# Nanopattern replication through plastic injection

*Andrés-Amador García-Granada*[1], *Jordi Pina-Estany* [1,2]

[1] *IQS-School of Engineering, GEPI Group Enginyeria Producte Industrial, Via Augusta 390, 08017 Barcelona*

[2] *SEAT Centro Técnico, Autovía A-2, Km. 585, 08635 Martorell, , Barcelona*

Contact *andres.garcia@iqs.edu* Website *www.meaagg.com/PLASTFUN/PLASTFUN.html*

## Introduction

Simulations and experiments have been performed to replicate several nanopattern structures at low cost by means of plastic injection. This study is currently being used to reproduce selfcleaning surfaces, antireflexion, hydrophobicity, diffraction colours,... within a group of companies supported by RIS3CAT-PlastFun project.

## 2D simulations to set injection paremeters

Plastic injection has been proved to be a good fabrication technique to produce a large number of parts where a nanopattern is replicated from the mould on the plastic part surface. However not all nanopatterns are transferred correctly and simulations and experimental validations have been implemented to define the most appropriate manufacturing parameters to obtain the best replication. Initial computer fluid dynamics (CFD) simulations studied the influence of manufacturing parameters on such replications using a 2D approach.[1]

## 3D simulations for non linear patterns

Next a study was carried out to determine in which cases 3D simulations where required to deliver good results.[2]

## Molecular Dynamics simulations for small cavities

In a third step the transition from CFD to molecular dynamics (MD) simulations for very small patterns to replicate [3]. Using MD the influence of tacticity of the polymer in the replication was studied. [4]

## Industrial application

Finally, an industrial application is presented for automotive lighting where nanoparticles used for light diffusion are replaced by nanostructured surface. [5]

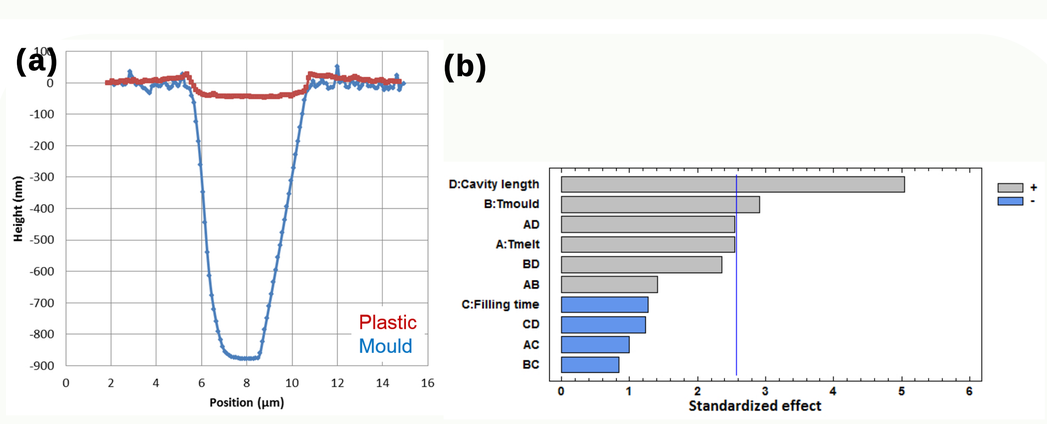


Fig.1. (a) 2D cavity and plastic , (b) and parameters that influence the replication in polymer [1].

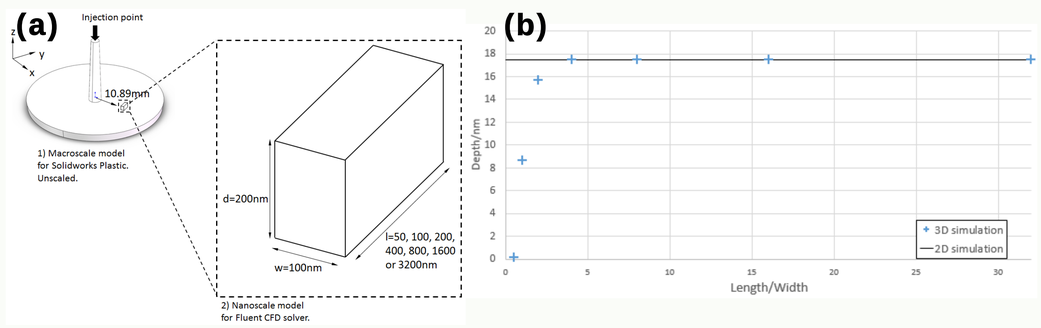


Fig.2. (a) 3D cavity, (b) results of copied depth as function of aspect ratio. [2]

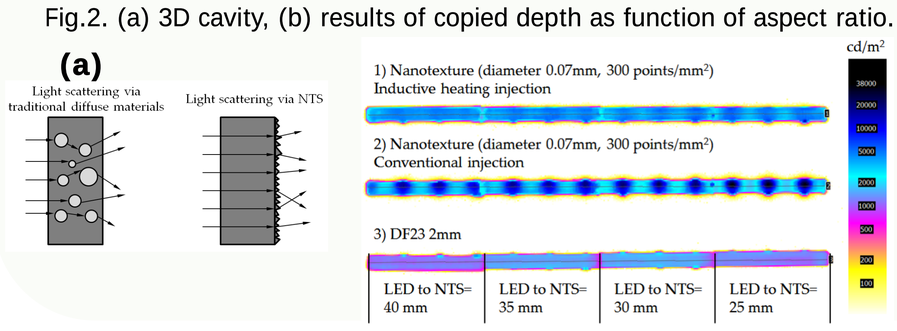


Fig.3. (a) Light diffusion with nanoparticles versus nanostructured surface, (b) light homogeneity measurements [5]

## Conclusions

Results showed using 2D CFD simulations that the cavity length, the temperature of the mould and the temperature of the polymer are positive effects on the replication. Filling time was proved to have a positive effect in experiments but not in simulations. 3D simulations were required for cavities with a
length/width relationship smaller than 4. On such cases 2D simulations overestimate replication. MD are used for cavities smaller than 100nm showing that smaller cavities required more time to complete replications. MD showed that tacticity of polymer influences the replication with syndiotactic polymer leading to a smaller replication (0.8nm) compared with an atactic (3.2nm) or isotactic (2.5nm) polymer due to the larger entanglement between adjoining chains. Finally, homogeneous light diffusion is successfully achieved when a random nanotexture is engraved with the nanosecond laser. Better homogeneity of the light and efficiency are obtained by using induction heating compared with conventional warming.

## References

[1] Pina-Estany, J., Colominas, C., Fraxedas, J., Llobet, J., Pérez-Murano, F., Puigoriol-Forcada, J. M., ... & Garcia-Granada, A. A. (2017). A statistical analysis of nanocavities replication applied to injection moulding. *International Communications in Heat and Mass Transfer*, *81*, 131-140.

[2] Pina-Estany, J., & García-Granada, A. A. (2017). 3D Simulation of Nanostructures Replication via Injection Molding. *International Polymer Processing*, *32*(4), 483-488.

[3] Pina-Estany, J., & García-Granada, A. A. (2017). Molecular dynamics simulation method applied to nanocavities replication via injection moulding. International Communications in Heat and Mass Transfer, 87, 1-5.

[4] Pina-Estany, J., & García-Granada, A. A. (2018). Computational analysis of polymer molecular structure effect on nanocavities replication via injection moulding. *Afinidad*, *75*(581).

[5] Pina-Estany, J., García-Granada, A. A., & Corull-Massana, E. (2018). Injection moulding of plastic parts with laser textured surfaces with optical applications. *Optical Materials*, *79*, 372-380.

## Acknowledgement

This project is supported by Fons Europeus de Desenvolupament Regional de la Unió Europea en el marc del Programa operatiu FEDER de Catalunya 2014-2020