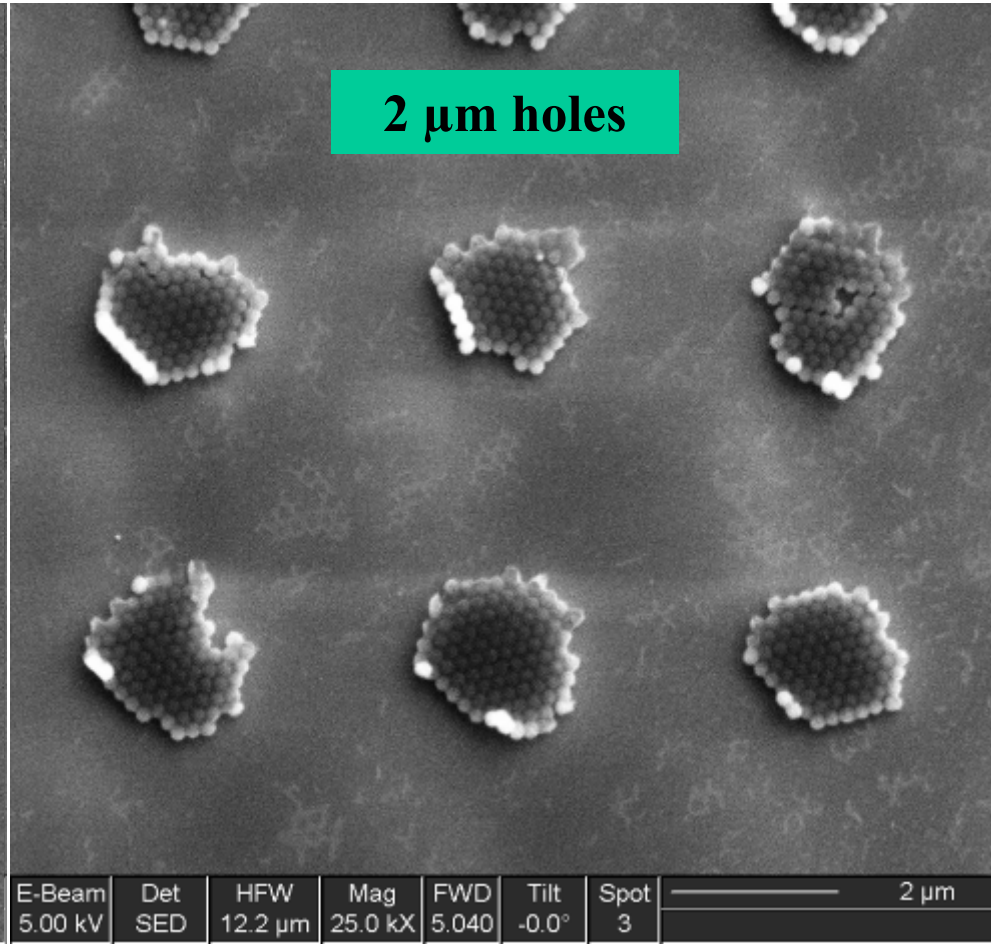


3.2. Patterning of nanoparticles

PMMA stamps – 200nm diameter PS beads

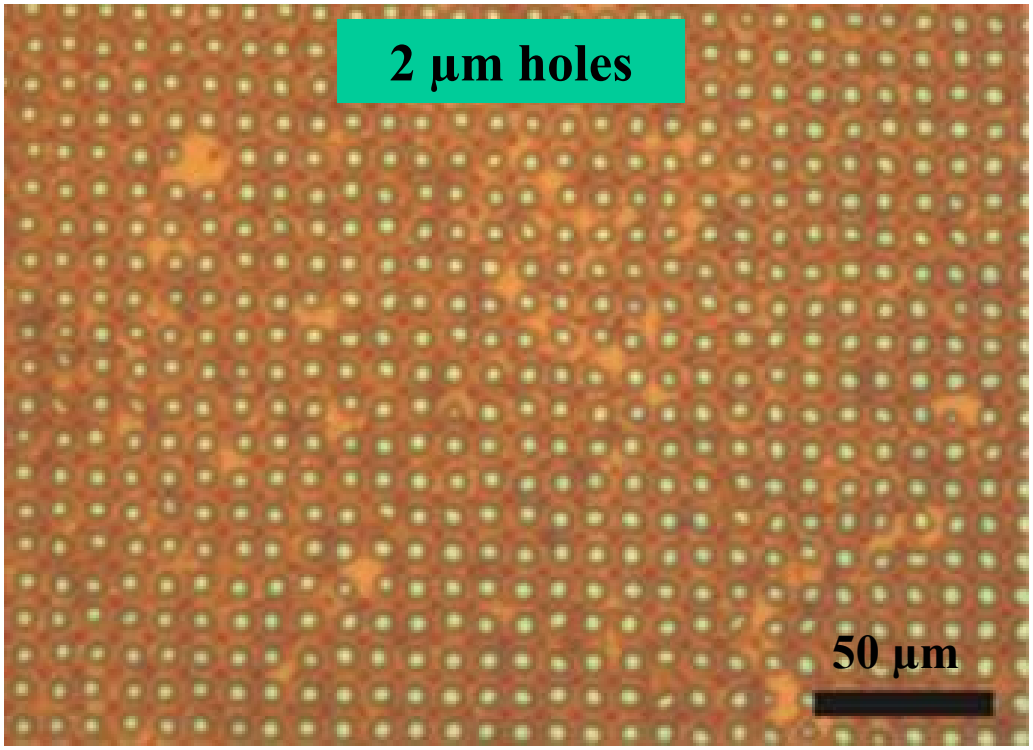




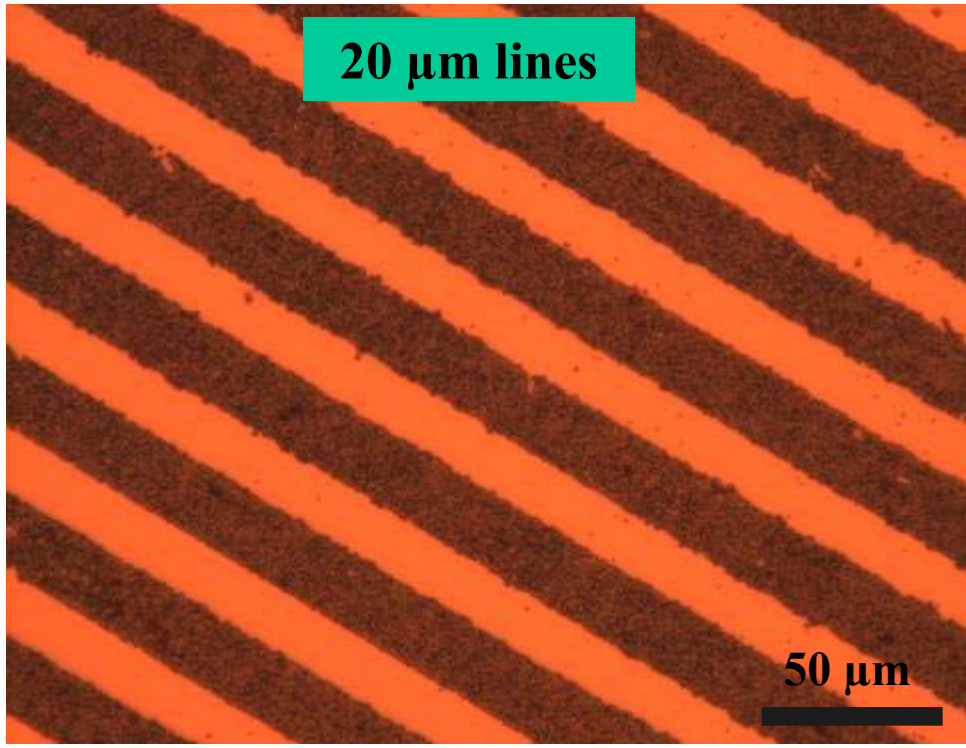


3.2. Patterning of nanoparticles

100nm diameter PS beads
Spin-coated film



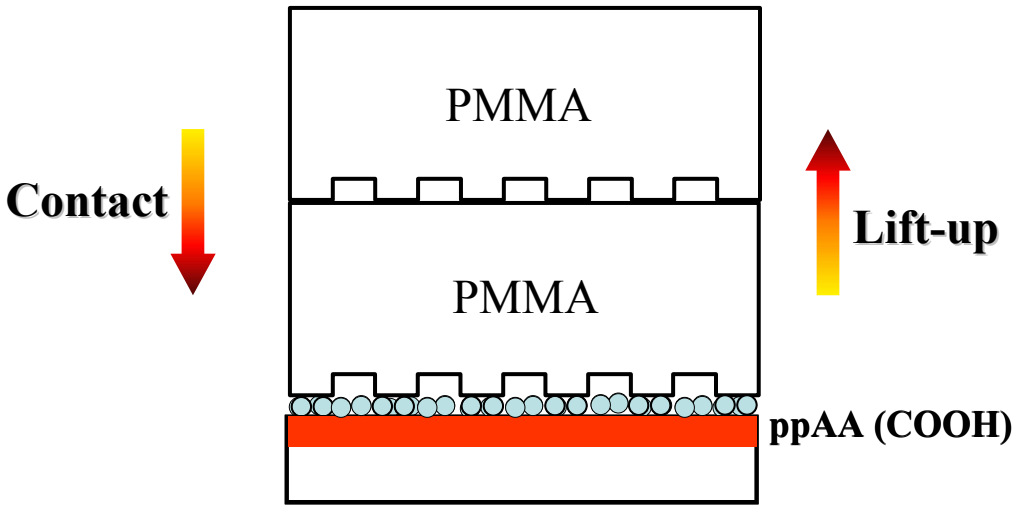
500nm diameter PS beads
Langmuir-Blodgett film

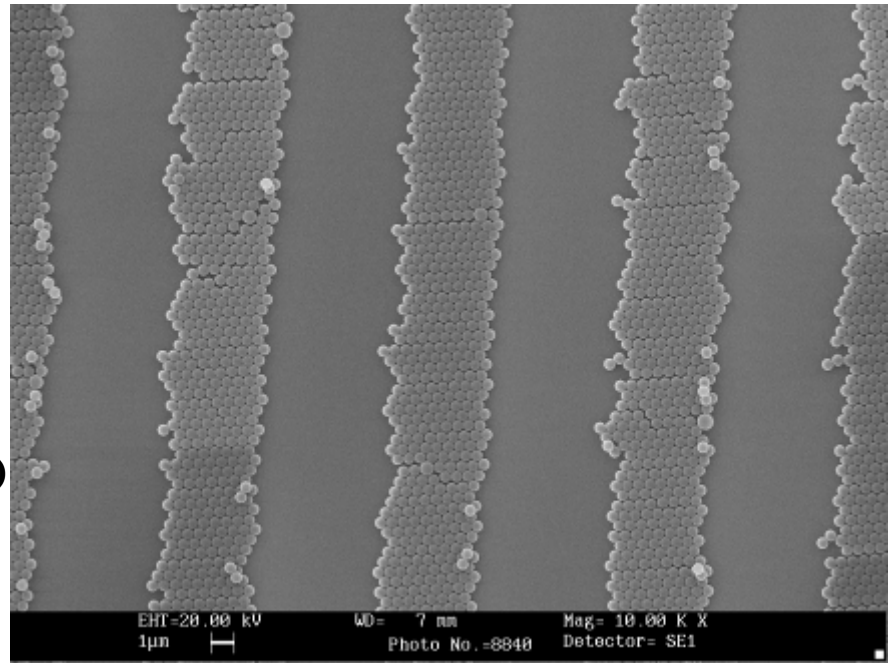


4. Microarrays of fouling nanodomes in non-fouling matrix

Fouling Polymer: Poly Acrylicacid (ppAA), COOH functional

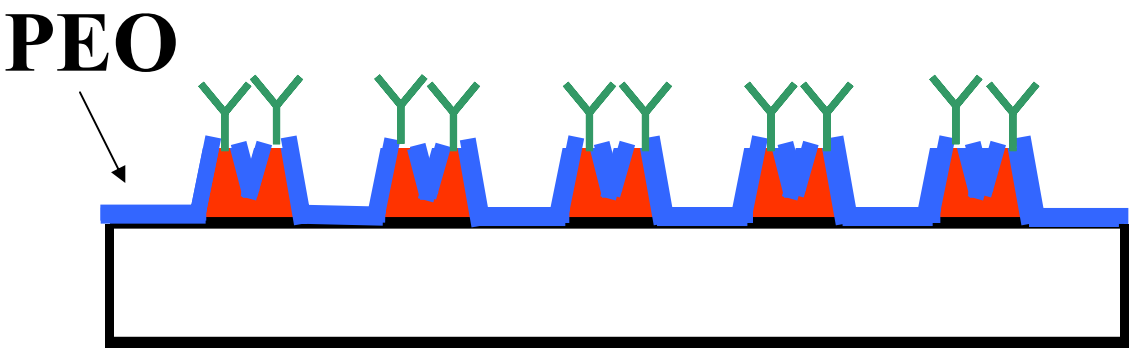
Micropatterned nanobeads

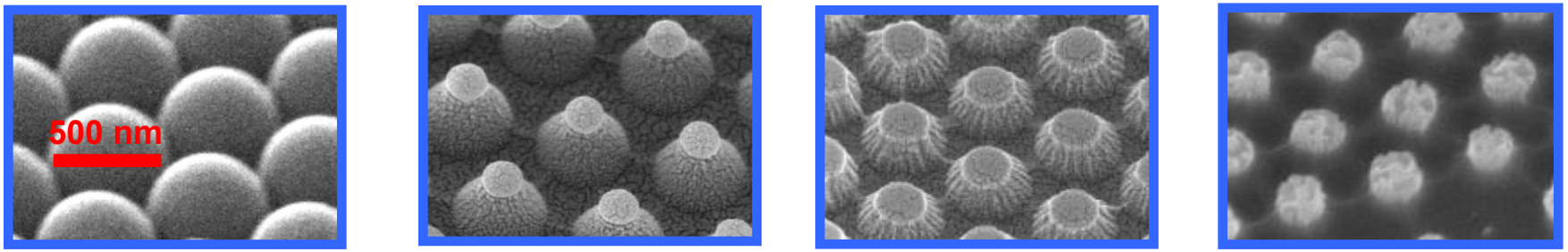




4. Microarrays of fouling nanodots in non-fouling matrix

Nanofabrication process

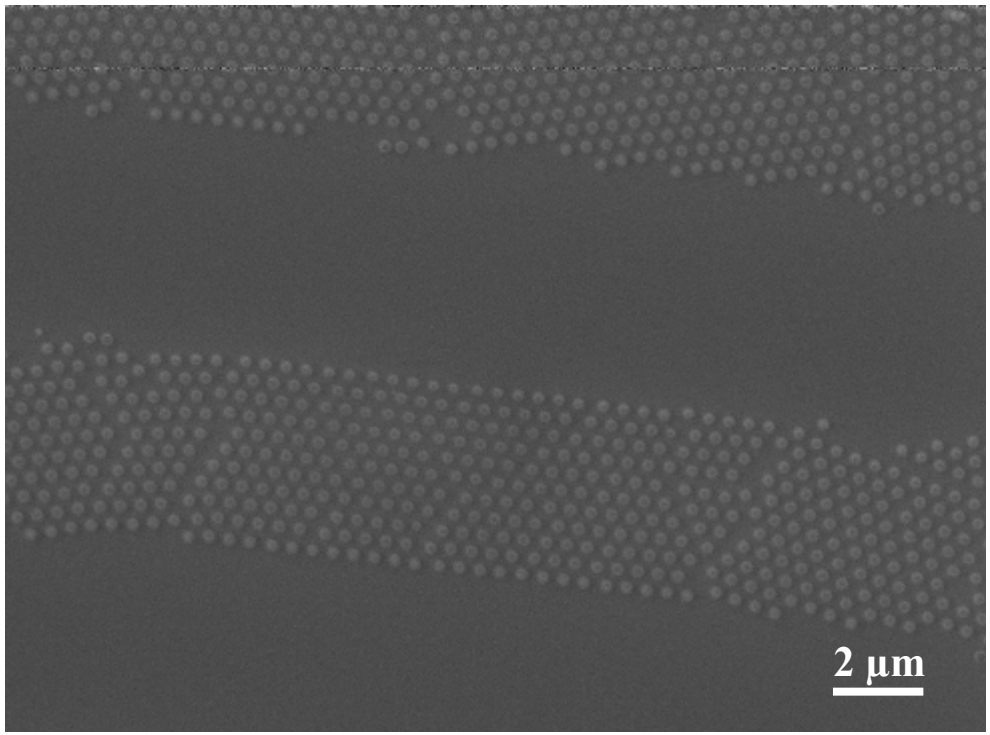


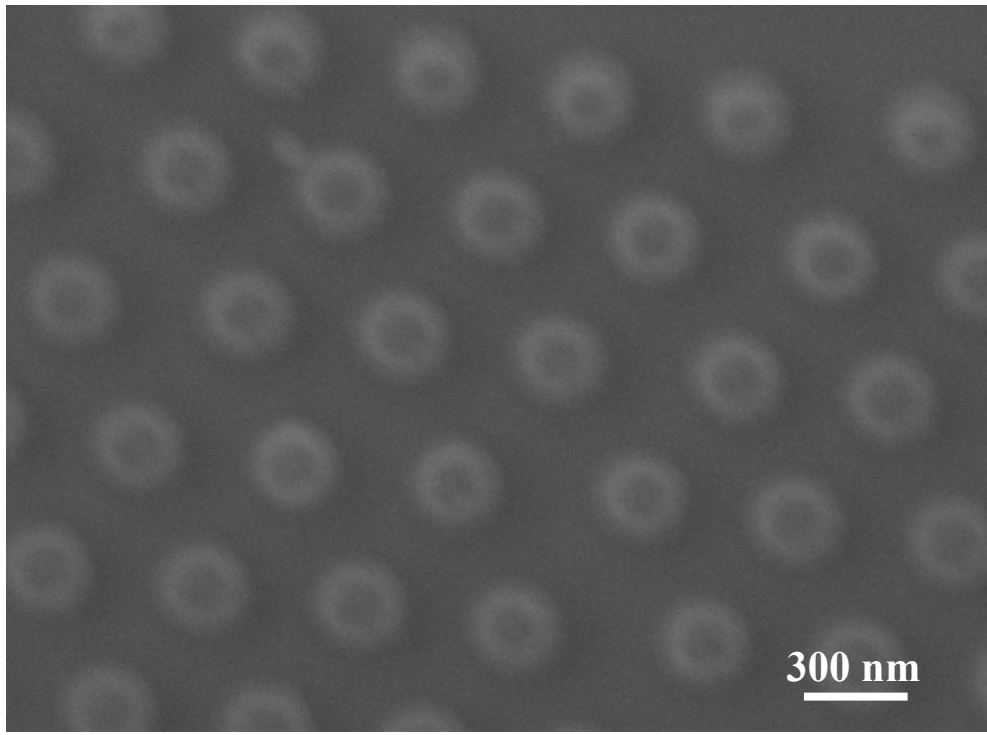


* Valsesia et al. *Adv. Func. Mat.*, 2006, 16(9)

4. Microarrays of fouling nanodots in non-fouling matrix

Nanodomes after etching. 500nm diameter PS beads





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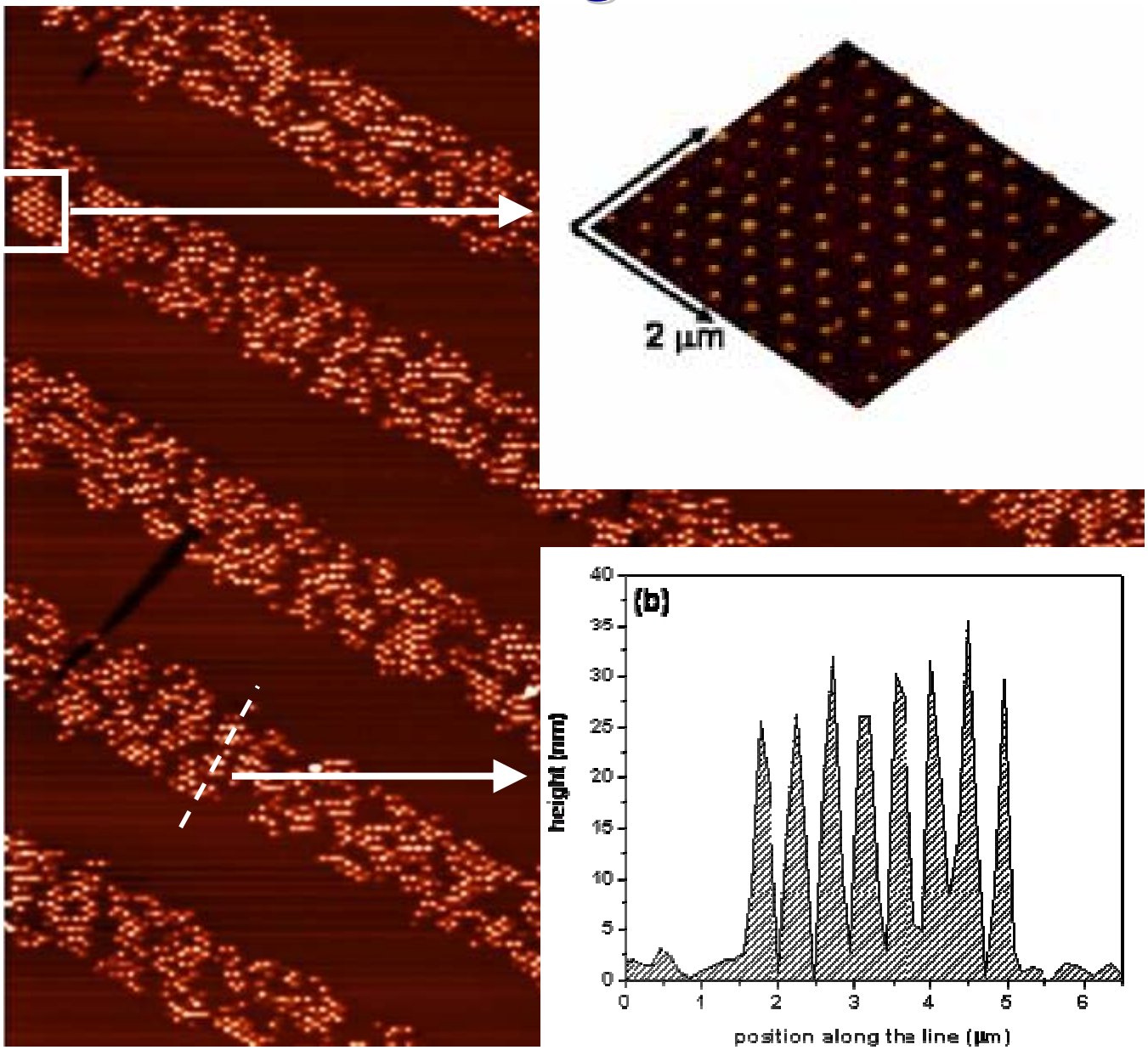
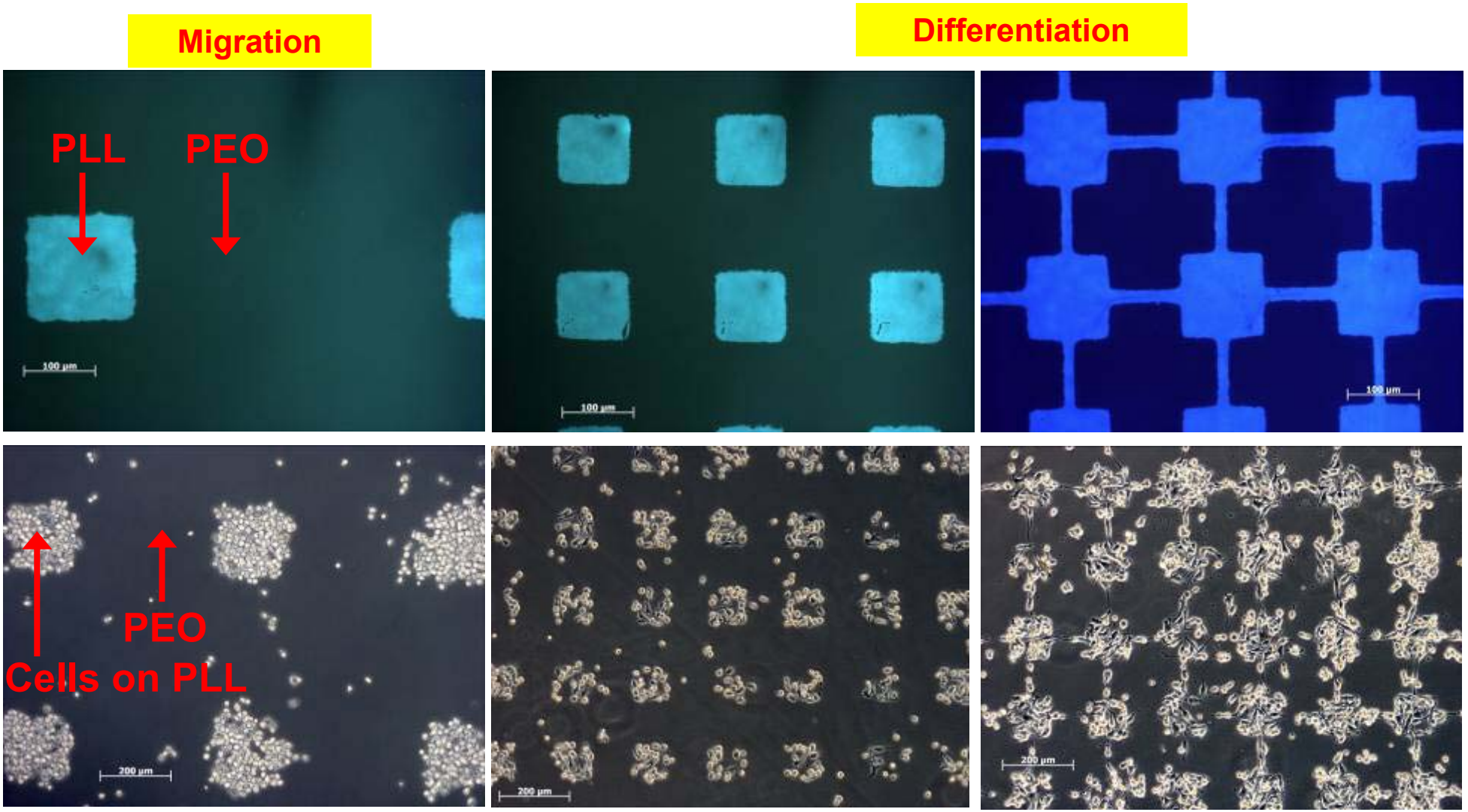


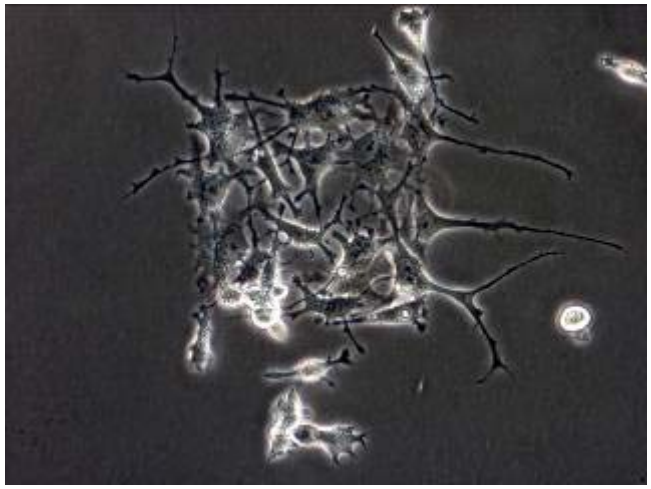
Future applications

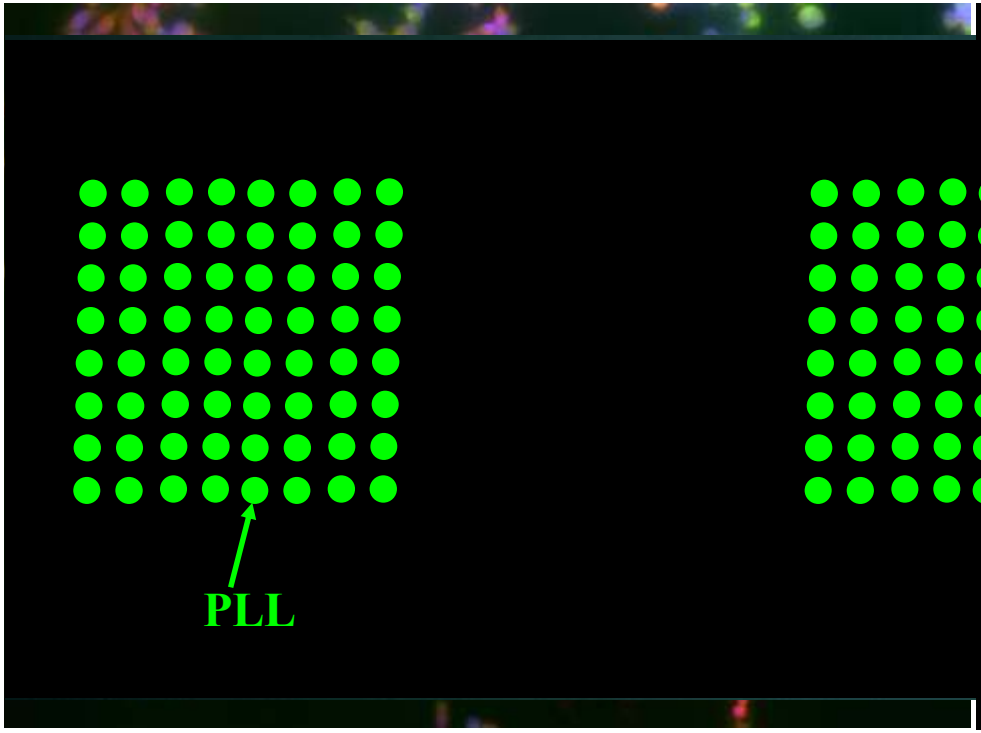
Micro-Patterning by direct printing on antifouling surfaces (MCP)

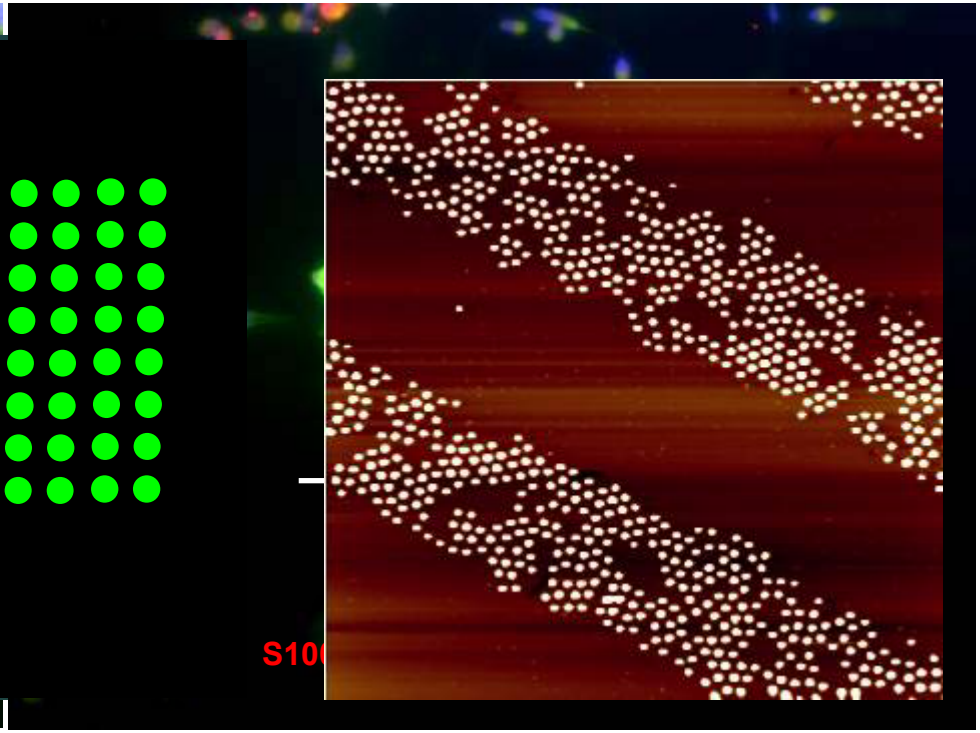
Designs to study neural stem cell migration and axonal protrusisons outgrowth



Future applications







5. Conclusions

- **New method for the micro-patterning of nano-beads at large scale**
  - More performant regarding bead-substrate adhesion.
  - High definition of patterned edges
  - Lower bead "contamination" between arrays
  - Highly controlable method possible that can be applied to other non-polymeric particles and substrates

- **Nanoimprint-assisted contact stripping:**
  - Use of homogeneous pressure and temperature to strip nanoparticles using PMMA stamps.
  - Stripping conditions adjustable to the bead-substrate system used.

- **Micro-patterns of PS nano-beads of different diameters and with different level of bead adherence**

- **1st application: Fabrication of surfaces with nanoscale chemical contrast inside the micro-patterns**
- **Other applications:**
  - Study of cell-surface interactions at the nanoscale
  - Fabrication of arrays of photonic crystals

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…… Thank you !