3D metallic nanotrenches arrays fabricated using nanoimprint lithography

INCDTIM

PIM 2021 International Conference Processes in Isotopes and Molecules

D Marconi[1], A Colniță[1], I Brezeștean[1,2], L Barbu-Tudoran[1,3], N E Dina[1] and I Turcu[1]

[1] National Institute for Research and Development of Isotopic and Molecular Technologies, 67-103 Donat, 400293 Cluj-Napoca, Romania
[2] Babeș-Bolyai University, Faculty of Physics, 1 Mihail Kogalniceanu St, Cluj-Napoca, Romania
[3] Babeș-Bolyai University, Faculty of Biology, 44 Republicii, 400006 Cluj-Napoca, Romania

daniel.marconi@itim-cj.ro

Abstract

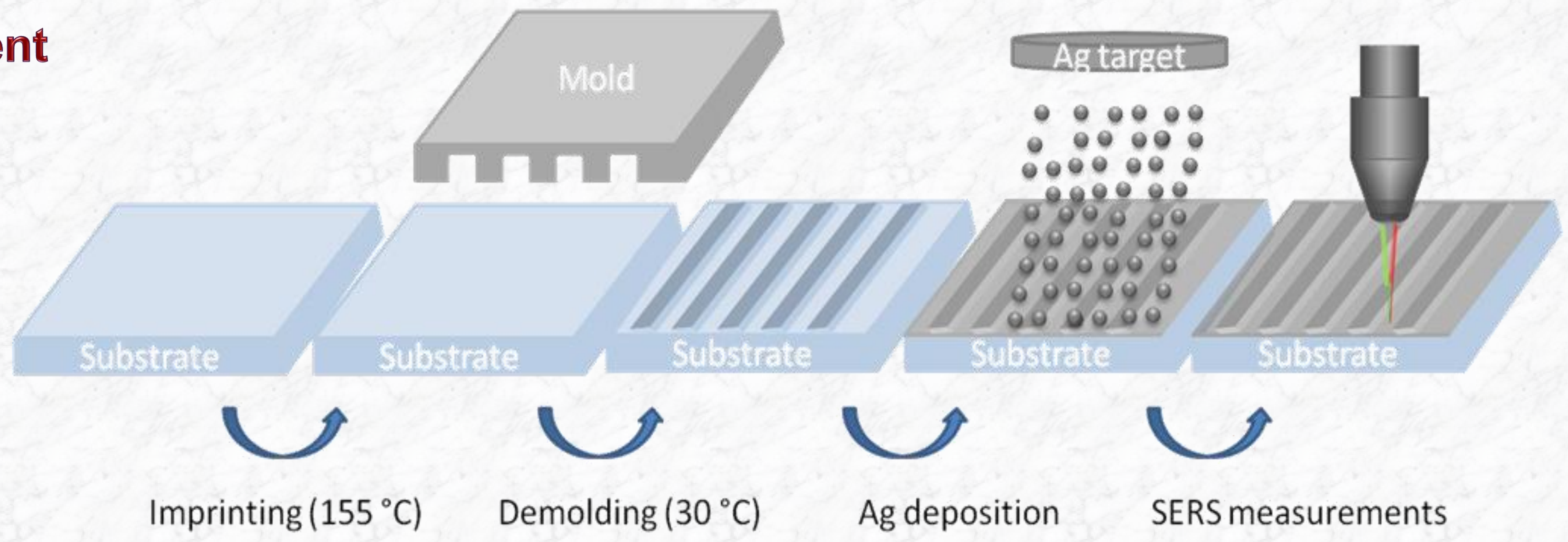
High-resolution nanoarrays are state-of-the-art elements frequently used due to their dependence on the optical property of size, shape and periodicity. Nanoarray architectures can be tailored to be used in the fabrication of nanodevices for electronics, photonics and biotechnology. Nanoimprint lithography (NIL) is a simple, reproducible and scalable method to create nanostructures over a large area. NIL enables the production of various periodic nanostructures on flexible substrates. Metallic nanotrenches show unique and attractive properties capable of ultrasensitive detection of molecules, active modulation as well as potential electrochemical applications. We report on a 3D plasmonic nanotrenches arrays fabricated by NIL on a flexible and transparent substrate with 300 nm height and 400 nm width, 800 nm pitch, metalized with silver (Ag) with thicknesses of 25 nm, 50 nm and 100 nm using magnetron sputtering deposition technique. For uniform nanotrenches imprinted in the substrate, the NIL process parameters were optimized. The topography of 3D metallic nanotrenches was assessed from Scanning Electron Microscopy (SEM) images.

EXPERIMENTAL

Integrated NIL-RIE equipment

Q150R PLUS sputtering coater equipment

Fabrication steps



Materials:

- 4,5 cm × 4,5 cm SiO_2 - stamp with a 1 cm × 1 cm square area which contains periodic nanotrenches and nanogaps with a depth of 300 nm and a pitch of 800 nm. , anti-adhesion treated; lateral tolerances: +/- 15%; vertical tolerances: +/- 15%
- 3” Ø IPS® substrates (T_g= 139.7 ˚C), 500 μm thickness

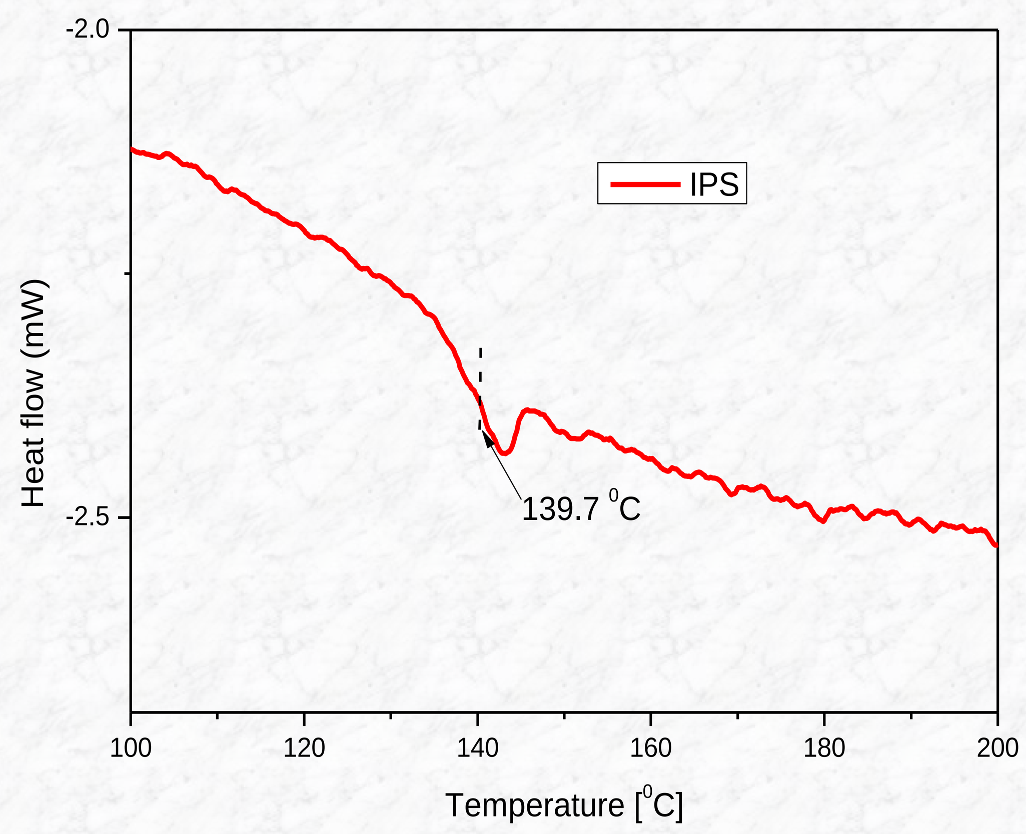
Characterization method: ultra-high-resolution SEM Hitachi SU-8230 (Tokyo, Japan) system operated in high vacuum conditions.

The experimental parameters used in the NIL fabrication process.

IPS® substrate

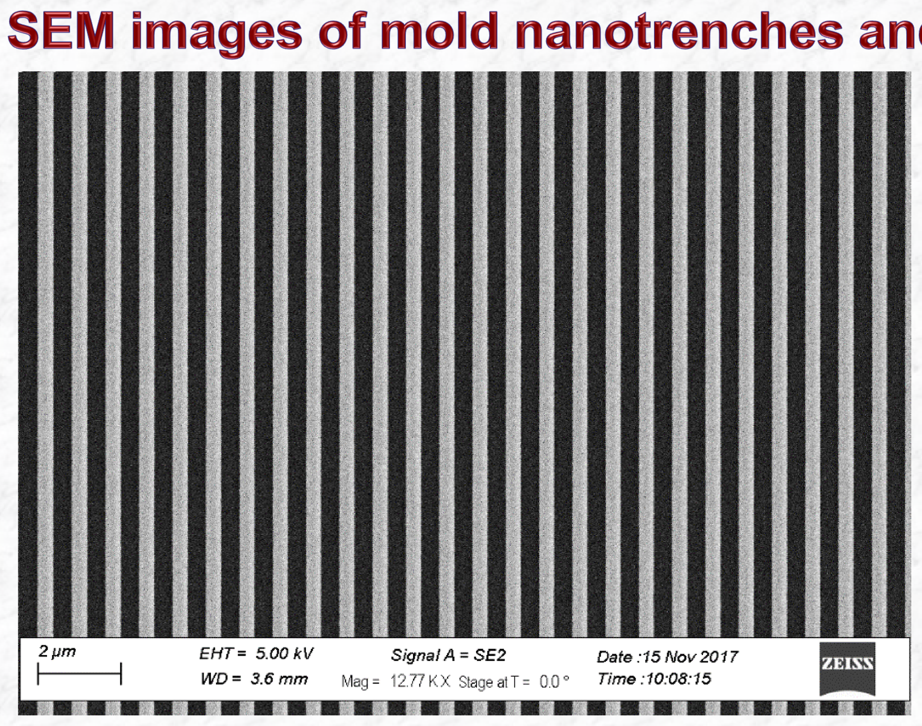
Temp °C	Pressure bar	Time s
165	40	60
100	40	20
70	40	10
50	40	10
40	0	0

Glass transition temperature from DSC measurements

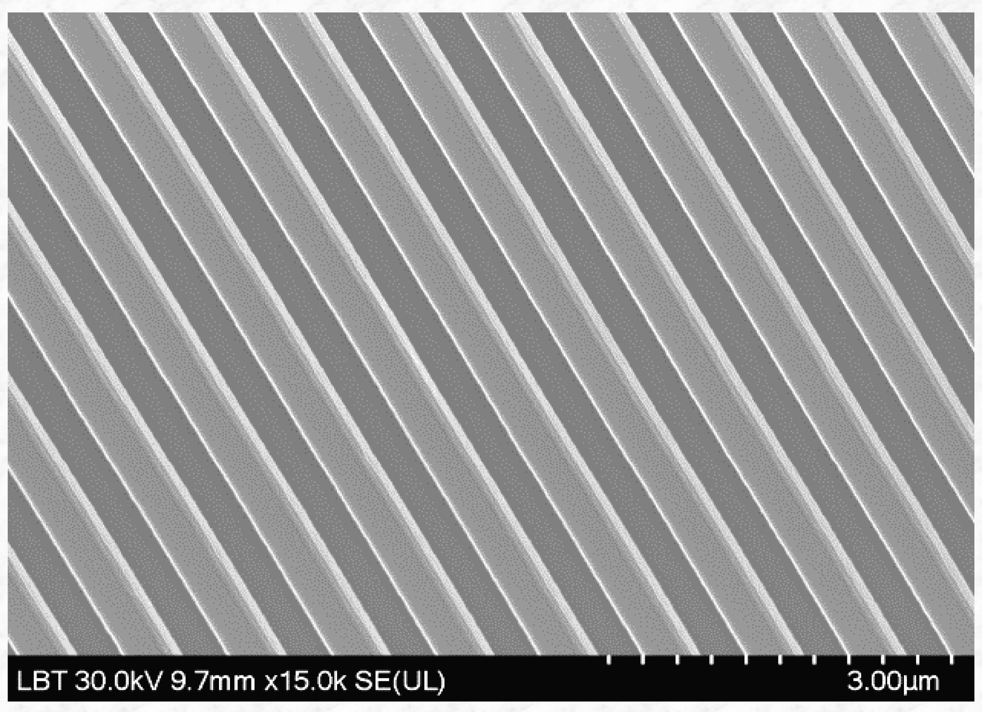


DSC analysis on IPS® flexible substrate in the temperature range of 100 °C – 200 °C

SEM images of mold nanotrenches and its imprinted architecture of an IPS® substrate

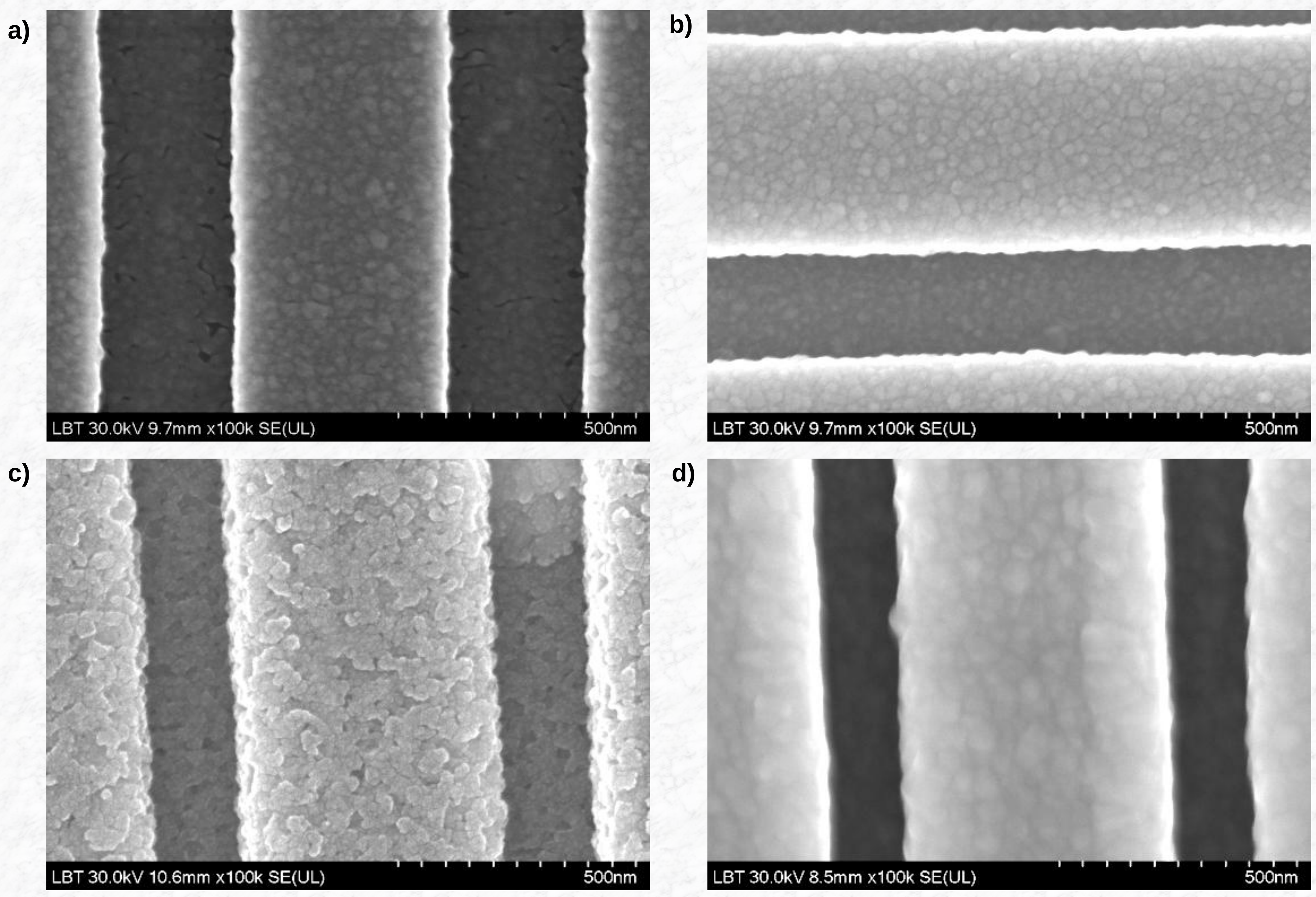


SEM image of the mold periodic nanotrenches and nanogaps used in the imprinting NIL technique (courtesy of NIL Technology ApS);



SEM image of an imprinted IPS® substrate

SEM images of the imprinted nanopillars-based QR code in PMMA substrate



Representative SEM images of the Ag coated nanotrenches with films of: **(a) 10 nm**; **(b) 25 nm**; **(c) 50 nm** and **(d) 100 nm** thickness, respectively.

Conclusions:

- 1 × 1 cm square area which contains periodic nanotrenches and nanogaps with a depth of 300 nm and a pitch of 800 nm was fabricated by NIL into IPS® thermoplastic, flexible substrate.
- Ag thin film was deposited on the patterned plastic with thicknesses of 10 nm (sample 1), 25 nm (sample 2), 50 nm (sample 3) and 100 nm (sample 4), respectively.
- In case of sample 1 with a Ag thickness of **10 nm** an irregular film is formed with possibly discontinued areas. The estimated granules size was obtain from SEM image and is about 20 nm.
- Ag film thickness of **25 nm** gives the chance of the Ag nanoclusters to connect and form a very thin and rough metallic substrate with a mean nanoclusters size of 30 nm estimated form SEM images.
- *Ag film thickness of* ***50 nm*** *helps decrease the distance between the nanotrenches, increase the roughness and the size of the Ag nanoclusters up to 35 nm. The uniform distribution on top and bottom of the close-packed Ag nanoclusters can lead to an increase of the surface-to-volume ratio of the plasmonic nanostructure.*
- *The Ag film of* ***100 nm*** *leads to a coalescence of metallic nanoclusters, with a mean nanoclusters size of 45 nm. This determines an increased uniformity of the nanostructured upper layer on the nanotrenches and a decreased uniformity in between nanotrenches.*

Acknowledgements:

This work was supported by a grant of the Ministry of Research, Innovation and Digitization, CNCS/CCCDI – UEFISCDI, project number PN-III-P1-1.1-TE-2019-0910, within PNCDI III, and through the Core-Program, Project No. PN 19 35 02 01.