

## Systematic study of replication fidelity of nanostructures by extrusion coating

Murthy, Swathi; Pranov, Henrik; Matschuk, Maria; Taboryski, Rafael J.; Pedersen, Henrik Chresten

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Swathi Murthy<sup>a,b,c</sup>, Henrik Pranov<sup>a</sup>, Maria Matschuk<sup>a</sup>, Rafael Taboryski<sup>b</sup>, Henrik C. Pedersen<sup>c</sup>

<sup>a</sup> InMold Biosystems A/S, Gregersensvej 6H, DK-2630 Taastrup, Denmark

<sup>b</sup> Department of Micro-nanotechnology, Danish Technical University, Denmark

<sup>c</sup> DTU Fotonik, Department of Photonics Engineering, Danish Technical University, Denmark

## 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 :  $\sim 50 \text{ cm}^2/\text{s}$ ; extrusion coating :  $\sim 20,000 \text{ cm}^2/\text{s}$

## Methods

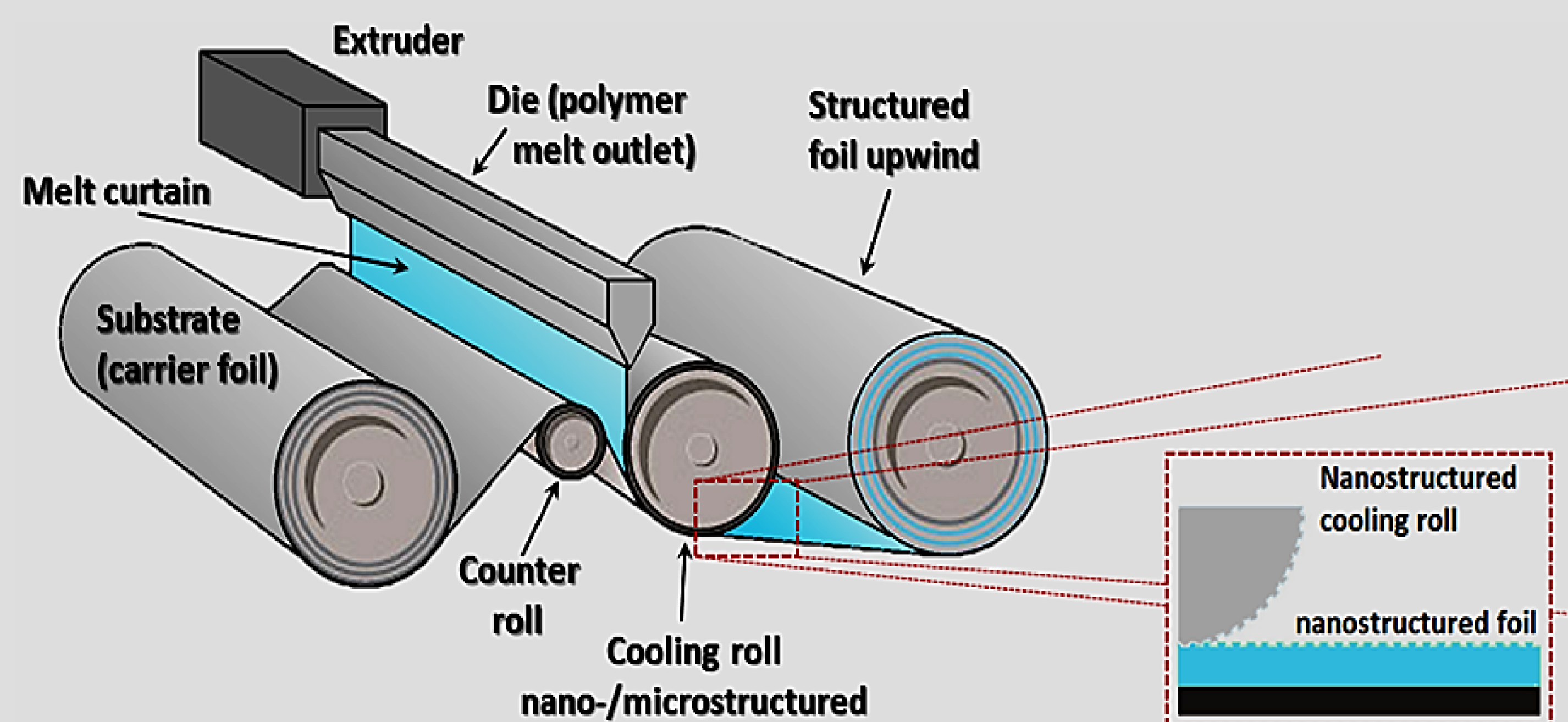


Figure 1: Extrusion coating process:

- 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.

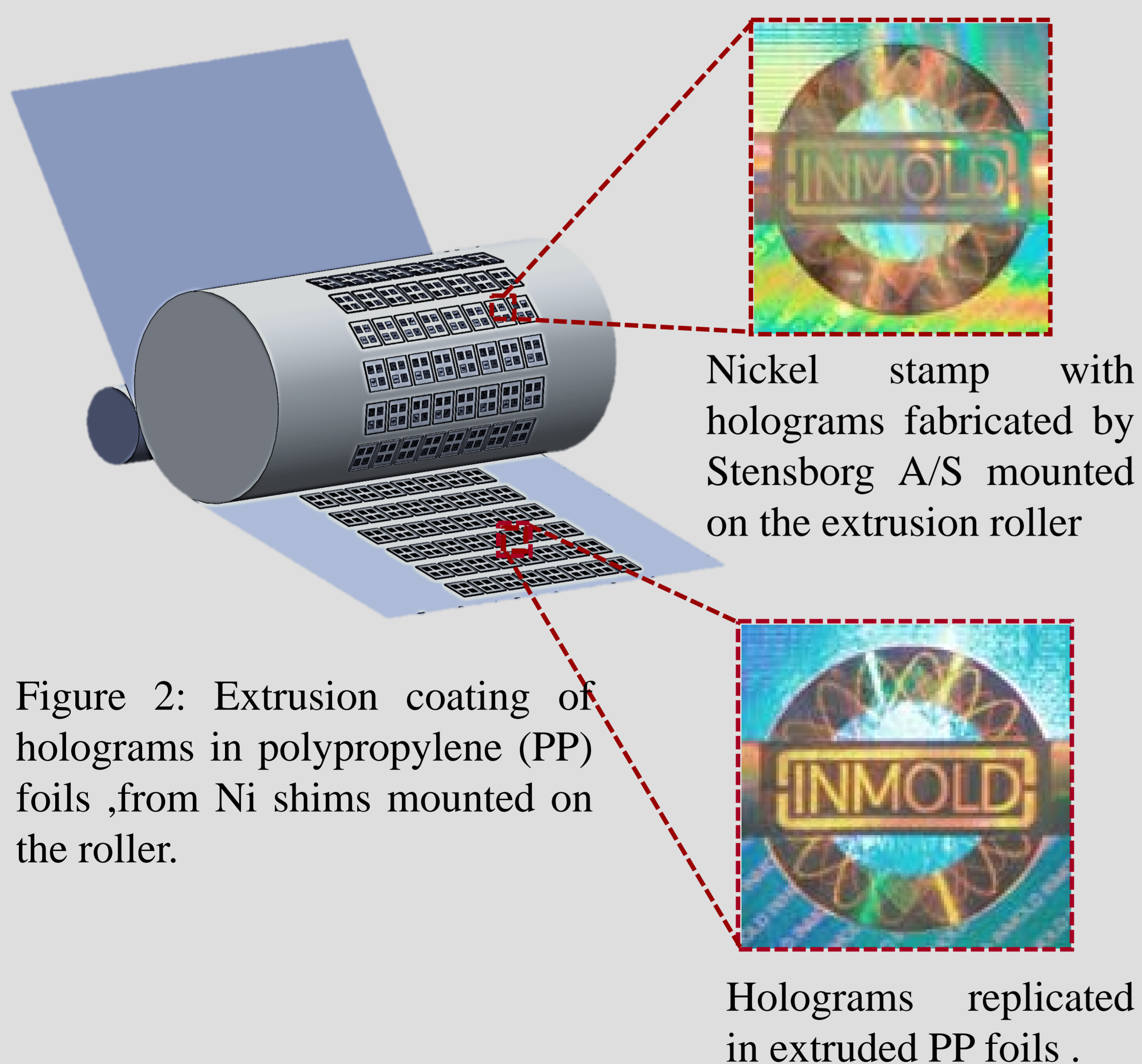


Figure 2: Extrusion coating of holograms in polypropylene (PP) foils, from Ni shims mounted on the roller.

## Results

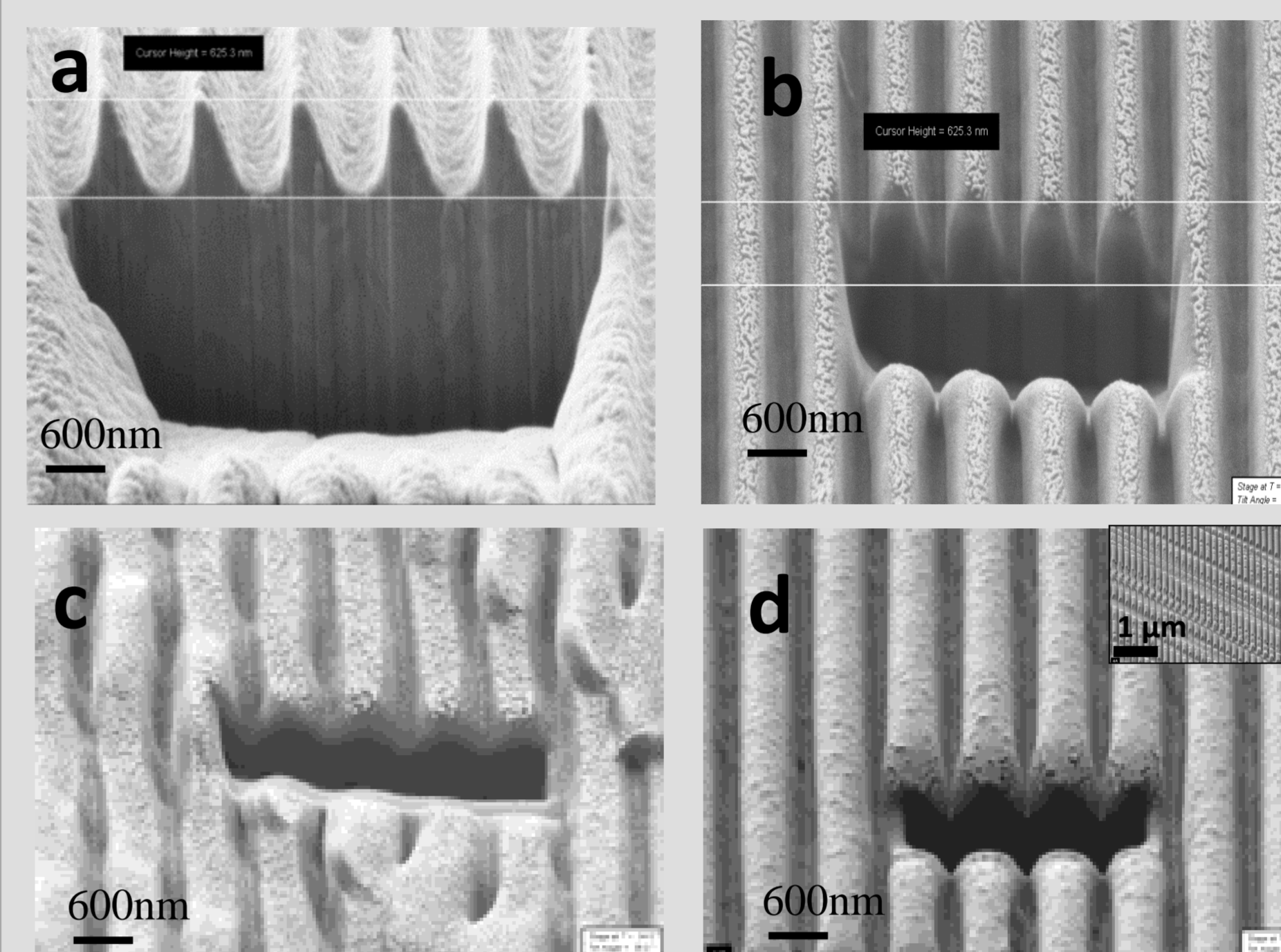


Figure 3: Optical diffraction gratings in nickel stamp (a), replica in extruded polypropylene (PP) (b), polyethylene (c), polyolefin (d) thereof.

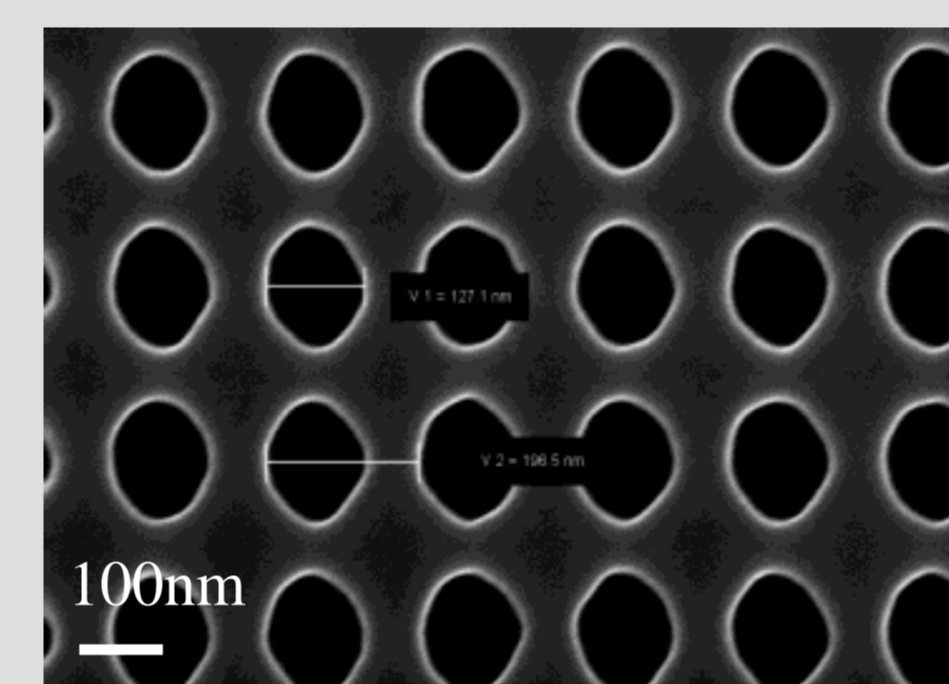


Figure 4a: Si master, e-beam lithography. Hole diameter : 120 nm; pitch : 200nm; depth : 100nm .

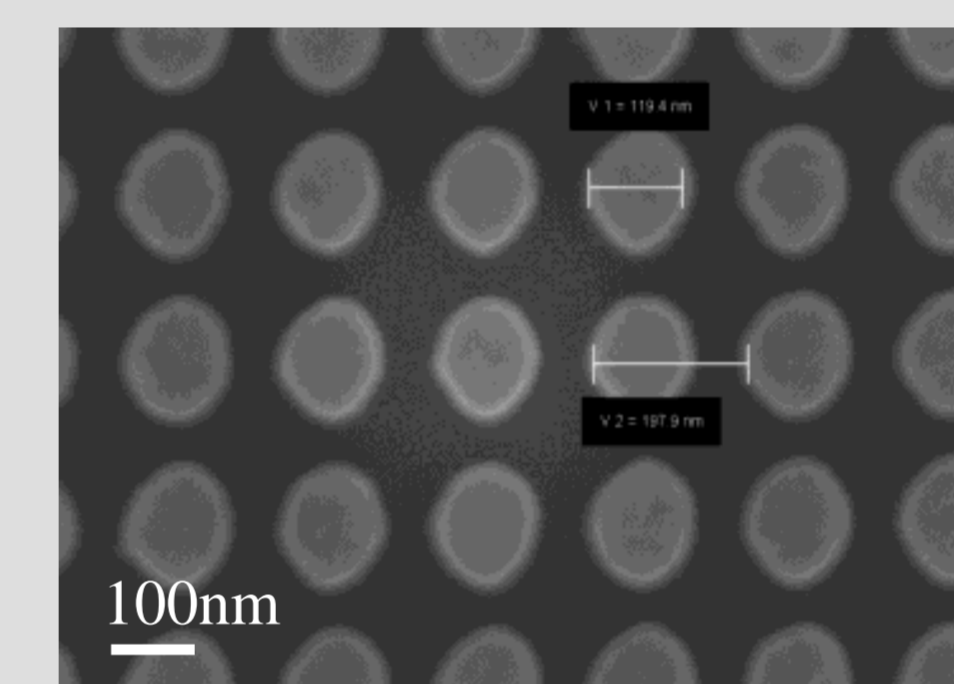


Figure 4b: Ni-stamp, electroplating. Pillar diameter : 120 nm; pitch : 200nm; height : 100 nm.

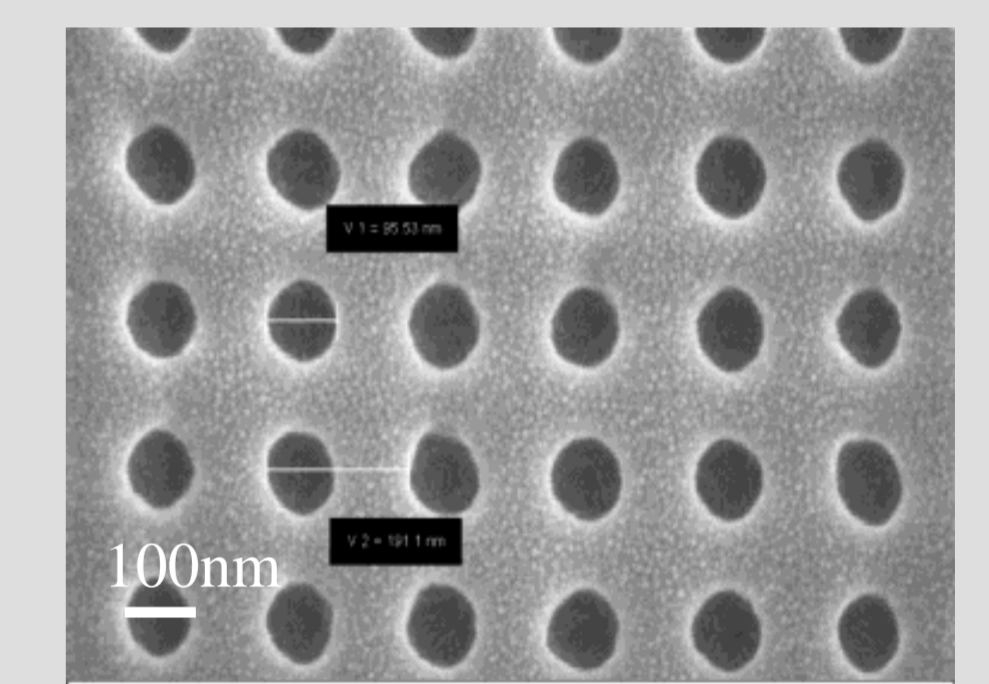


Figure 4c: Extruded PP replica. Hole diameter : 100 nm ; pitch : 190 nm; depth :  $\sim 90\text{nm}$

## Smallest structures replicaed in PP

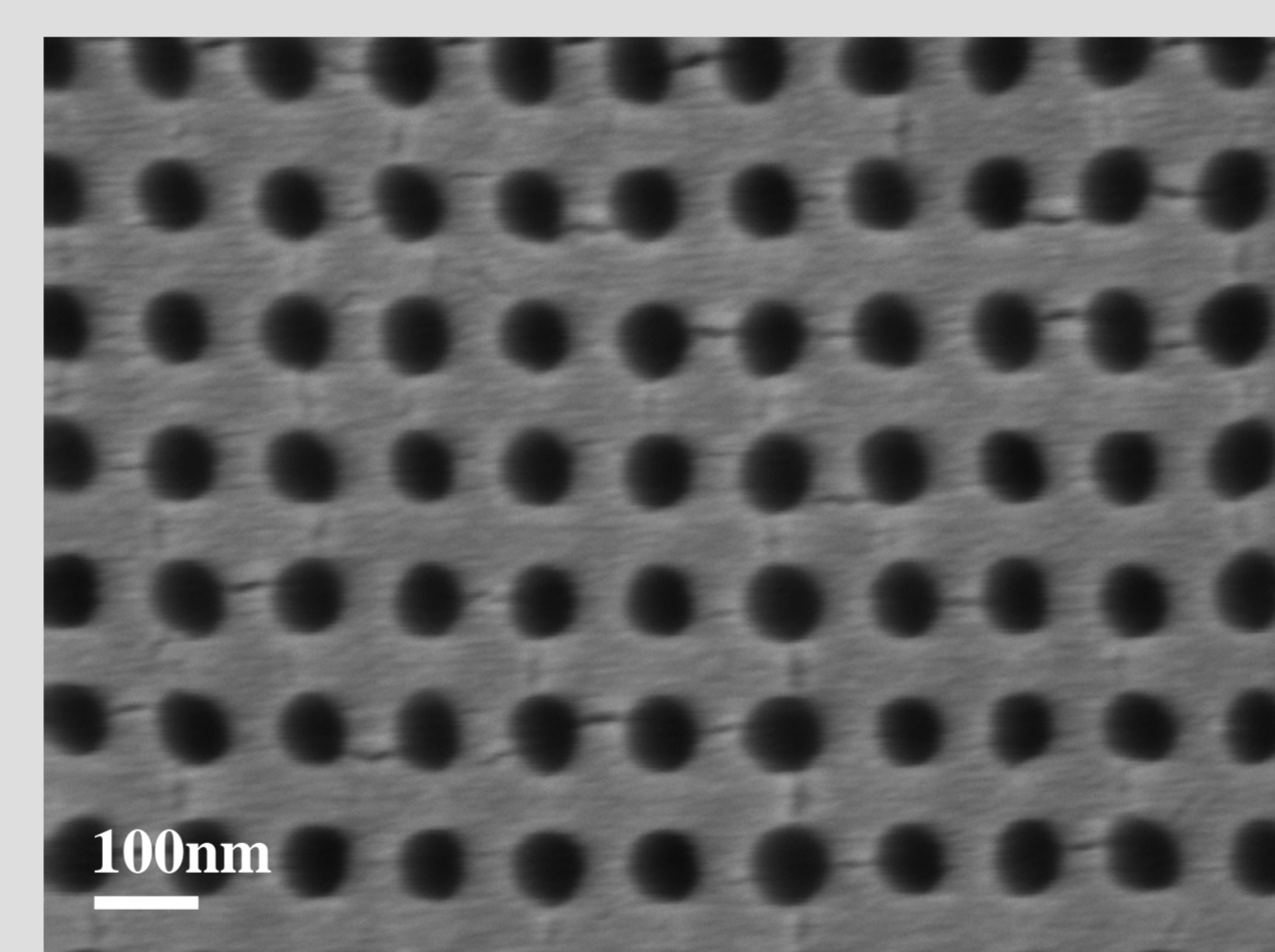


Figure 5a: Nanoholes in extruded PP. Diameter: 70 nm; pitch: 110 nm; depth:  $\sim 90\text{nm}$ .

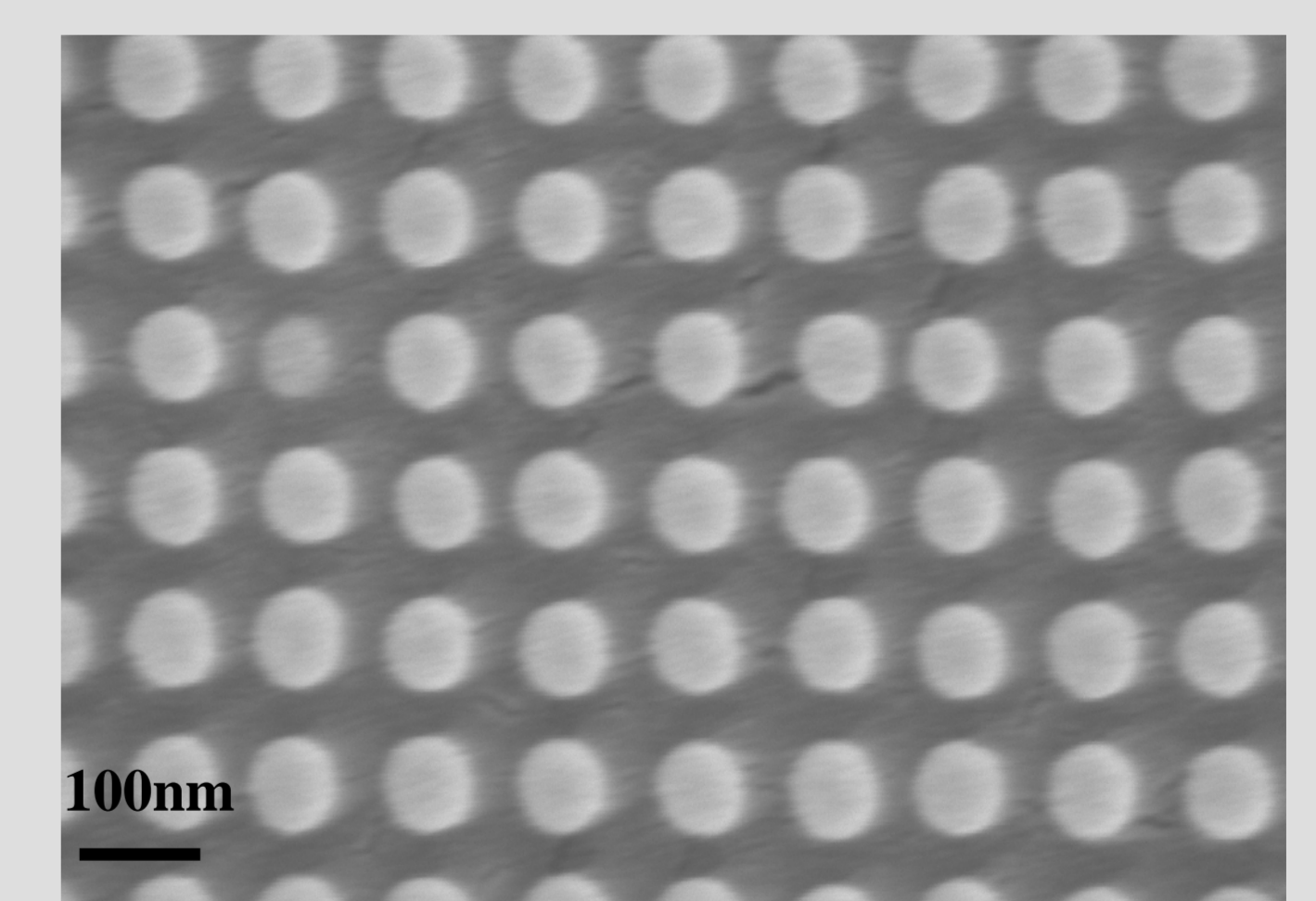


Figure 5b: Nanopillars in extruded PP. Diameter: 70 nm; pitch: 130 nm; height:  $\sim 90\text{nm}$ .

## 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.