Combined film extrusion and roller imprinting for large scale structuring of polymer films

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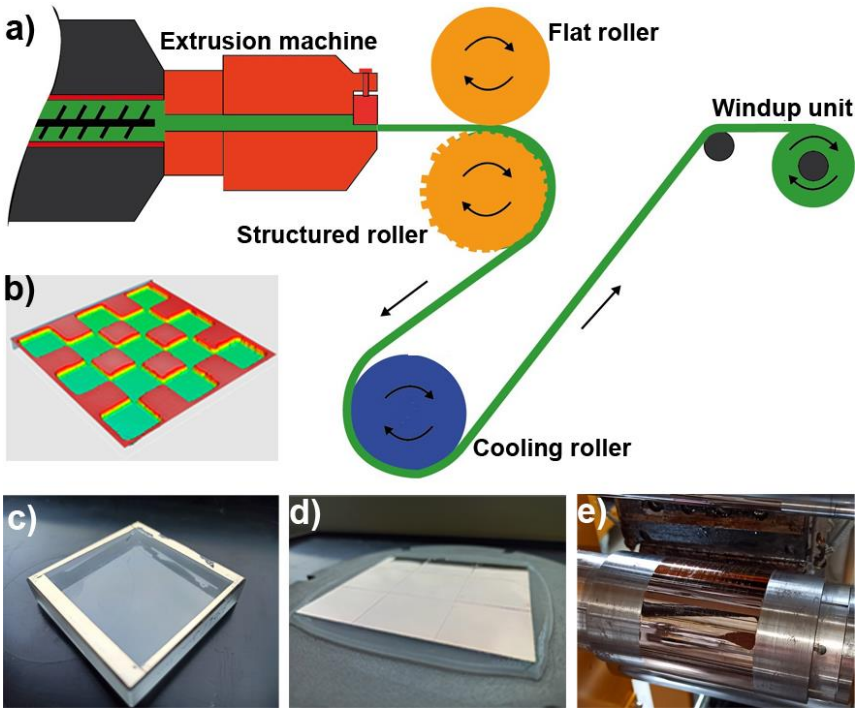
Micro- and nanoscale fabrication techniques greatly advanced in the last decades. However, many of these techniques struggle to be upscaled to structure large areas. One solution to solve this problem is roll-to-roll (R2R) hot embossing to continuously structure polymer films. A drawback of this technique is that the surface of the polymer film has to be heated up to its melting temperature so that it can flow into the fine cavities of the mold. This has to happen during the very short time period when the polymer sheet is actually touching the structuring roller.

Our process aims to mitigate this problem by using a single screw extrusion machine with a film nozzle to extrude a thin film of polymer. Immediately after that, this thin film is passed between two rollers that emboss microstructures directly into the polymer melt. In this way, the rollers are cooling the film rather than heating it. Therefore, we can wrap the film around the structuring roller to significantly increase the time to fill cavities and solidify the polymer film. Furthermore, by wrapping the film around the roller, we can excerpt a holding pressure onto the polymer film while it is solidifying, resulting in precise structuring. Lastly, the demolding is done when the polymer is cooled down already, leading to high-quality imprinting in a R2R process.

The main challenge of this process is the manufacturing of sufficiently large molds. Most micromanufacturing equipment used for mold production is limited to substrate diameters of 4 to 6 inches. We, therefore, developed a stitching process that enables to assemble multiple smaller masters to form a larger mold. Our process utilizes UV imprinting, readily available tools to stitch the master structures, and electroplating to produce the final mold.



a) Schematic of the utilized roller imprinting process. **b)** Confocal scanning microscope image of a checkerboard pattern imprinted with the presented process. The dimensions are 120 x 120 µm **c)** Glass Master structure with dimensions of 40 x 40 mm^2 **d)** Stitched shim with a 3 x 3 array of the glass master structure shown in c). The dimensions are about 120 x 120 mm^2. This shim is then used as a master structure to create an even larger nickel shim that can in turn be attached to the roller. **e)** A shim mounted on the structuring roller in the R2R machine.