R2R-UV-nanoimprinting as a powerful mean for large-area fabrication of freeform micro-optical elements

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R2R-UV-nanoimprinting sets new benchmarks for the fabrication of miniaturized, low-cost and low-weight freeform micro-optical elements applicable in lighting, display, medical diagnostics, etc. We demonstrate the related process chain, combining optical design, direct laser lithography mastering, S&R- and R2R-UV-imprinting.

Recently, R2R-UV nanoimprinting has proven to be very useful and unrivalled for the large-area fabrication of high-resolution, hierarchical structures at reasonable throughput for the realization of mechanically flexible functional surfaces useable in bionic applications like drag-reducing films or transparent conductive electrodes [1], [2].

Here we report on the utilization of UV-NIL for the manufacturing and upscaling of optical components in lighting and µ-fluidic applications. One key prerequisite for a versatile deployment of UV-nanoimprinting is the adjustability of the imprint resin towards the targeted application scenario. It should be tunable in terms of elasticity and surface tension to account for easy demolding and wettability and it should have low enough viscosity to allow for large-area coating. For optical polymer components such as freeform micro-lenses or light out-coupling / reflecting structures the tunability of the refractive index and optical dispersion is particularly important.

Another important aspect is the master fabrication and its upscaling to large-area imprint tools. Here we introduce a Step & Repeat UV-NIL technique allowing for a high-precision nearly stitch-free multiplication of small scale masters onto polymer films resulting in large and flexible imprint stamps that are readily mounted around the imprint roller.

With these ingredients we R2R-fabricated complex freeform µ-optical element (FF-MOE) designs with small height that enable a tailored redirection of light from discrete LED sources. These FF-MOEs were used to demonstrate ultra-thin direct lit luminaires with a very homogenous illumination over an area with a pore-defined shape [3]. Another application of film based R2R-imprinted FF-MOE was realized for the improved outcoupling of the chemiluminescence signal of in-vitro diagnostic chips for the detection of diverse pathogens. The biosensor signal was increased by a factor of ~1.7 as tested in a portable read-out device of a commercial chip testing platform.

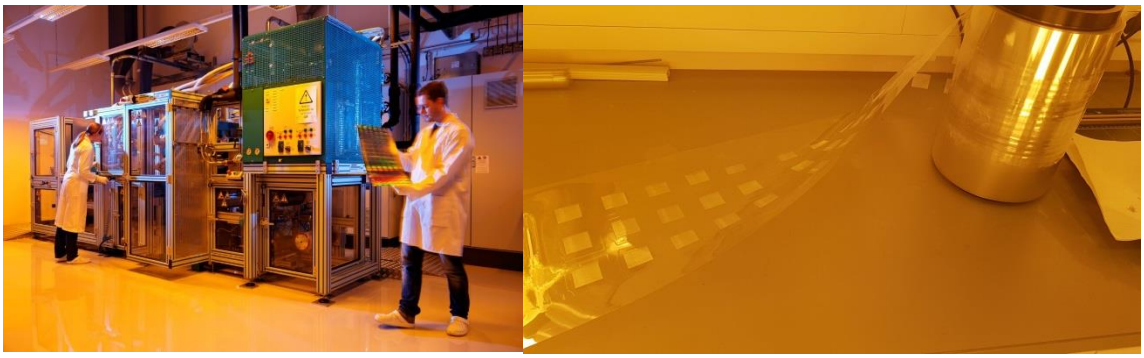

Fig. 1. R2R pilot line and rolls with sawtooth-like micro-optical structures for improved outcoupling of the chemiluminescence light.

Reference:

[1] M. Leitgeb et al., “Multilength Scale Patterning of Functional Layers by Roll-to-Roll Ultraviolet-Light Assisted Nanoimprint Lithography”
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[2] D. Nees et al., “Experiments towards Establishing of Design Rules for R2R-UV-NIL with Polymer Working Shims”
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[3] P. Hartmann et al., “Roll-to-Roll UV Nanoimprint Lithography for Large-Area Nano- and Micro-Structuring of Flexible Substrates”
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