

Roll-to-roll Nano-patterning of Packaging Films: Analysis Using AFM, SEM and FIB SEM

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Roll-to-roll extrusion coating (R2R EC) is a well-established and well-studied process in the field of the packaging industry. Within the last 5 years the pattern replication using EC has shown promising results for mass-production of large-scale micro- and nano-pattern transfer into several thermoplastic polymers [1-3]. R2R EC has a capacity for production of up to 2m wide packaging foils at production speed up to 1000m/min.

The main objective of this study is production of functional surfaces that include both micro- and nano-scale patterns (for example hierarchical patterns for superhydrophobicity). An investigation of the yield of the pattern transfer is carried out using the state of the art FIB-SEM techniques and atomic force microscopy. An example of a micro/nano pattern is shown in Figure 1A: an SEM image of the structures in Si produced by UV lithography and deep reactive ion etching. The pattern is transferred into polypropylene using R2R EC. In Figure 2B-D the replicated pattern in PP is presented. Packaging foils with this particular surface pattern show a superhydrophobic behavior.

The yield of replication was analyzed with respect to the different extrusion parameters. In prior studies, for nano-sized patterns [1,2] and micro-sized patterns [3], an interesting inconsistency is observed for the influence of the production speed during this process: the nano-sized structures seem to form best at the higher speeds and the micro-sized structures seem to form best at the lower speeds. The influence of these parameters for different scale patterns is addressed in this study.

Some of the interesting applications of superhydrophobic foils are self-cleaning surfaces for food packaging, as well as anti-icing and protection against corrosion. A wide variety of other functional structures that can be produced using this process varying from 100 nm plasmonic structures up to 100 μm microfluidic and optical patterns.

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- [3] N. Okulova, et.al., *MEE* 176 (2017) 54-57.

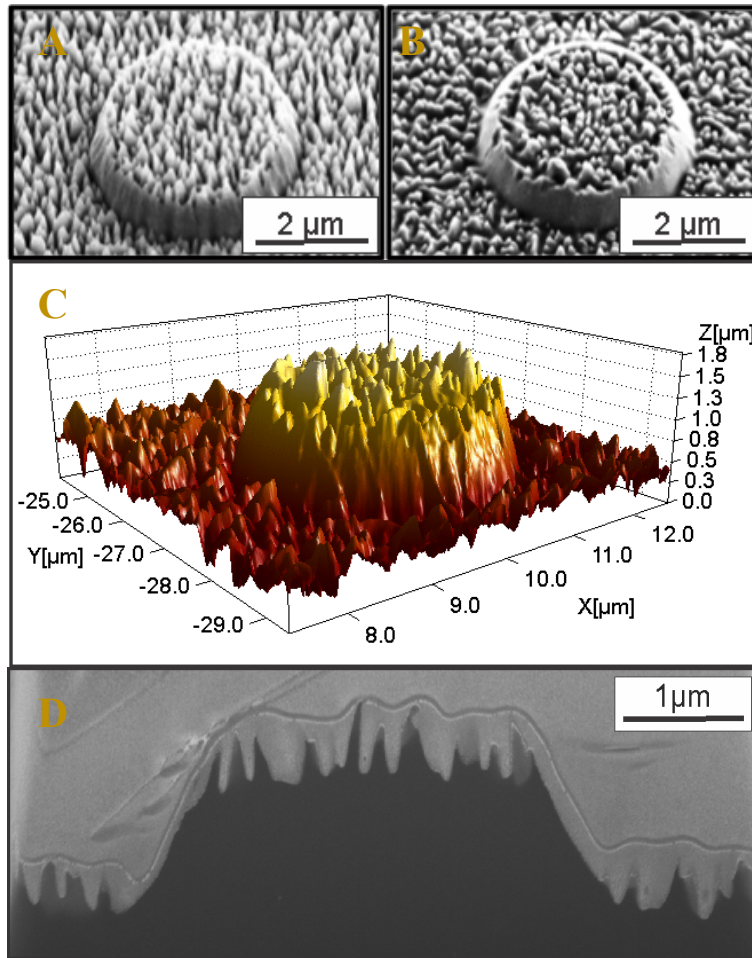


Figure 1: Hierarchical structures in Si and PP:

Superhydrophobic structures are fabricated in Si and then replicated in thermoplastic polymers using a mold in extrusion coating process. A: The master structure in Si. B,C,D: Similar structure replicated in PP. B: SEM image, polymer surface was coated with 5nm Au to avoid charging. C: AFM measurement of the PP surface. D: FIB SEM image of the produced pattern.