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Systematic study of replication fidelity of nanostructures in polymer down to 40nm by extrusion coating: Preliminary results

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Introduction

- Nanostructuring of plastic materials has not penetrated the consumer market yet, mainly due to high costs.
- We propose a high-speed roll-to-roll technology compatible with existing manufacturing equipment, called extrusion coating.
- Standard thermoplastic materials may be structured at low cost, with high throughput.
- Production rates: specialized injection molding and ultra violet roll imprinting : ~50 cm^2/s; extrusion coating : ~20,000 cm^2/s

Methods

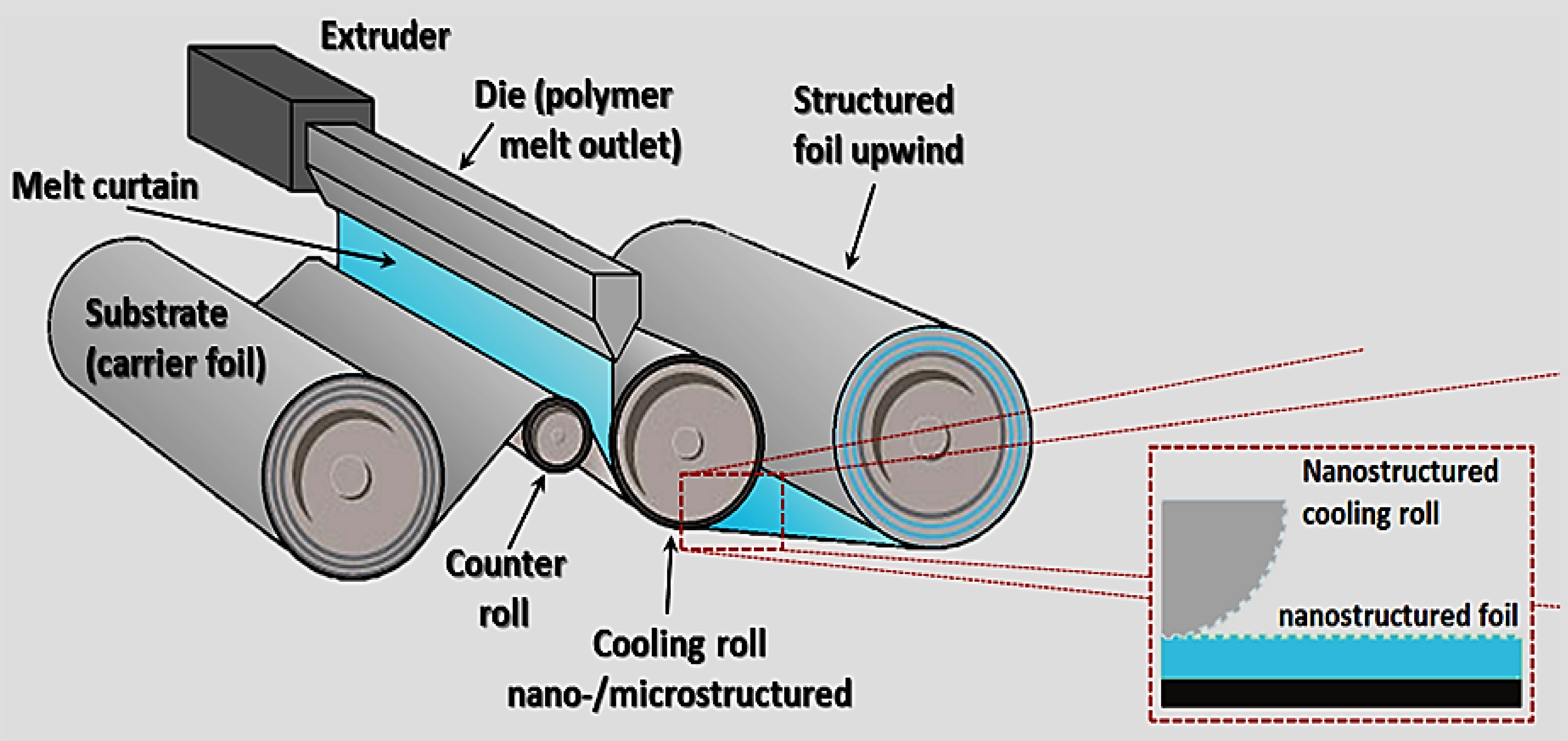
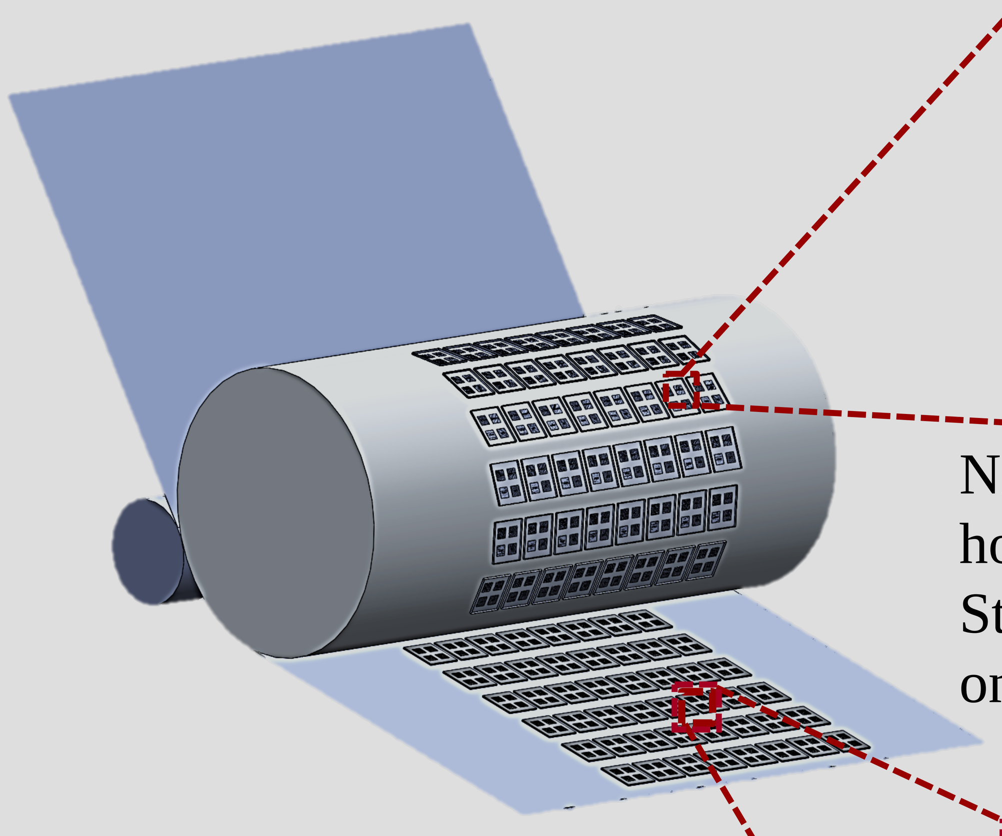


Figure 1: Extrusion coating process:
- Hot polymer melt is extruded into the nip between the cooling roll and the counter roll.
- Pressure applied by the two rolls force polymer melt into micro- and nanostructures present on the cooling roll.
- Roll temperature is kept below the glass transition temperature of the polymer causing instant solidification of the melt. Structured foil is wound up.



Nickel stamp with holograms fabricated by Stensborg A/S mounted on the extrusion roller

Figure 2: Extrusion coating of holograms in polypropylene (PP) foils ,from Ni shims mounted on the roller.

Holograms replicated in extruded PP foils .

Results

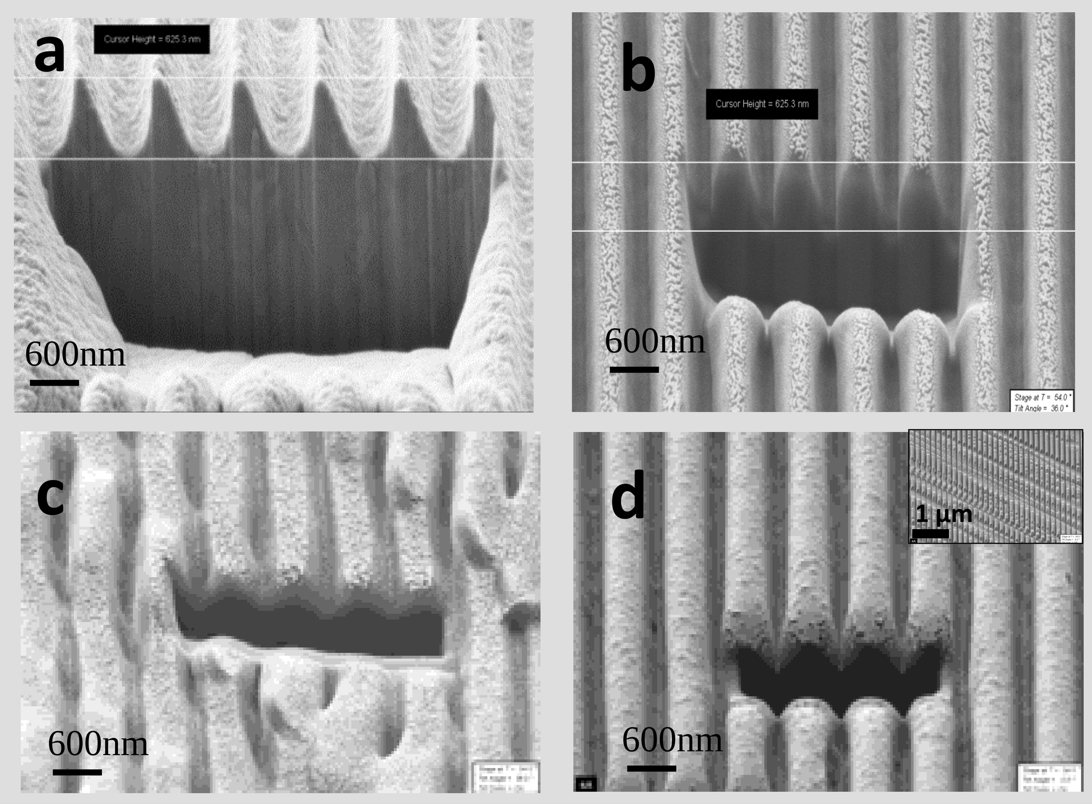


Figure 3: Optical diffraction gratings in nickel stamp (a), replica in extruded polypropylene (PP) (b), polyethylene (c), polyolefin (d) thereof.

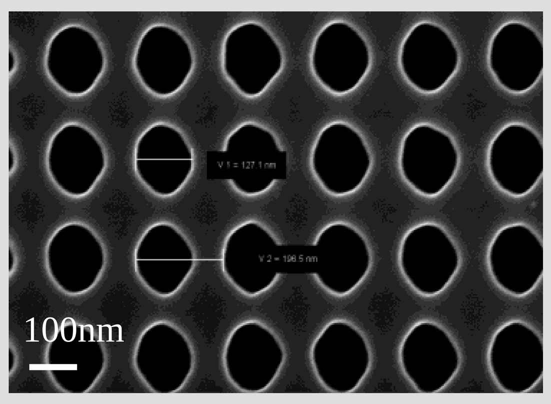


Figure 4a: Si master, e-beam lithography. Hole diameter : 120 nm; pitch : 200nm; depth : 100nm .

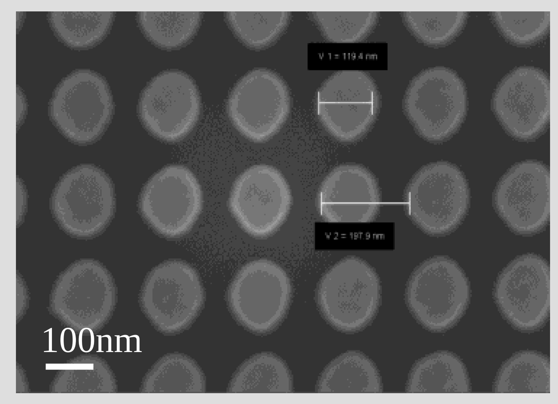


Figure 4b: Ni-stamp, electroplating. Pillar diameter : 120 nm; pitch : 200nm; height : 100 nm.

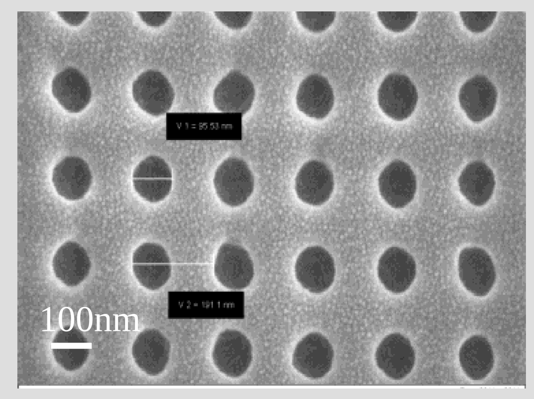


Figure 4c: Extruded PP replica. Hole diameter : 100 nm ; pitch : 190 nm; depth : ~90nm

Smallest structures replicaed in PP

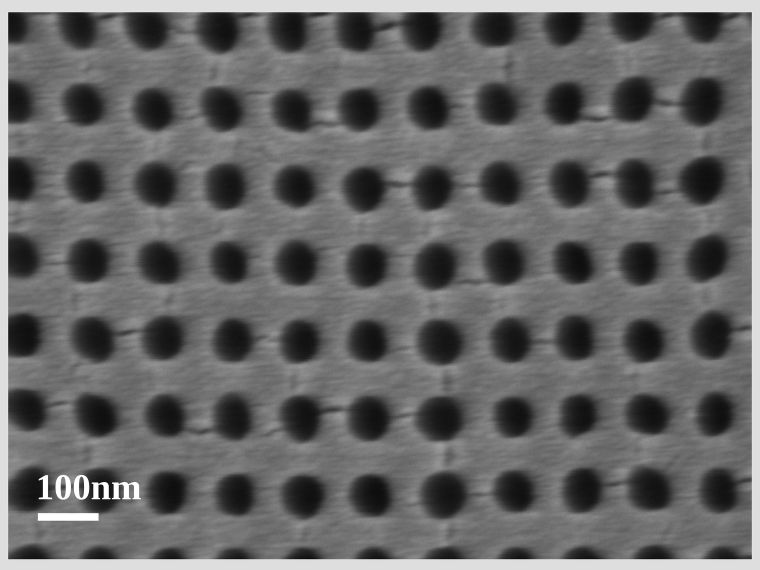


Figure 5a: Nanoholes in extruded PP. Diameter: 70 nm; pitch: 110 nm; depth: ~90nm.

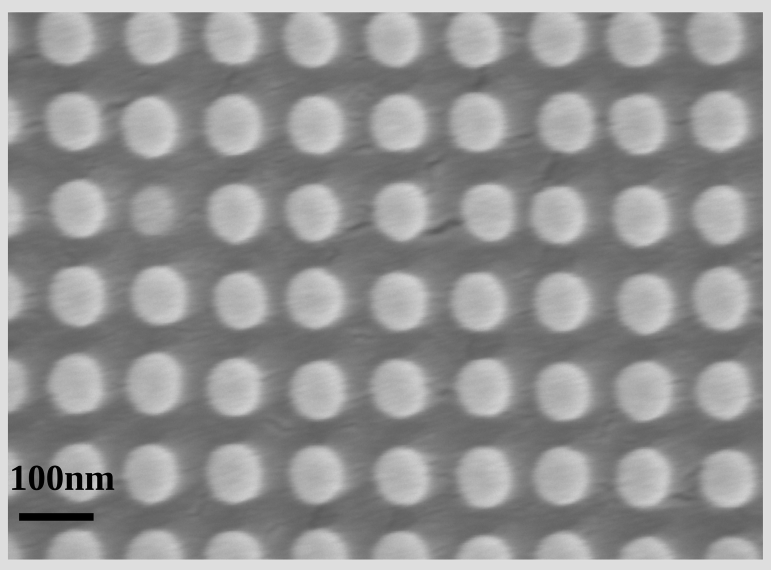


Figure 5b: Nanopillars in extruded PP. Diameter: 70 nm; pitch: 130 nm; height: ~90nm.

Conclusion

The presented results demonstrate the realization in large area nano-structuring with high through-put and low cost fabrication method. We anticipate that extrusion coating process can act as a key technology for further development and industrialization of a wide range of applications, such as antireflection surfaces, structural colors, self-cleaning surfaces, super hydrophobic surfaces etc.. More detailed analysis is currently in progress, also to increase production rates even further.