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Centre Tecnològic de Catalunya

Replication of hierarchical nanostructures on Polycarbonate via Isothermal injection moulding using *NIL*-textured films

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Eurecat

PRN 2021 Polymer Replication on Nanoscale

Contents

Innovation with an impact

Proximity and trust

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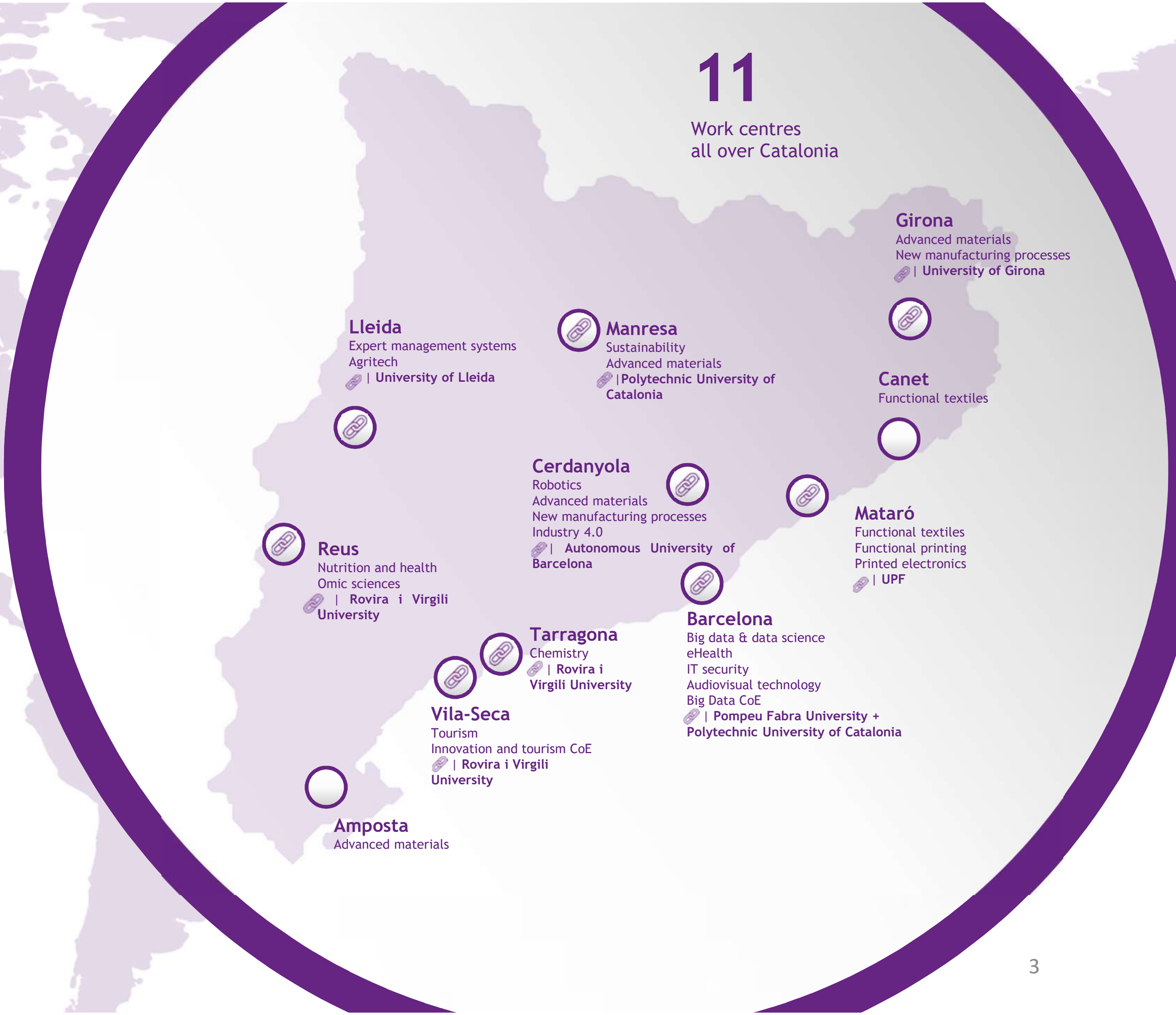
We stay **close to our clients and their challenges** through our broad regional deployment in Catalonia.



Integration of multiple technologies

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Industry

1. Advanced materials (metals, composites, polymers) and new manufacturing processes
2. Functional printing and embedded devices
3. Interactive and autonomous robotics
4. Functional textiles
5. Chemical Technology
6. Innovation and product development

Digital

1. Sensor systems and IoT
2. Artificial intelligence
3. Big Data & Data Science
4. E-Health
5. Cybersecurity
6. Multimedia technologies

Biotechnology

1. Nutrition and health
2. Omic sciences

Sustainability

1. Water
2. Air
3. Soil
4. Waste
5. Energy
6. Batteries
7. Environmental impact

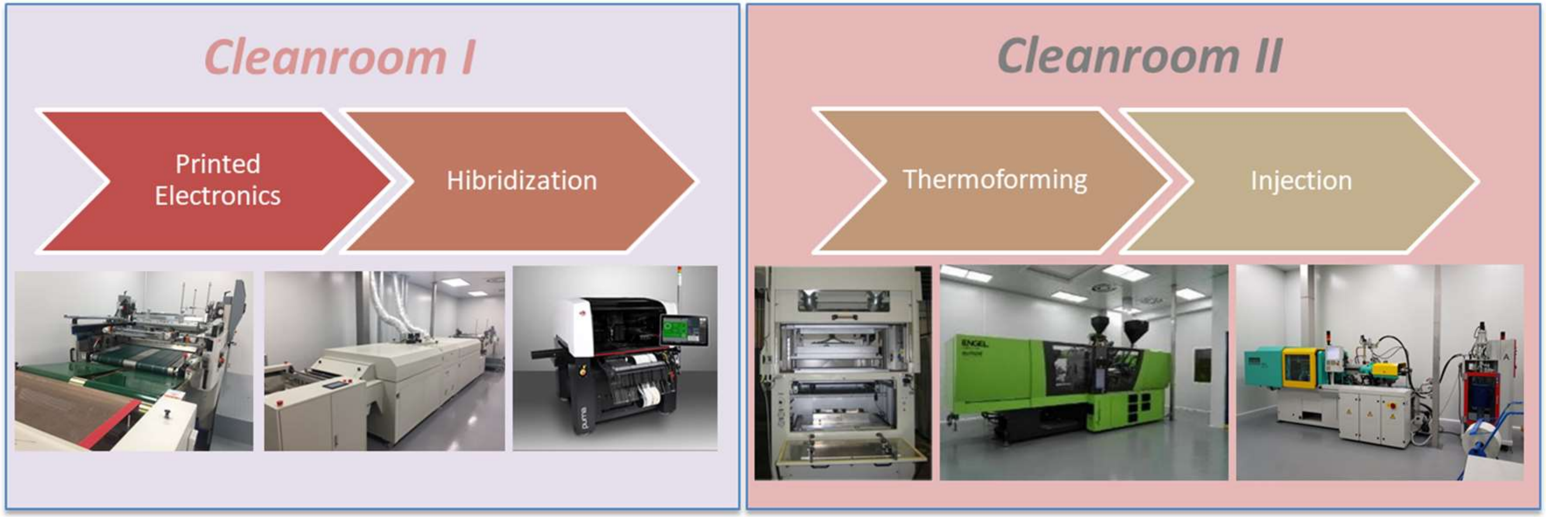
Our differential value:

Our multi-technological capacities allow us to face complex challenges.

1. Intro

Plastic transformation pilot plant

It is southern Europe's largest pilot plant for new technologies in plastic transformation.
Technical experience and capacity focused on trials, manufacturing and industrialization, with the most innovative plastic transformation technologies (over-injection, printing, etc.).



- *In-mould* electronics
- Functionalization of polymeric parts by surface micro- & nanotexturisation
- Biopolymers

2. Film-insert manufacturing via *NIL* Nano-Imprint-Lithography

Level 1: LA

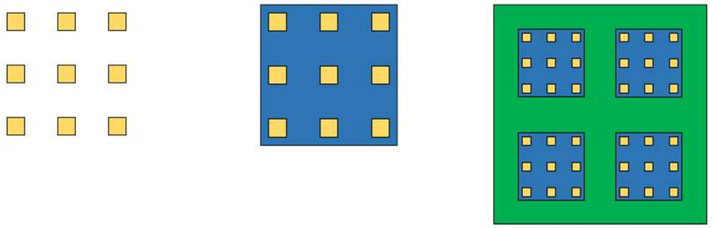
ID	D = Side size (µm)	P=Pitch (µm)
LA11	0,4	0,94
LA12	0,6	1,58
LA13	0,7	1,89
LA14	0,8	2,21
LA15	1	2,84
LA16	1,2	3,4

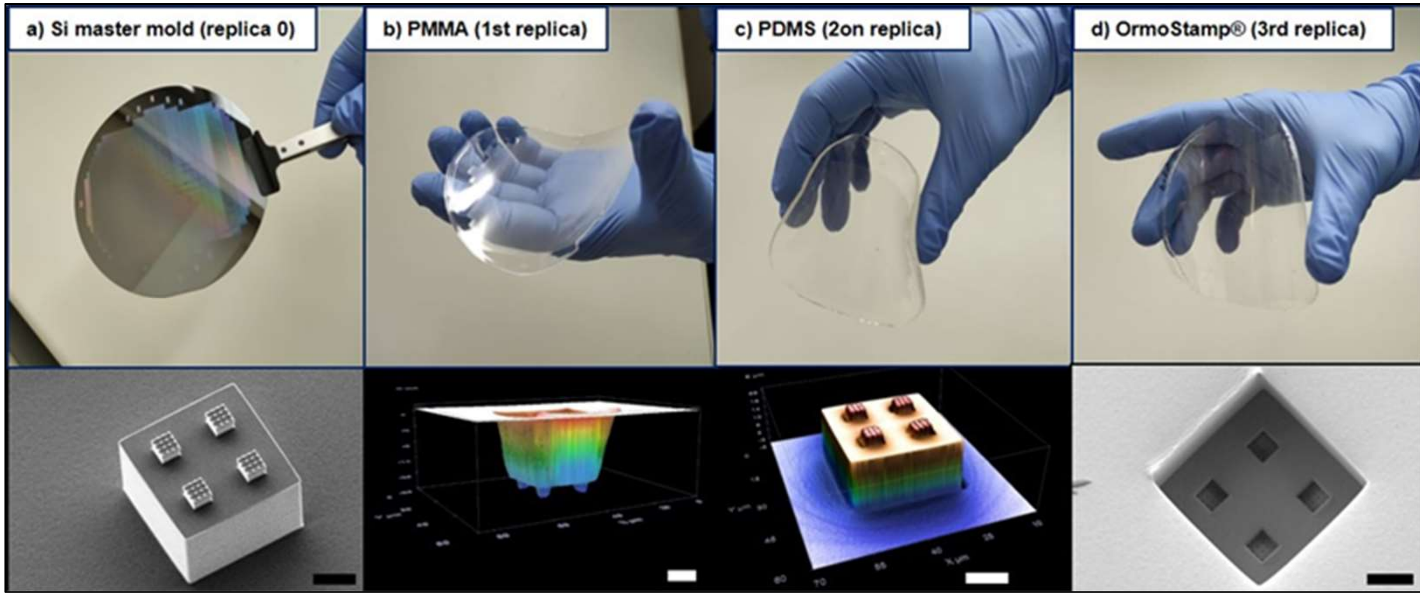
Level 2: LB

ID	D = Side size (µm)	P = Pitch (µm)
LB21	4	9,4
LB22	6	15,8
LB23	7	18,9
LB24	8	22,1
LB25	10	28,4
LB26	12	34

Level 3: LC

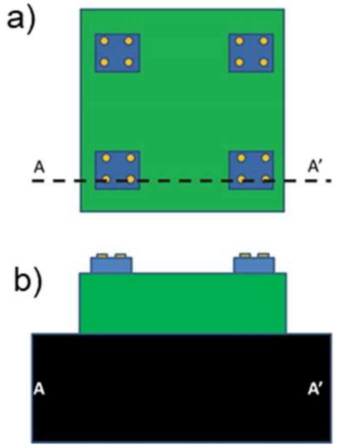
ID	D = Side size (µm)	P = Pitch (µm)
LC31	30	91,64
LC32	35	107,44
LC33	38	116,92
LC34	50	154,84
LC45	55	170,64
LC46	60	186,44

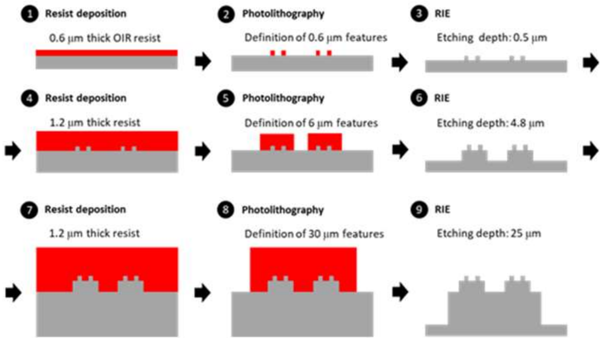




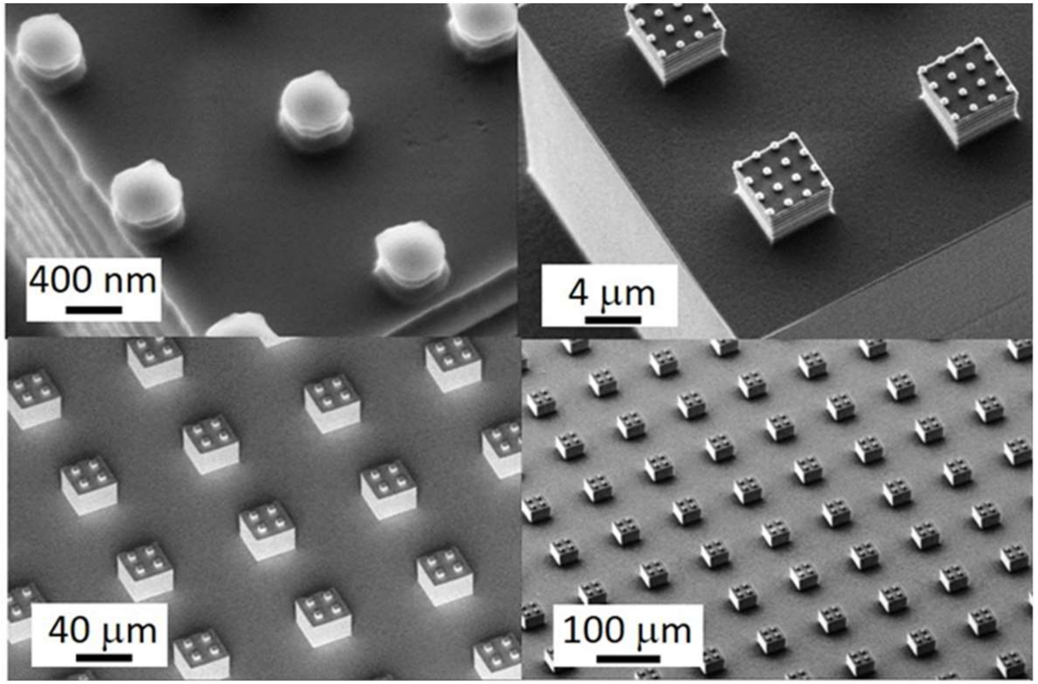
From: Fabrication of films with surface hierarchical micro/nano structures for plastic injection molding;

O. Muntada [a], P. C. Sousa [b], J. Llobet [a], C. Saez [c], N. Lozano [c], F. Perez-Murano [a]





2. Film-insert manufacturing via *NIL* - Replication on polymeric film



SEM images of the silicon mould

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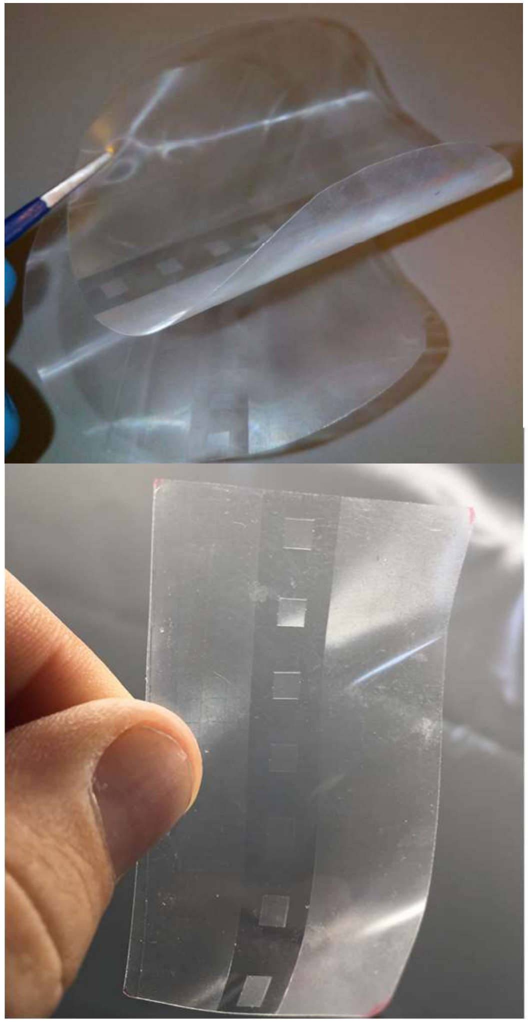
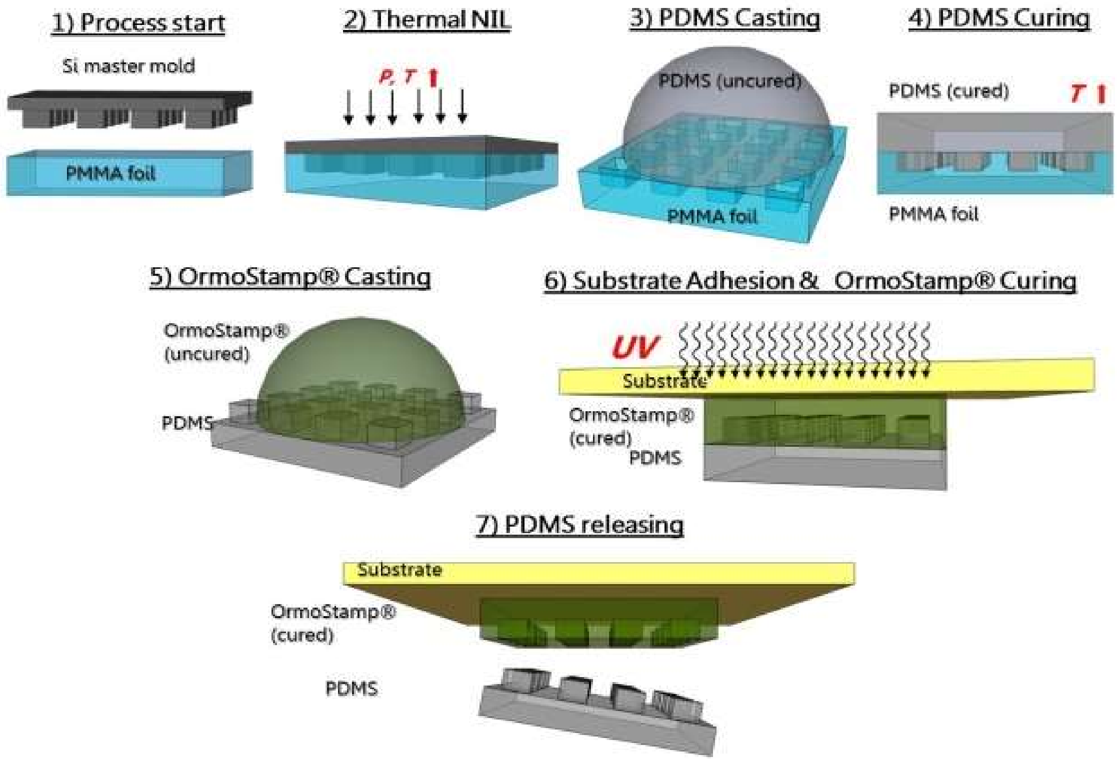


2. Film-insert manufacturing via *NIL* Nano-Imprint-Lithography
Film & Coating materials



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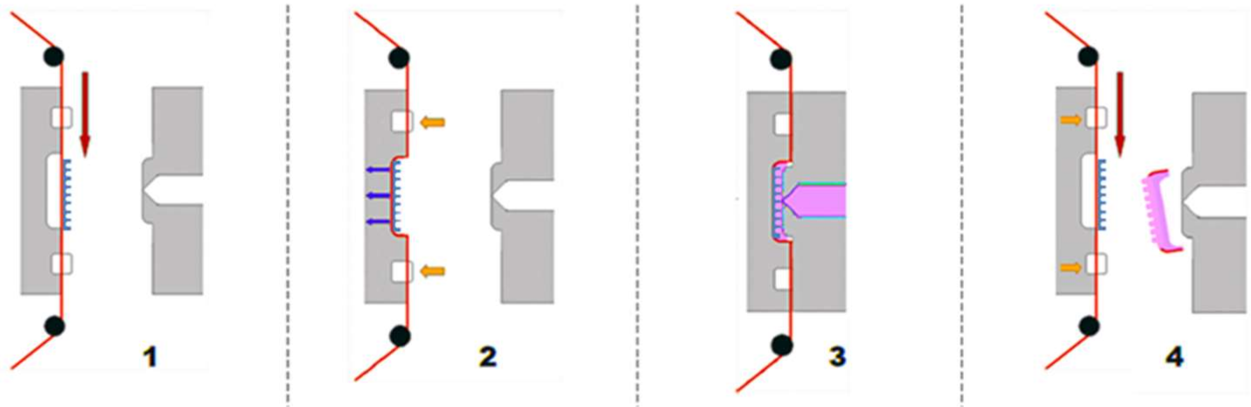
Substrates	Coating material	Thicknesses
PET /PC /PMMA	Ormocomp ®	50/125/250/500 vs 50µm
PET /PC /PMMA	Ormostamp ®	50/125/250/500 vs 50µm

3. Replication via isothermal injection moulding

Engel 160 Tn
3K Machine 50 mm / 22 mm / 25 mm
Mobile 6 Axis Robot

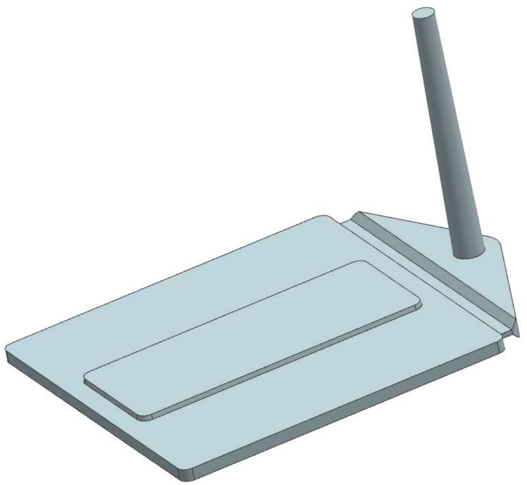
Engel e-motion 50 Tn
1K Machine 25 mm

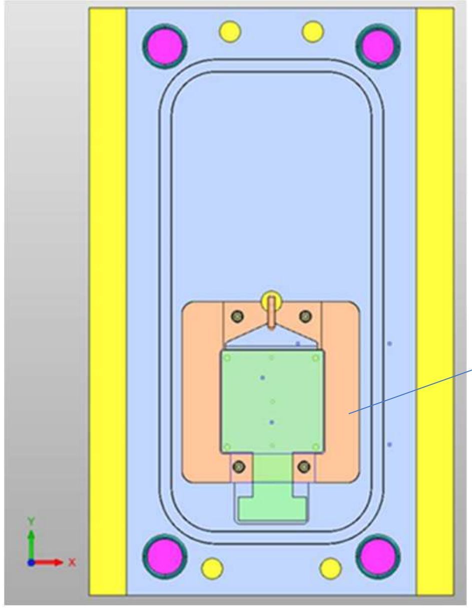
General process



- Potentially consistent process (up to 100 cycles) – scalable
- Resolution: low µm/ nm (> laser inserts + hierarchical structures)
- Low cost
- Film & coating thermally favourable (delayed polymer freezing)

3. Replication via isothermal injection moulding - Tooling





Part dimensions

70x70x1,25 to 4 mm

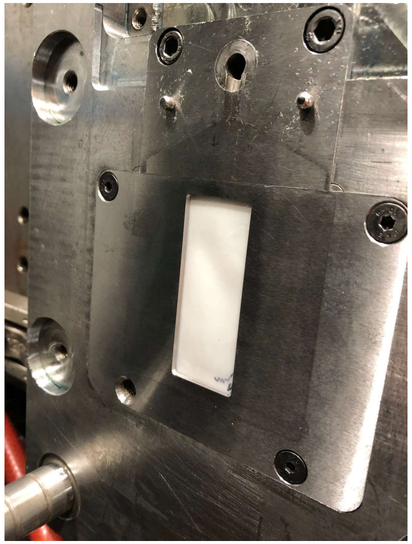
Textured zone

60x23 mm

Fan-gate type

Polymers injected

PC, PMMA, PET,
TPU,PLA, PBS, PHA



Insert & film mounted on mould

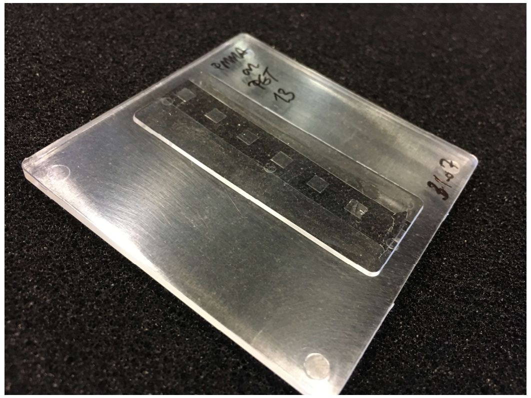
3. Replication via isothermal injection moulding - Processing

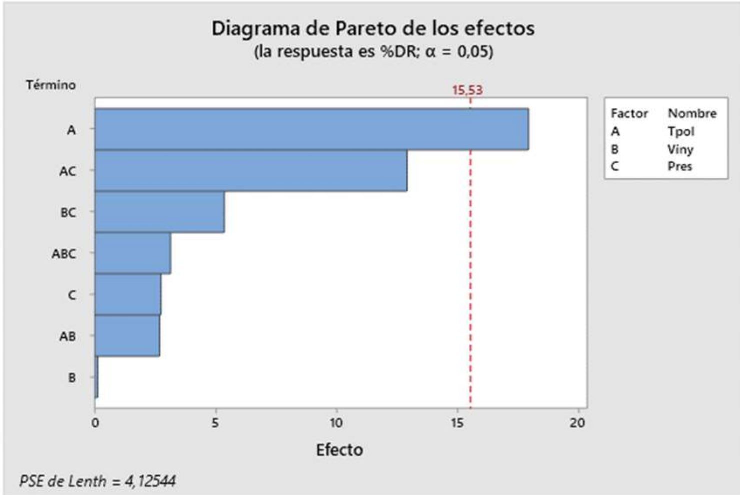
- Injected polymers

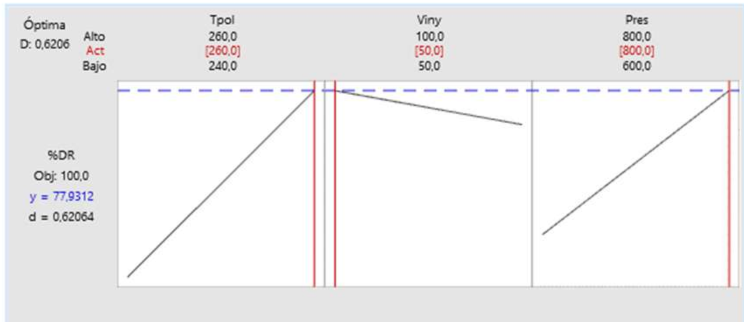
  PC/PMMA/TPU/PET

  PLA/PHA/PBS

- Check for compatibility-non adhesion- film “survival” cycles
- 2^3 D.O.E. with T_m, V_{inj}, P_h







3. Replication via isothermal injection moulding - Parameters

- *Critical Parameters*

T_m, V_{inj} , P_h, anti-stick coatings,compatibility between materials

$T_m > T_g$ favours replication

V_{inj}: high speed~ 100/150 mm/s

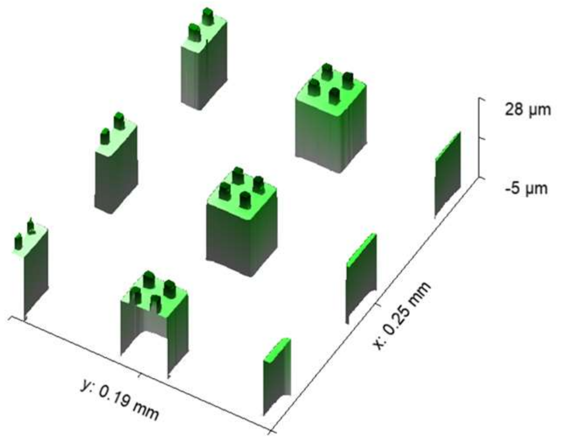
P_h: high levels

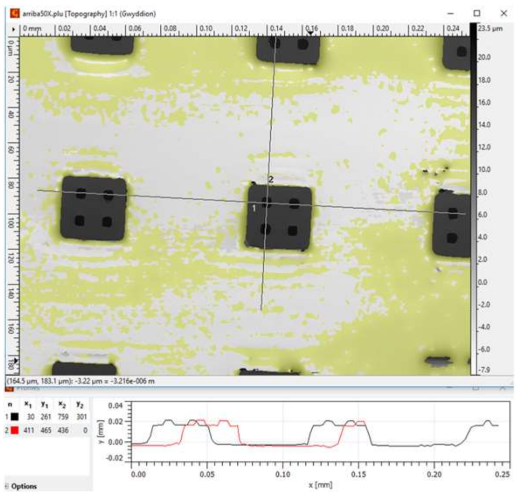
Long $t_{cooling}$

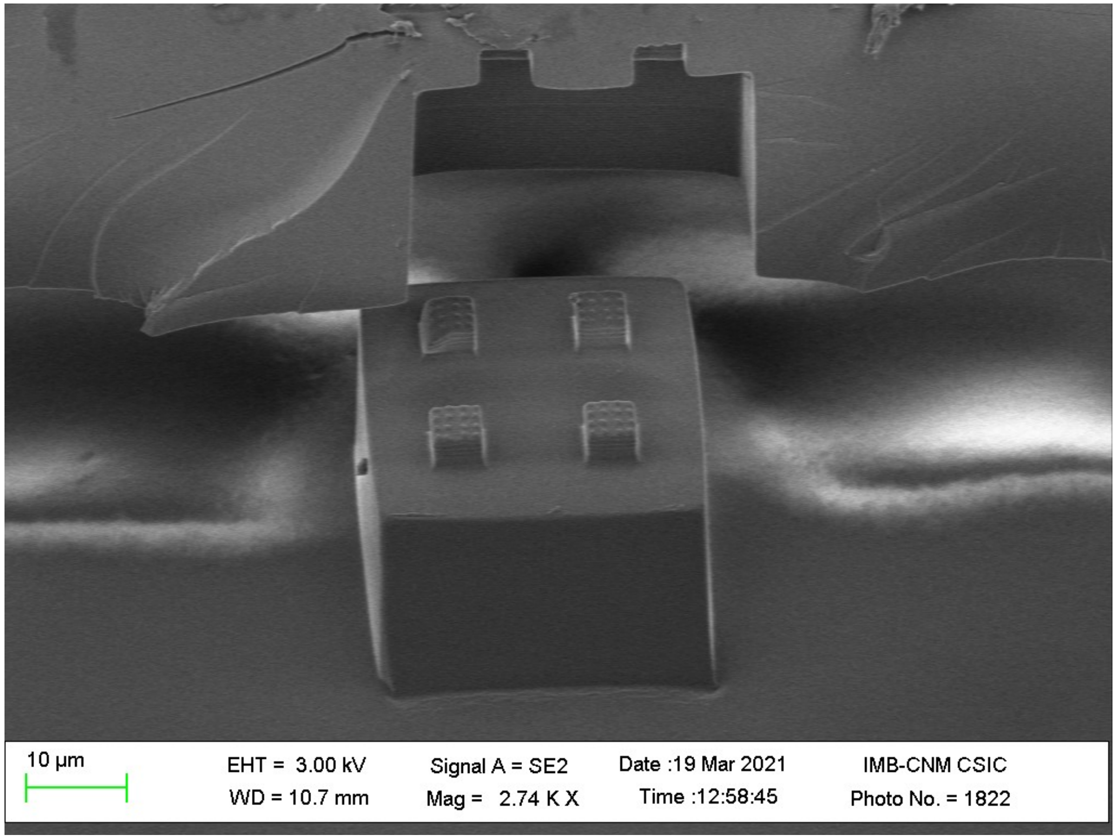
Factors should be balanced depending on nanoestructure (AR)

4. Results

PC



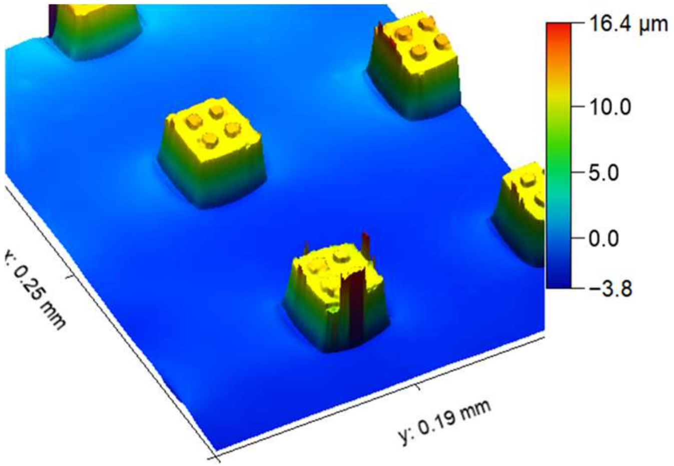


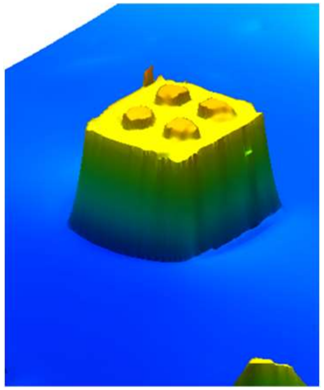


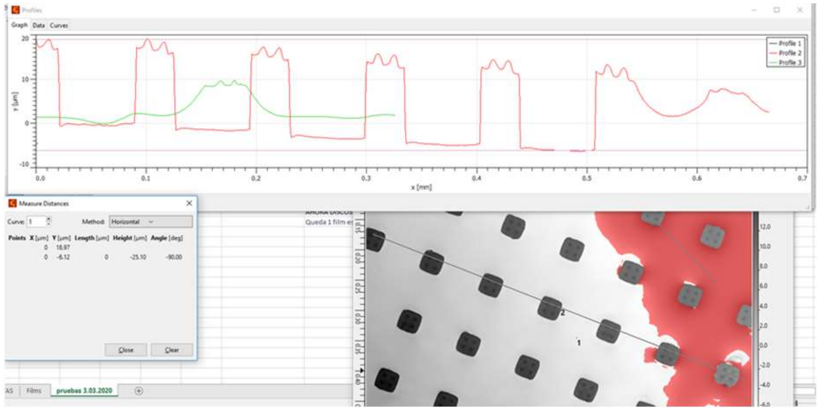
Best results for PC on PC + Ormostamp® films

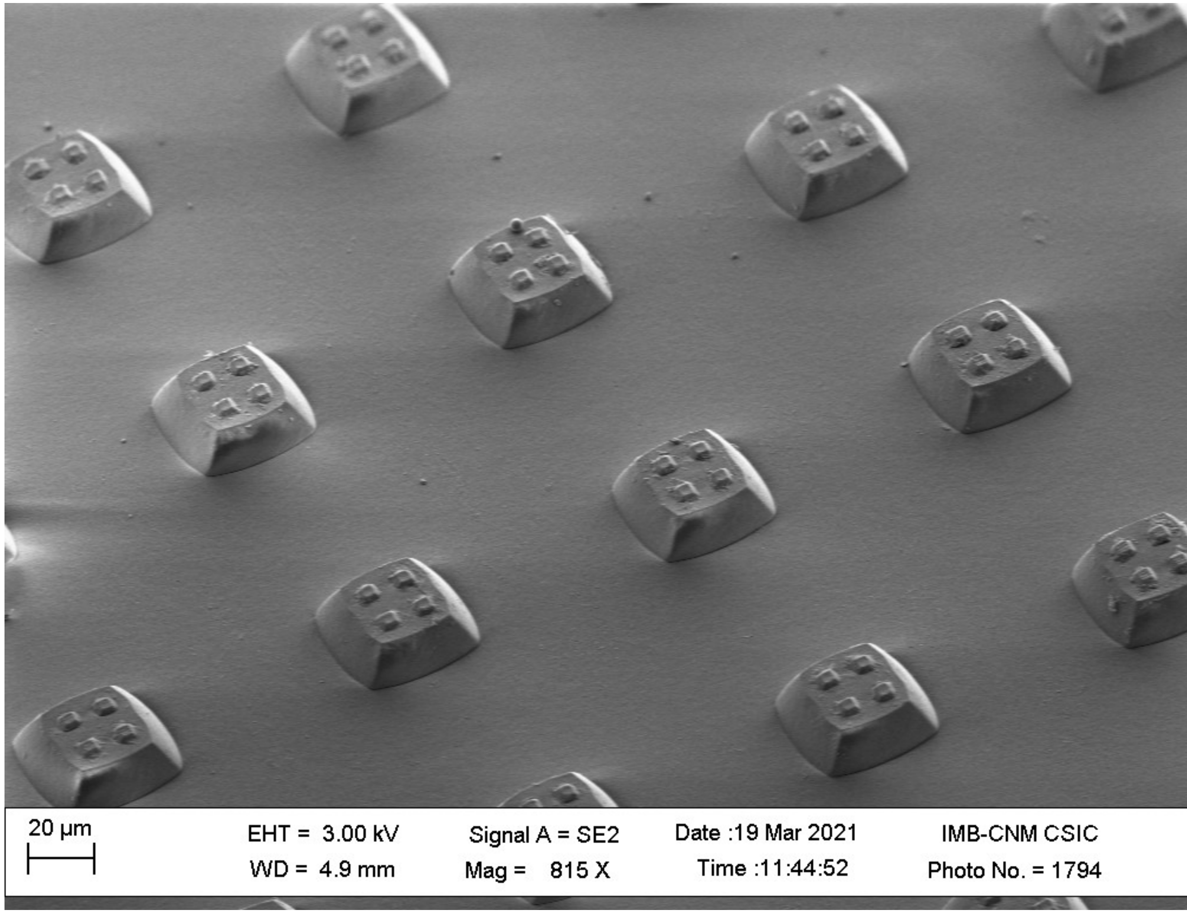
4. Results

PMMA





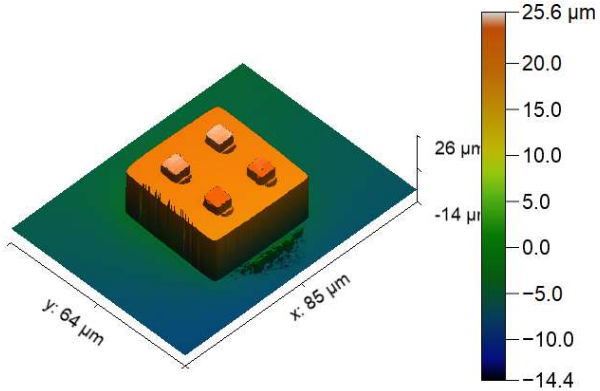


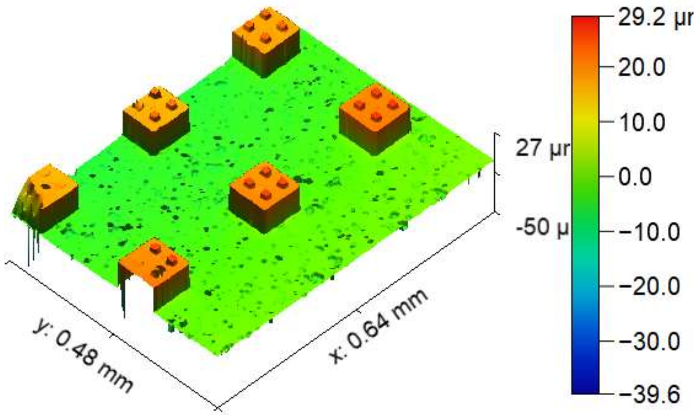


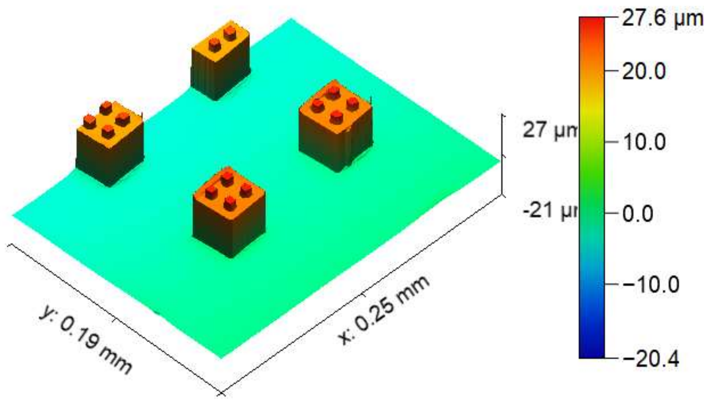
Lateral wall-angle distortions for PMMA on PC + Ormostamp® films

4. Results

PLA	PHA	PBS

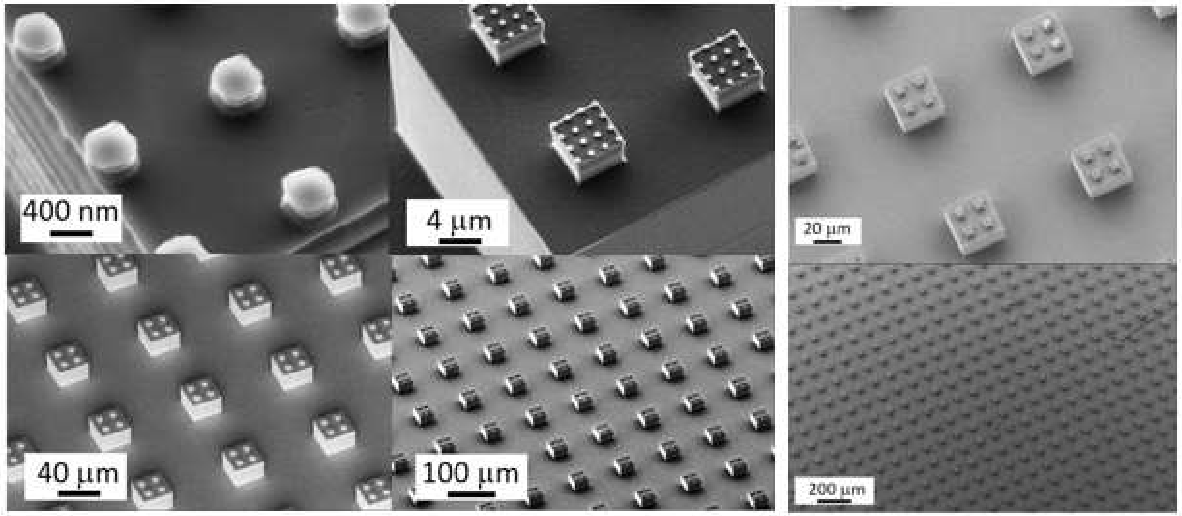


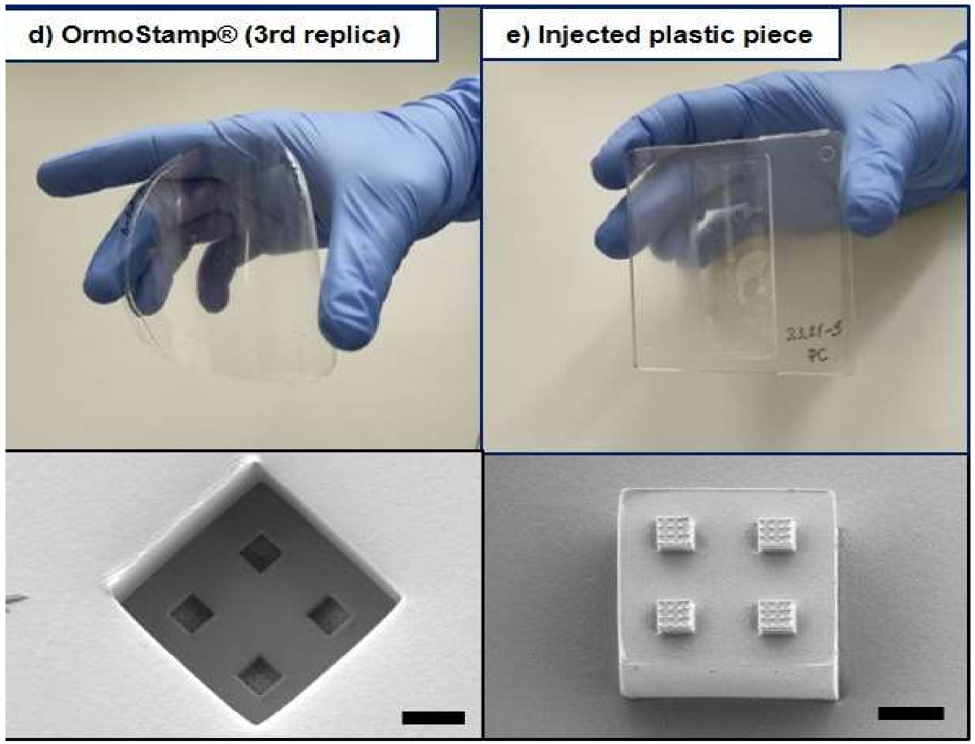




Good replication results for all biopolymers tested at standard moulding conditions

4. Results

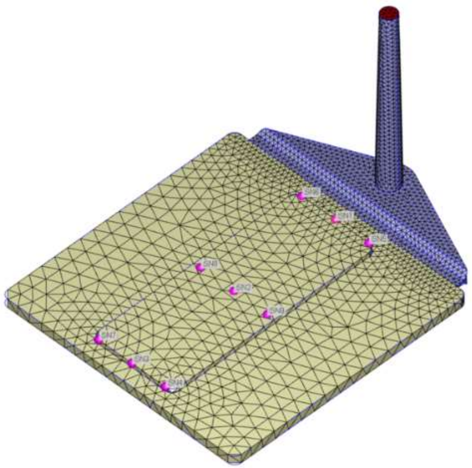

400 nm
4 µm
20 µm
40 µm
100 µm
200 µm


d) OrmoStamp® (3rd replica)
e) Injected plastic piece

5. Conclusions

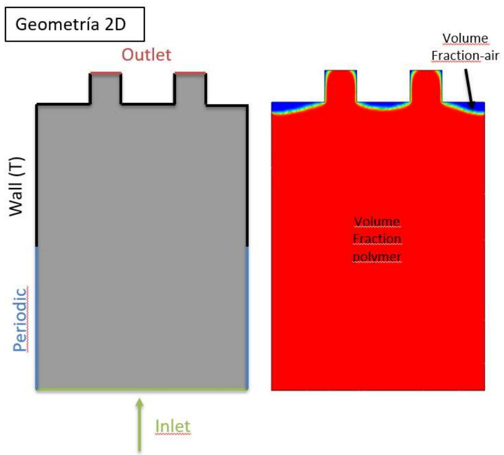
- Need to improve film-coating assembly (*adhesion*) in order to increase cycles/film; working on:
  - Base film material
  - Coating material
  - Adhesion improvement
  - Automatic cutting – film handling
- Optimization of anti-stick coatings needed, especially for PC/PMMA
- Need to implement large area characterization techniques
- Working on applications (medical & optics)
- Take to 3D!

5. Next steps



Detail of the mesh used for the injected part in the macroscale simulation (MOLDEX 3D)

Detail of the mesh used for the injected part in the micro-nanoscale simulation (ANSYS POLYFLOW)



Fluidos

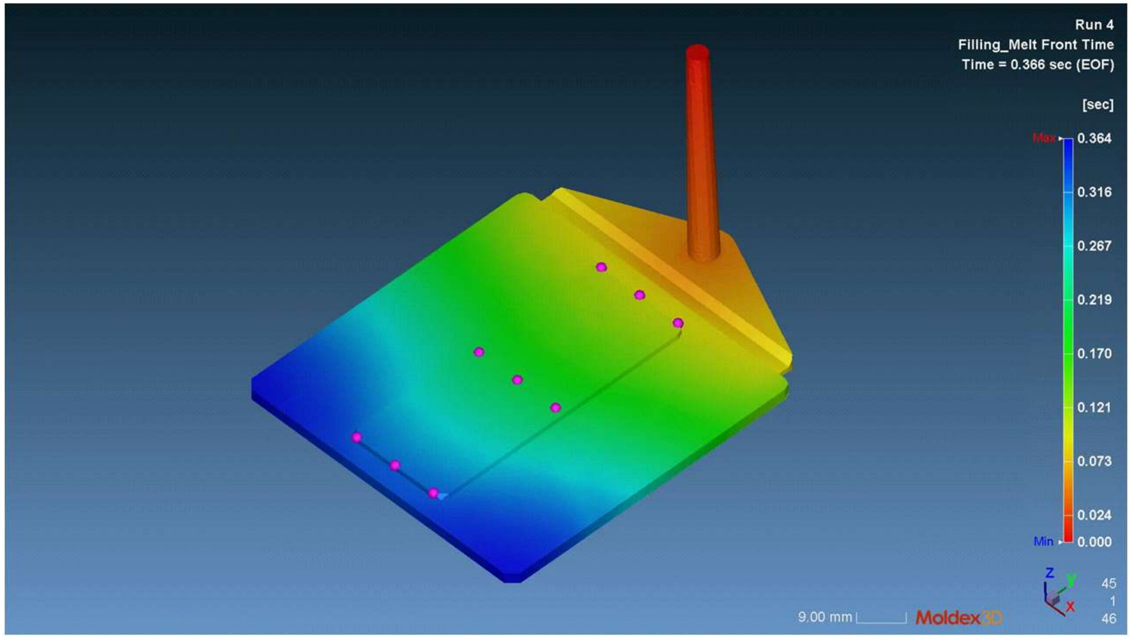
- Aire: propiedades en función de T
- Polímero:
  - ρ= 1190 kg/m³
  - μ: en función de shear rate y temperatura.
  - c_p, λ: en función T

DOE 2³

- Temperatura polímero
  - Tp_{min}
  - Tp_{max}
- Temperatura molde
  - Tm_{min}
  - Tm_{max}
- Velocidad
  - v_{min}
  - v_{max}

Output

- % de llenado de la microcavidad?
- Volume Fraction de polímero



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Thanks

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Generalitat de Catalunya
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