A woman with blonde hair tied back, wearing a blue lab coat and white gloves, is working on a nanoimprint lithography machine. She is carefully handling a transparent substrate on the machine's stage. The machine has various mechanical components, cables, and a yellow laser line visible on the substrate. The background shows a laboratory setting with shelves and equipment.

Maskless and free: grey scale and step & repeat nanoimprint lithography for advanced optics

JOANNEUM
RESEARCH
MATERIALS 

Paul Hartmann
Neuchâtel, 08.11.2019



MATERIALS - Institute for Surface Technologies and Photonics

Organisation, Structure of Research Groups

- 5 Research Groups
~ 90 Employees
- 3 Locations in Austria
 - Weiz
 - Niklasdorf
 - Pinkafeld
- Annual revenue ca. 10 Mio €
 - 40% funded research
 - 40% contract research
 - 20% own funds



**Hybrid Electronics
and Patterning**
Barbara Stadlober

**Light and Optical
Technologies**
Christian Sommer

**Laser and Plasma
Processing**
Wolfgang Waldhauser

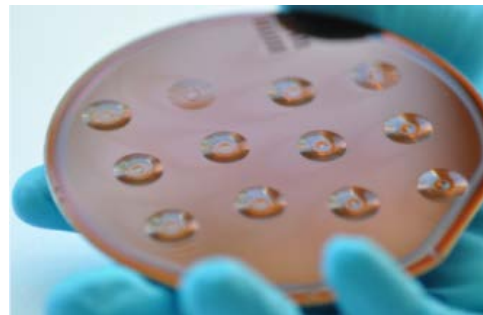
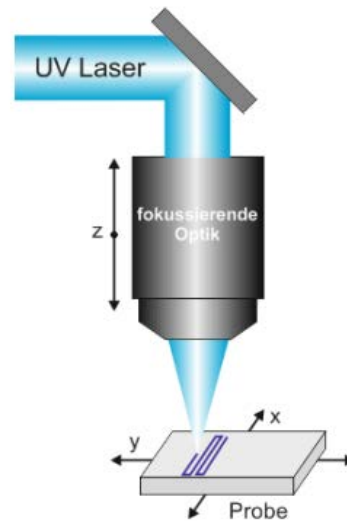
**Sensors and
Functional Printing**
Jan Hesse

Smart Connected Lighting
Franz-Peter Wenzl

Upscaling Process Flow@JR

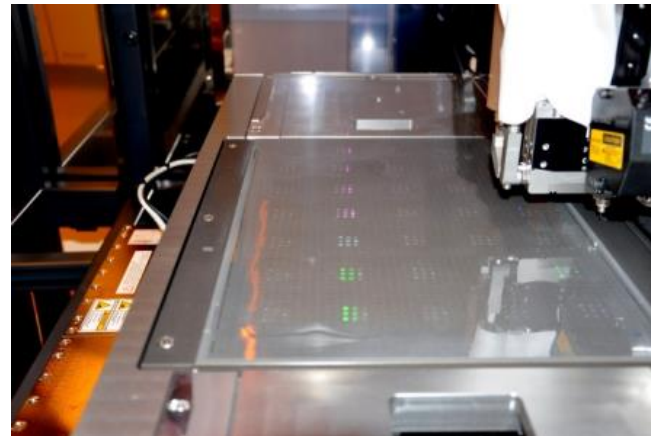
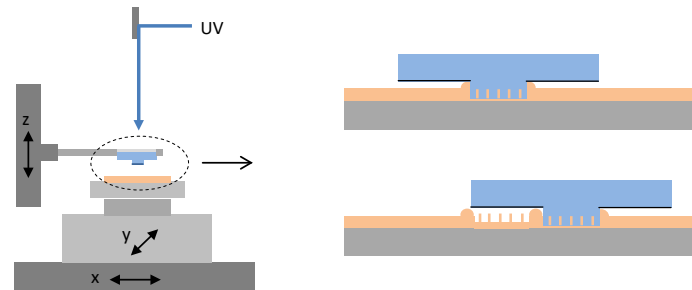
3

MASTER



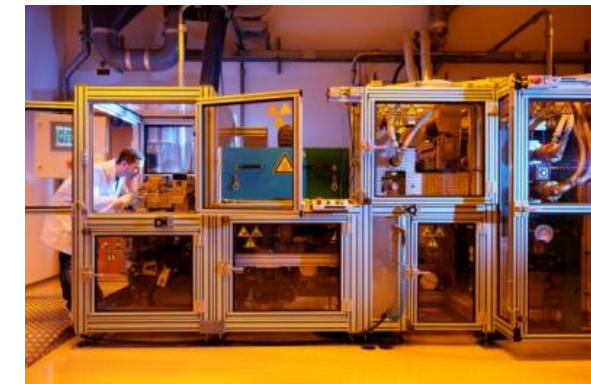
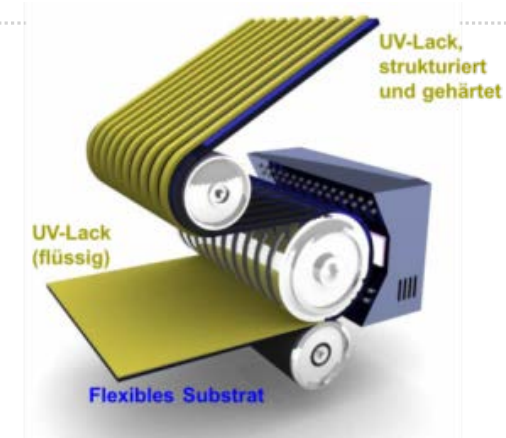
Maskless Laser Lithography

STAMP/SIM PRODUCTION



Step & Repeat UV-NIL

REPLICATION

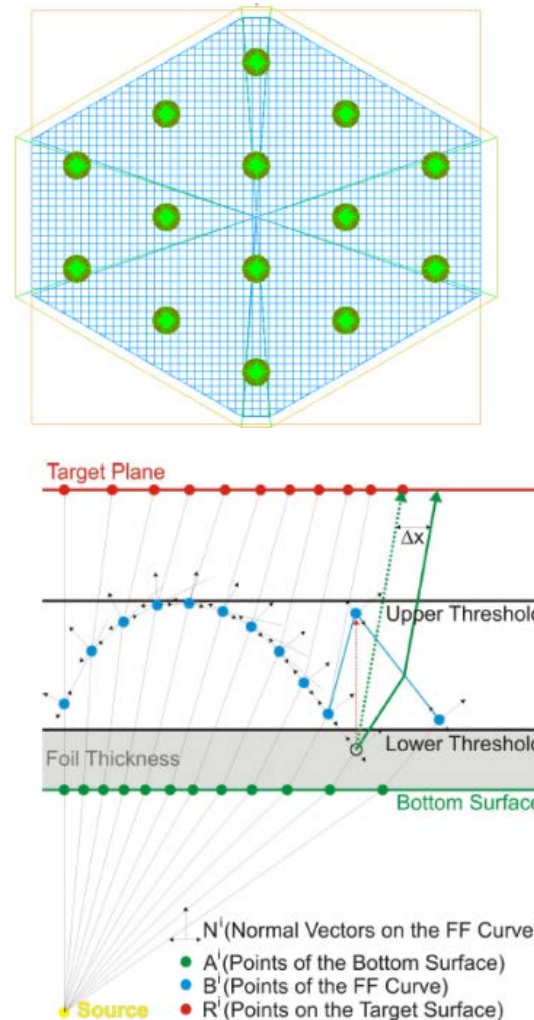
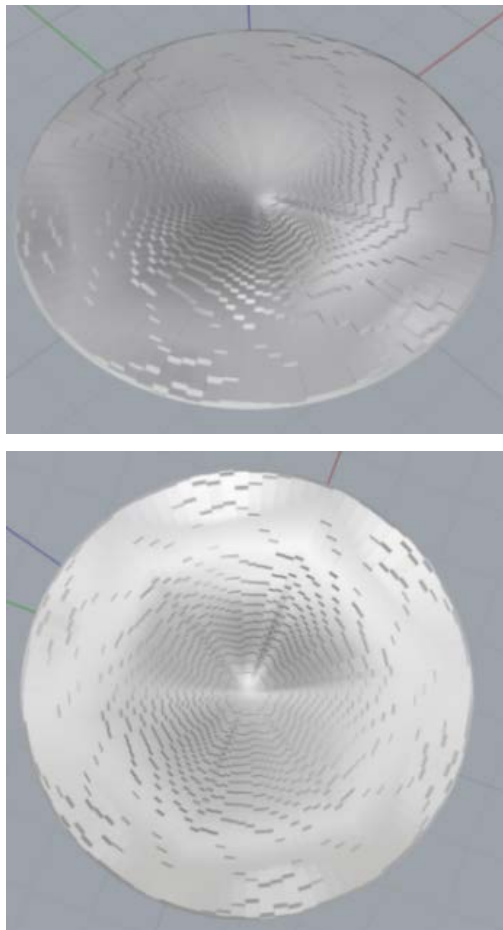


R2R-UV-Nanoimprinting

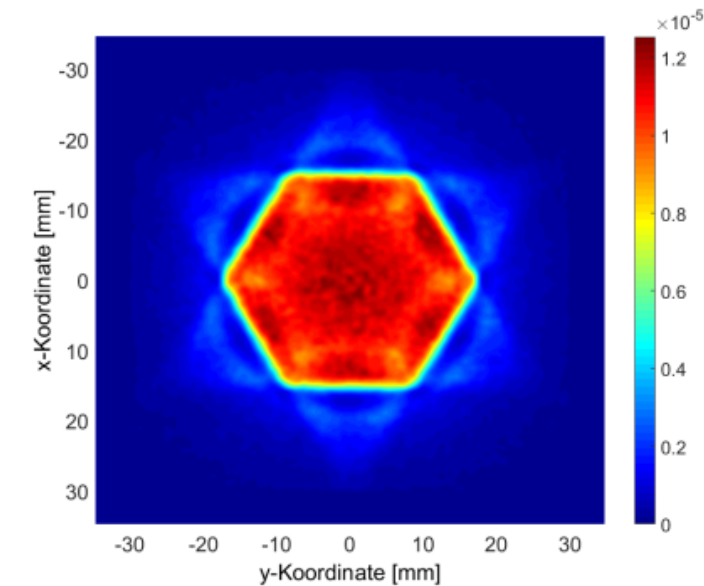
UPSCALING

Application: Free Form Optical Micro-Structures

Facette-type FF- μ Lense ($h=50\text{ }\mu\text{m}$)

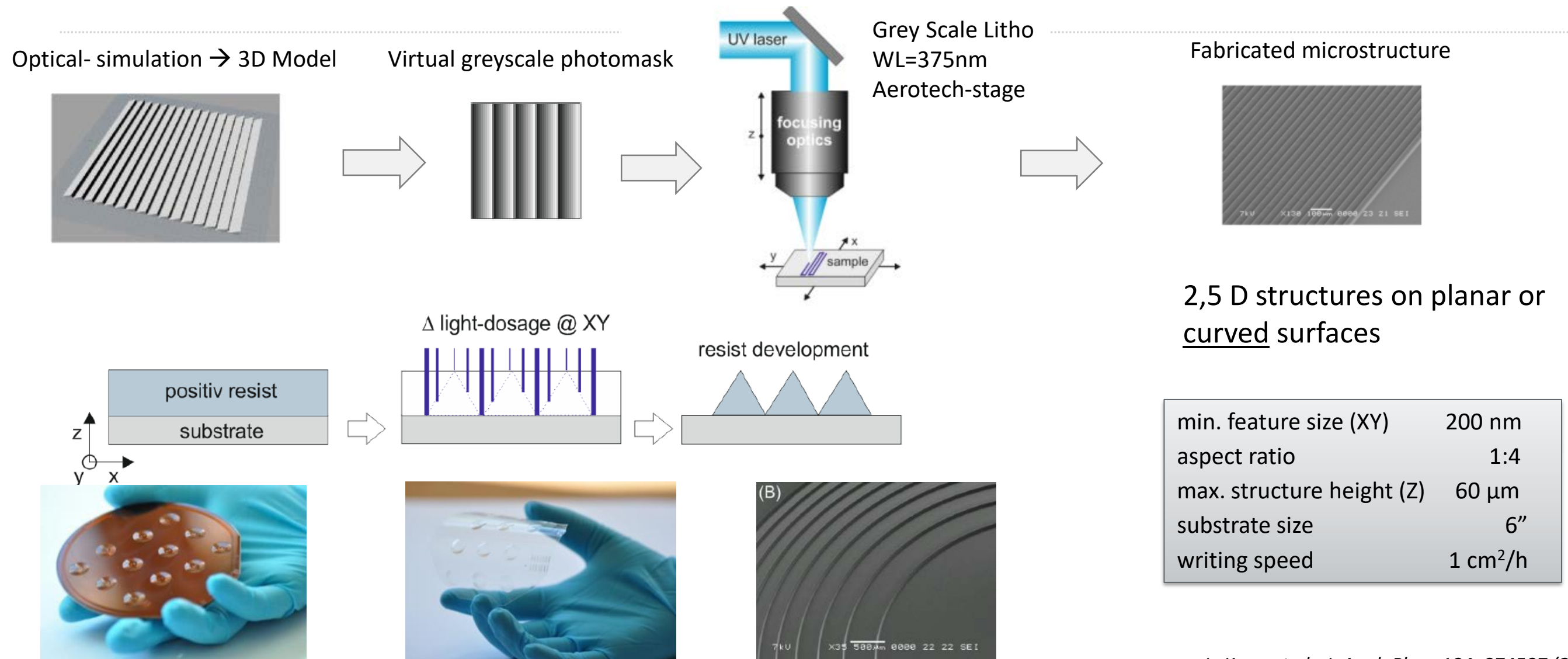


- Example: 14 hexagonally arranged LEDs for thin backlit luminaires



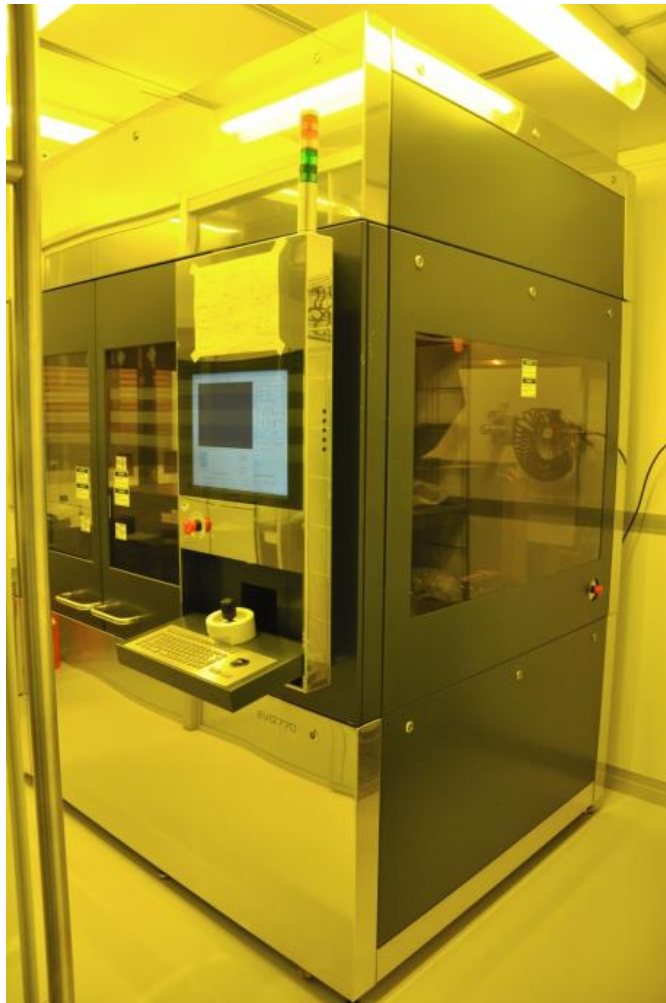
Sequential ray mapping algorithm with lower and upper threshold

Mastering by UV Grey Scale Laser Lithography

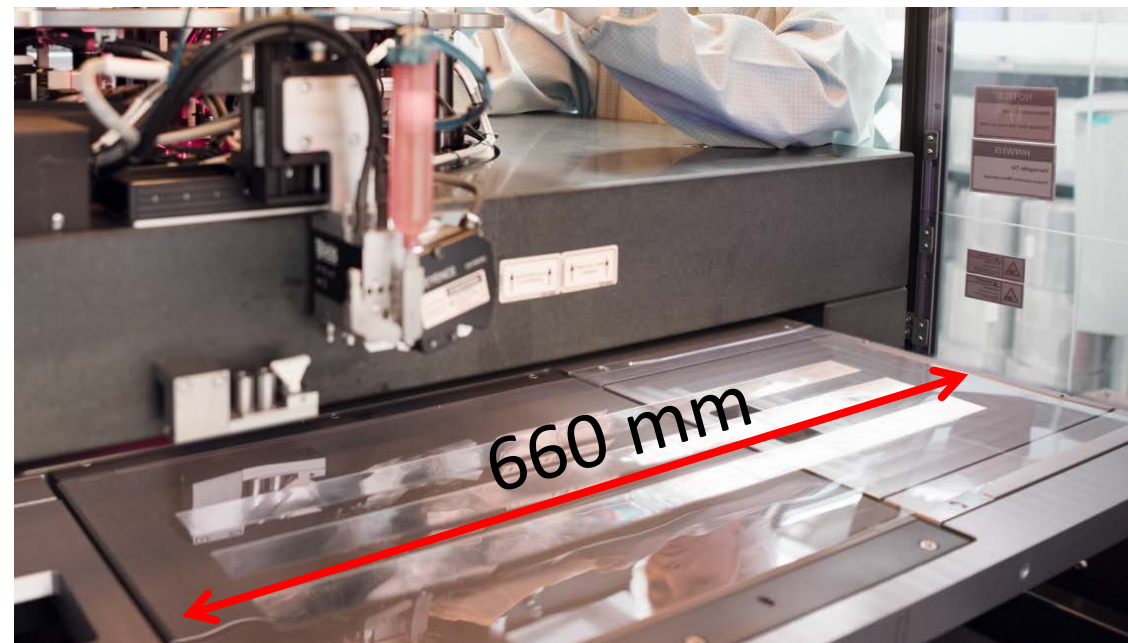


Modified EVG 770 „foil stepper“ @ JR (cleanroom)

6



- Larger stage and vacuum chuck for shim foil handling
- Larger housing
- Extended active stamp area
- Two additional top-side microscopes for live alignment
- New software packages for foil alignment



Substrate area: 270 x 660 mm
(longer is possible)

Substrate types: 8" wafer, foils

Positioning accuracy: < 1 μm

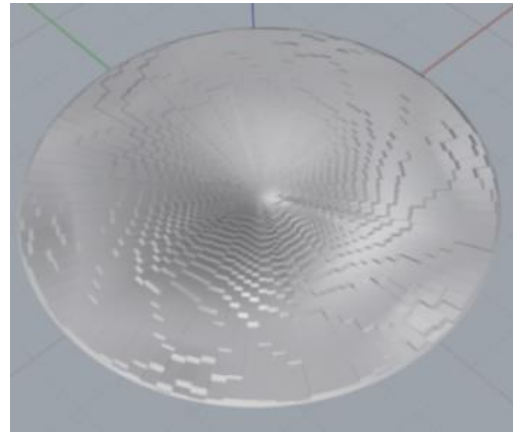
Stitching Accuracy:

No alignment: 5 μm

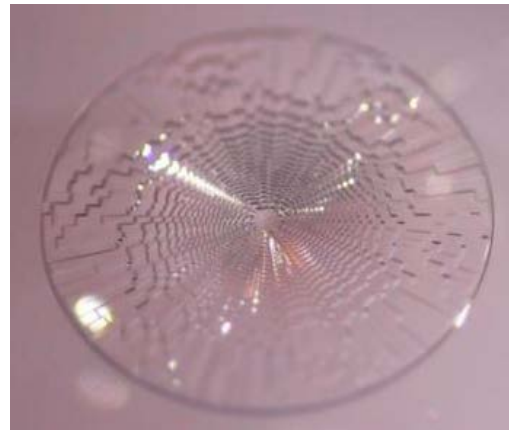
With alignment: 1-2 μm

The key: Materials and Processes

Design



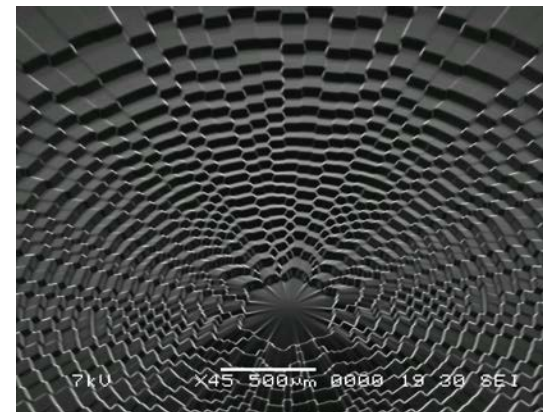
Master



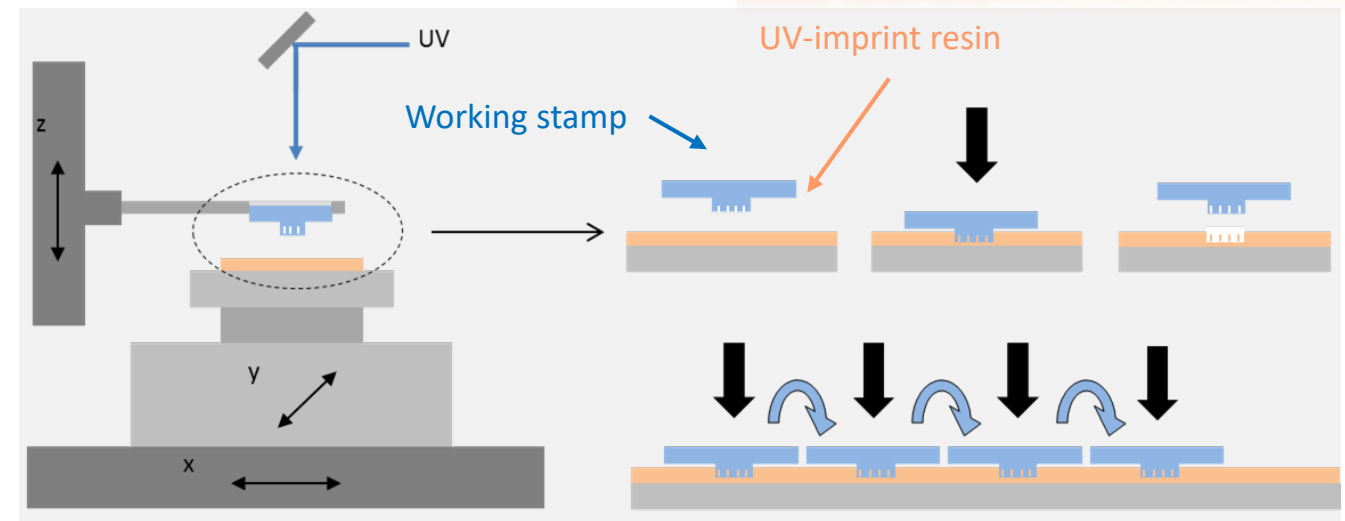
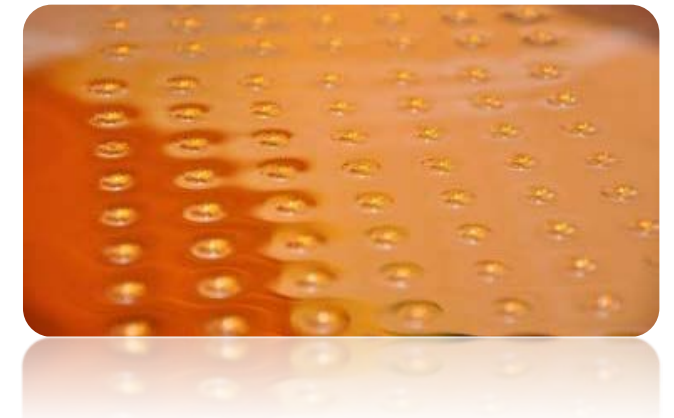
S&R Template



From small-scale masters ...



... to a medium-scale polymer shim



Imprint Resins: Basic compositions

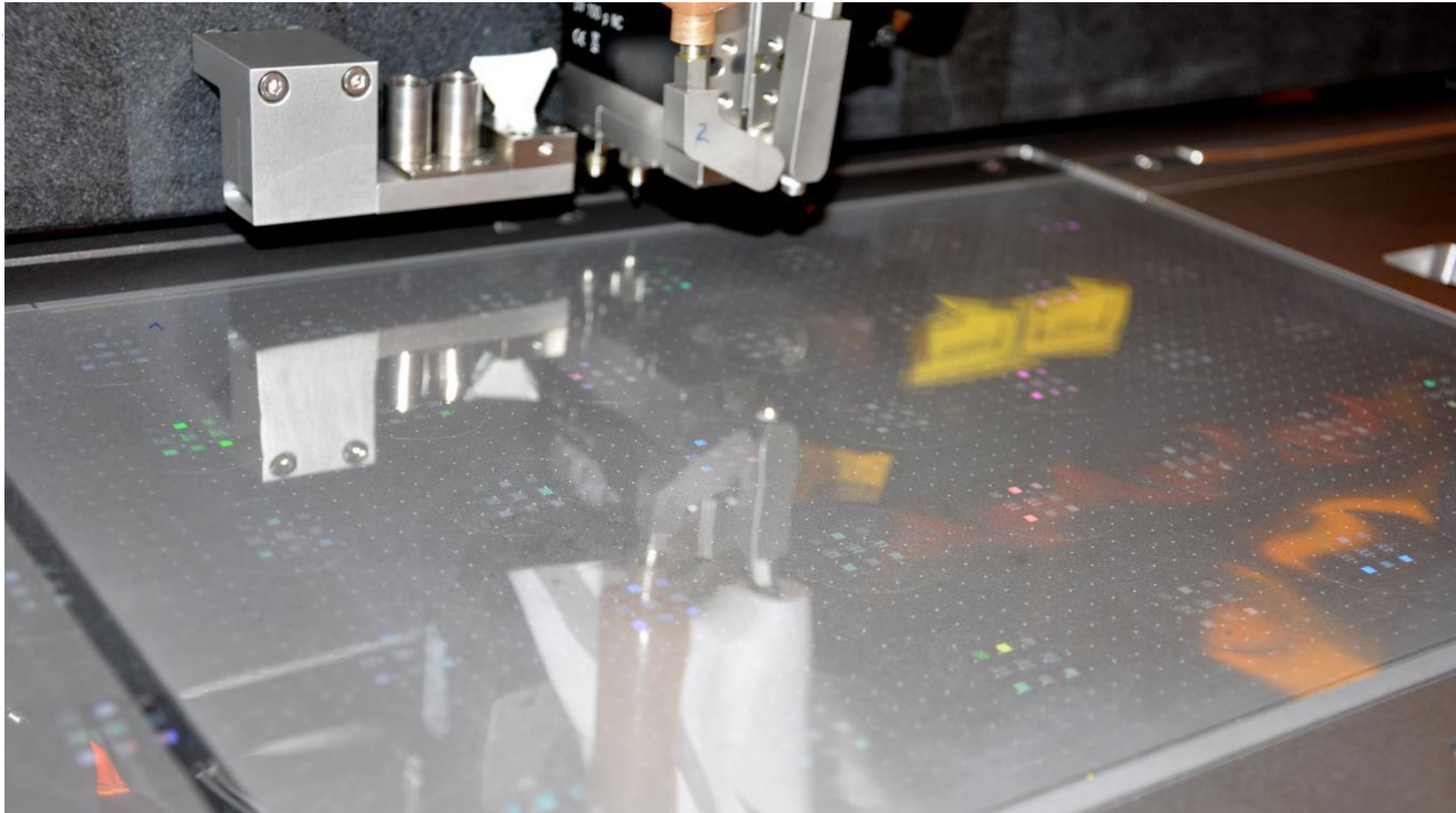
- Imprint materials optimisation:
 - Challenge to find a good combination of favourable template properties and very good imprint properties (when later used as a shim for R2R NIL)
- Multicomponent UV-curable acrylate formulations
 - **Aliphatic urethane acrylate oligomers**
as binders with functionality $F \geq 2$, very stable
 - **Acrylate monomers and Poly-Thiols**
as reactive diluents with $F \geq 1$ to tune elasticity
 - **Additives** to tune surface energy: consider haze !



Patents pending: WO2016/090395A1, WO2016090394A1

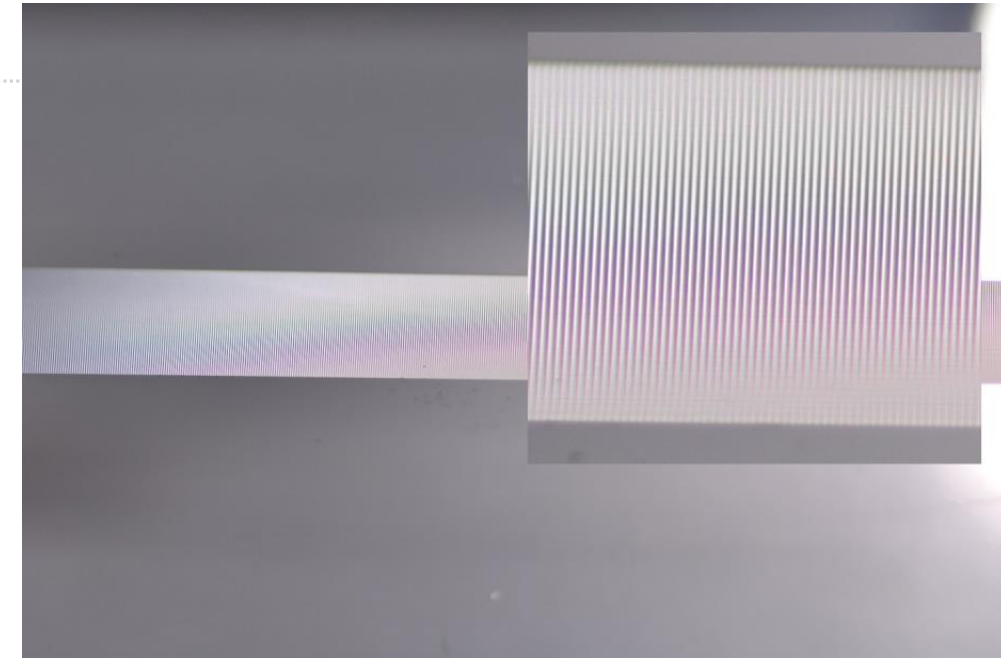
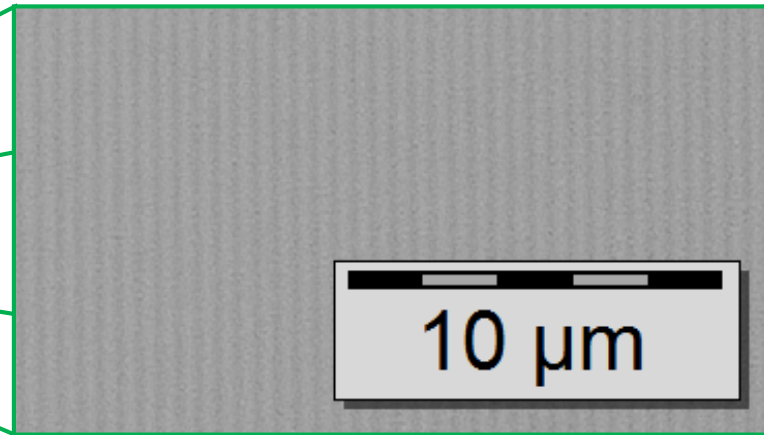
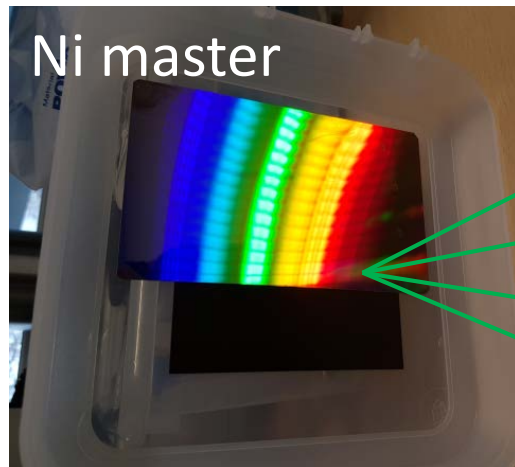
M. Leitgeb, D. Nees, B. Stadlober et al. ACS Nano 2016

Example: optical gratings produced by S&R UV-NIL



Mastering of 500 nm optical line grid

10



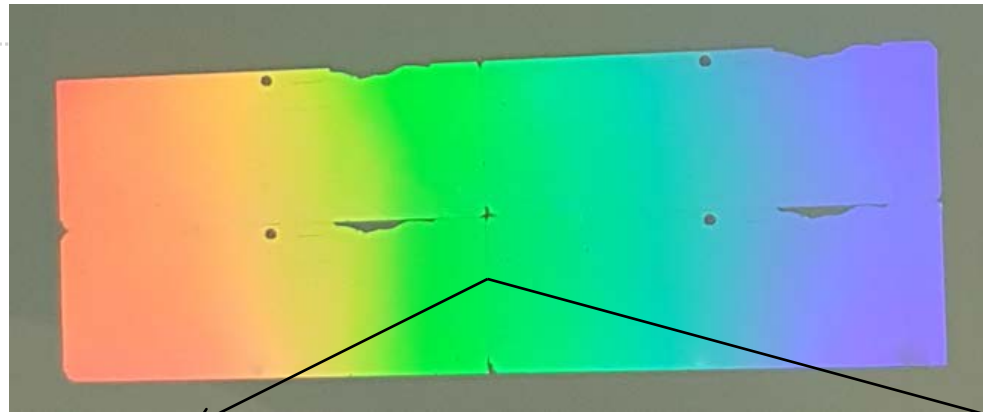
S+R working stamp



Result: S&R Stitching of 500 nm optical line grid

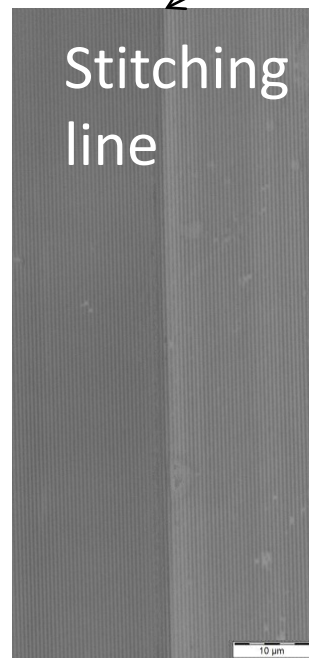
11

4 stitched imprints

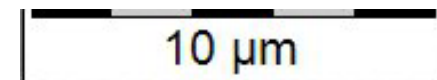


Stitch lines can hardly be seen by naked eye

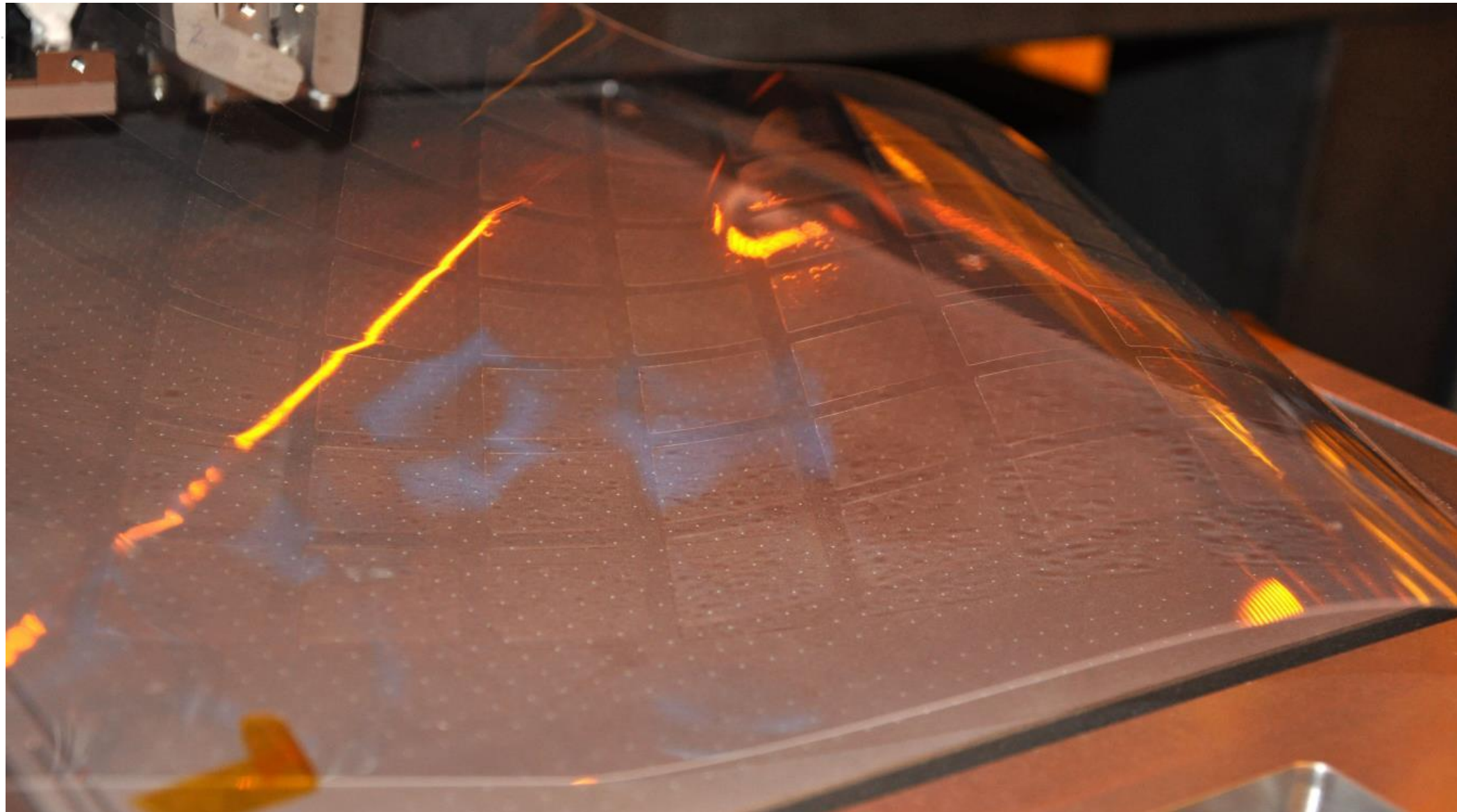
Stitching line



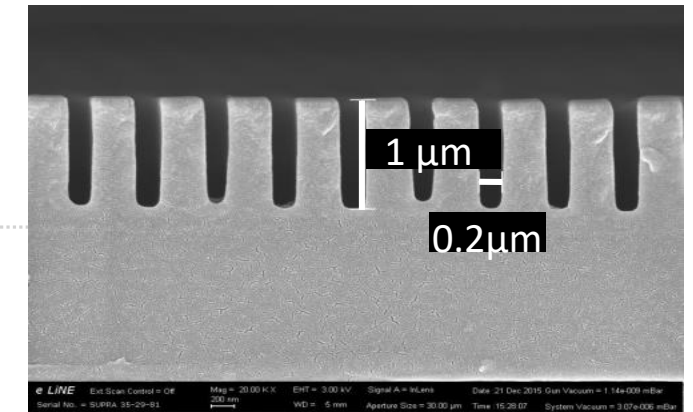
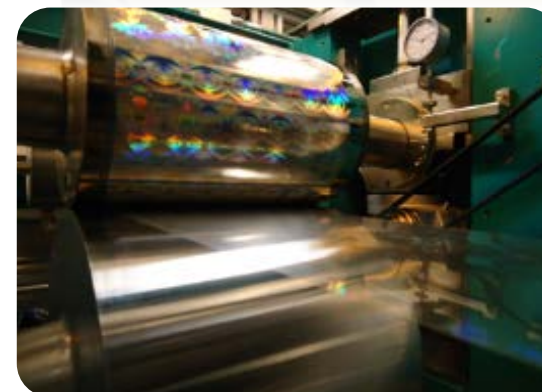
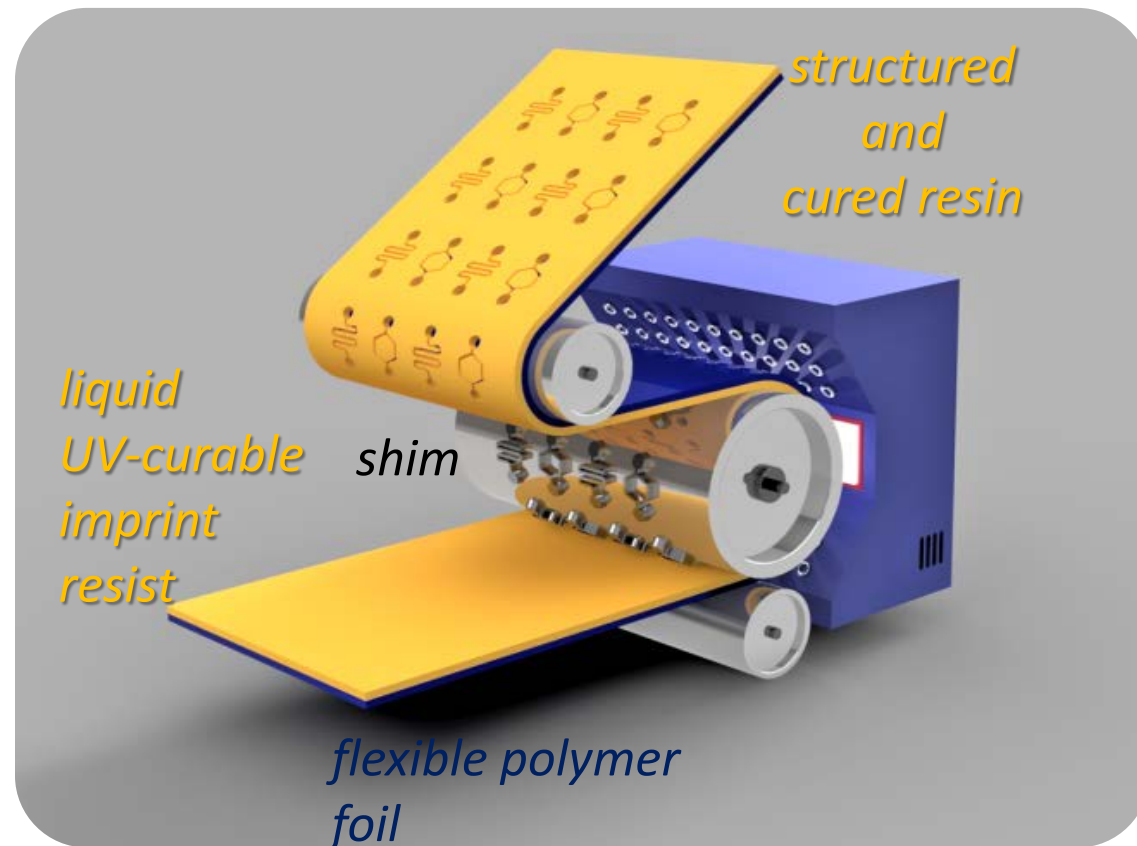
Stitching
line



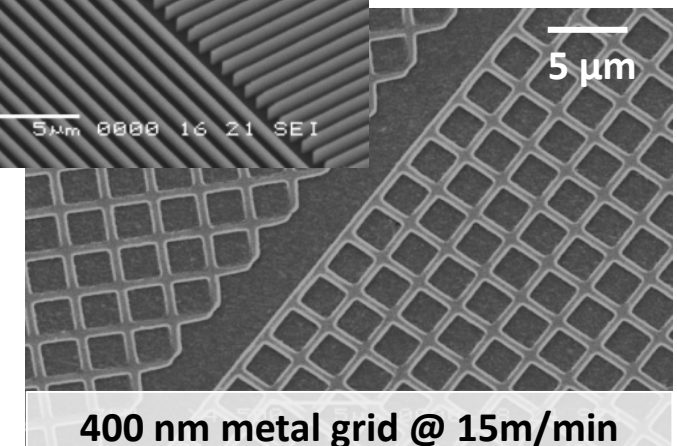
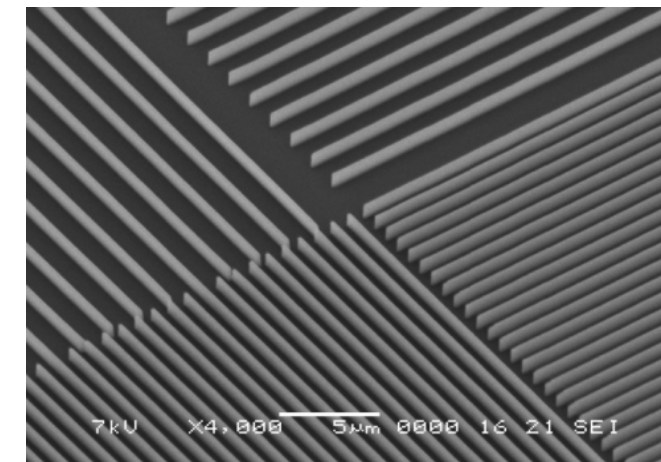
Example: Flexible polymer shims for R2R and R2P processes



R2R-UV-Nanoimprinting with polymer shims

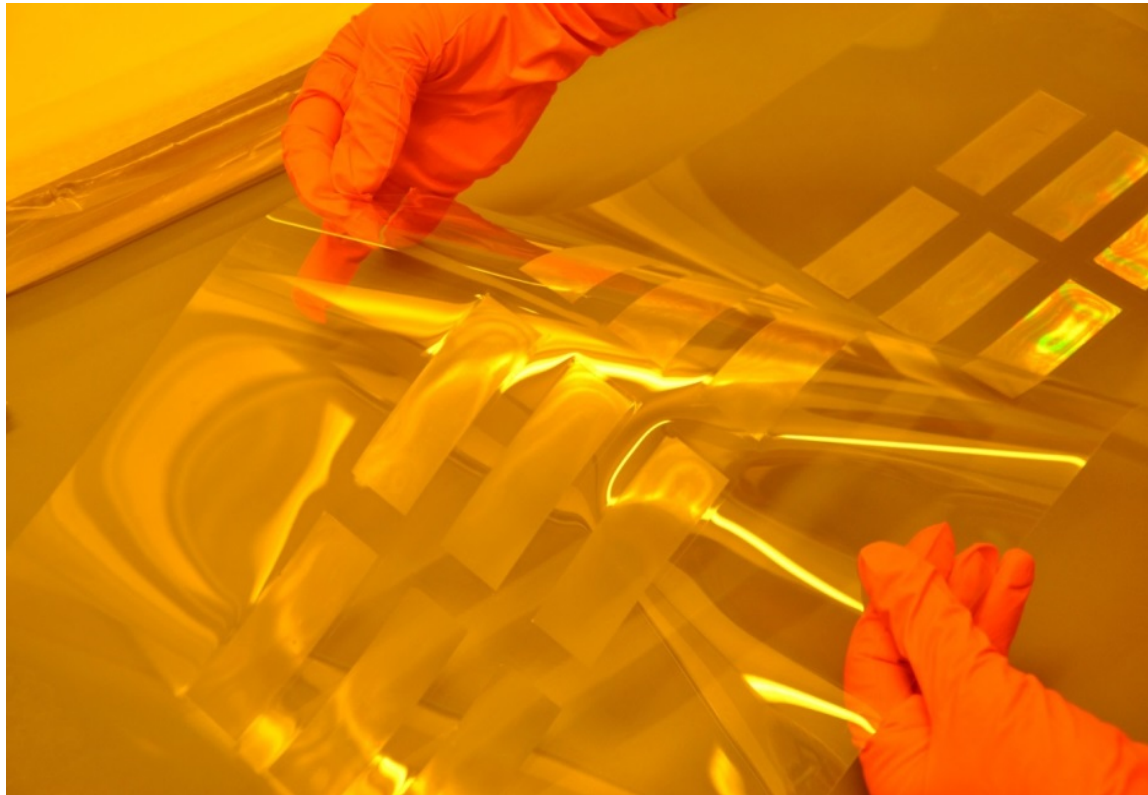


High Aspect Ratio 5:1 @ CD=200nm



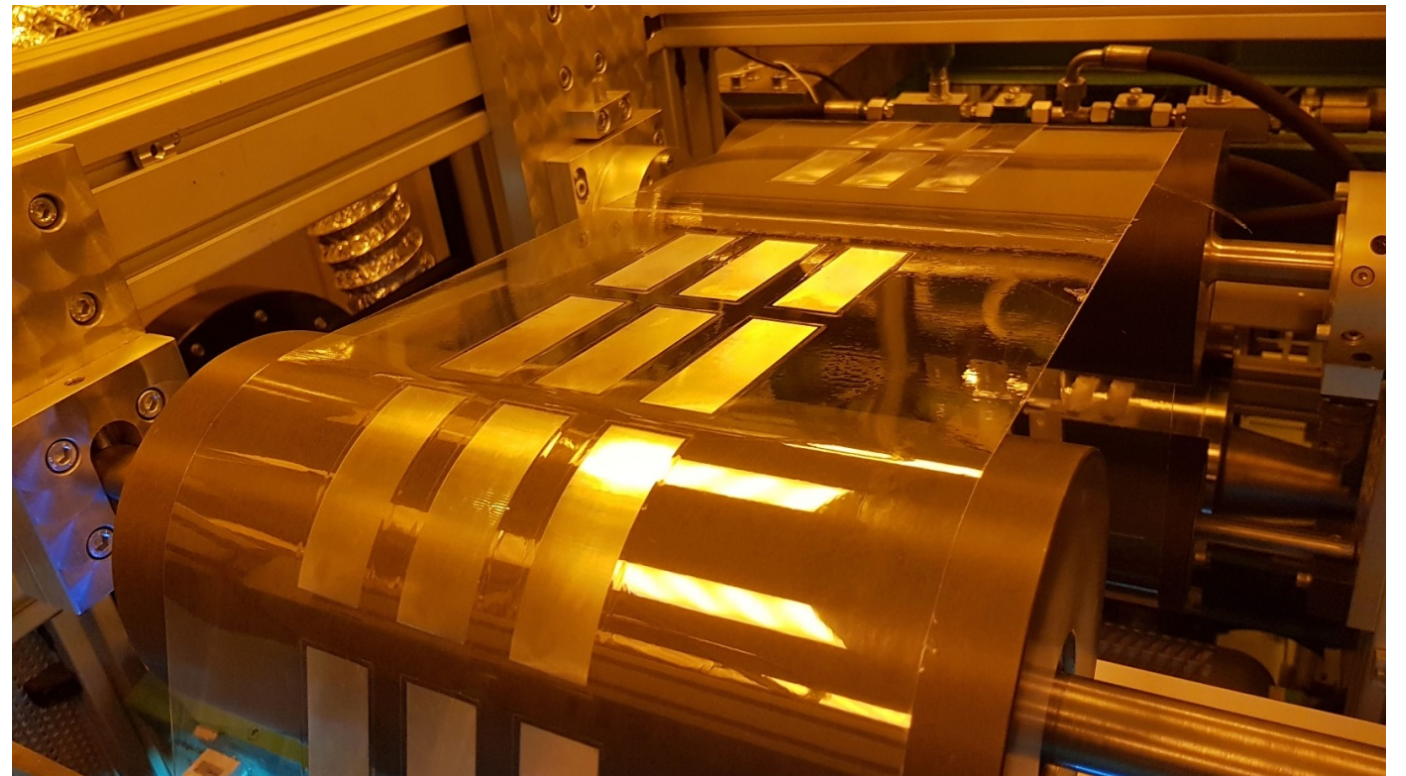
400 nm metal grid @ 15m/min

Example: Optical focusing pattern (2.5D) for biosensing Lab-on-a-chip



Polymer shim made by S&R UV-NIL

R2R replication in index-matched resin on PS foil



PHABUL μ OS: European pilot line (H2020 ICT-03-2018-2019)

Who

- Front-running **Research & Technology Organizations (RTOs)** and **Companies** along the manufacturing value chain

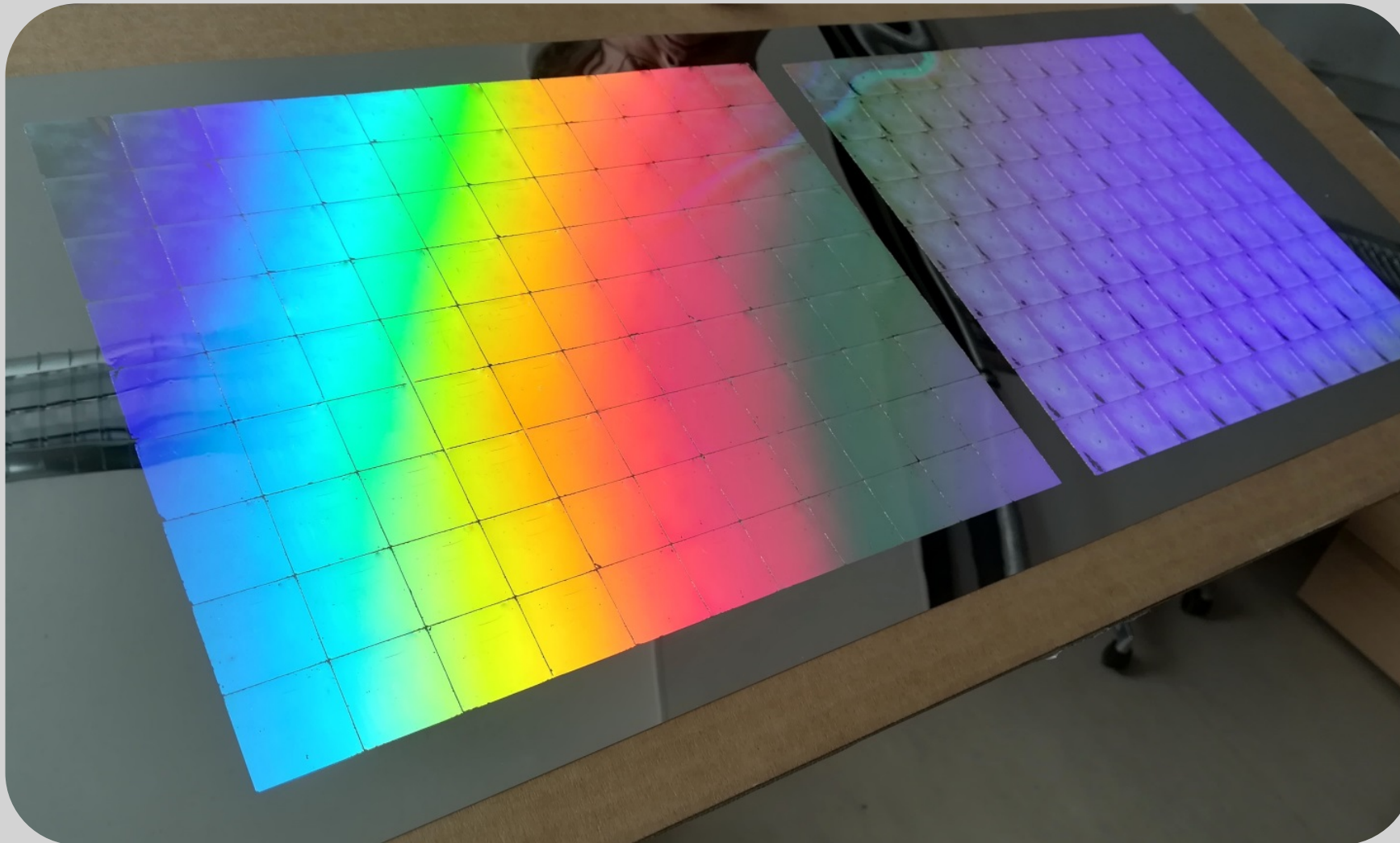
What

- Setting up a **European pilot line for the manufacturing of freeform micro-optical components** addressing the needs of the optoelectronic and photonic industry with a clear roadmap for future high volume production in Europe at competitive cost

How

- Unique access to **3 UV replication technologies** (wafer scale, R2P, R2R) fully adaptable to the application needs
- **Accelerated innovation cycles** from free-form optics prototypes to large volume production
- Boost in **new product developments** in strategic application areas
- A manufacturing **one-stop shop** for SMEs
- An **European ecosystem** in replication of free form micro-optical components





Special thanks to

- Ursula Palfinger
- Ladislav Kuna
- Dieter Nees
- Claude Leiner
- Barbara Stadlober



*Thank you very much for your
attention!*

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This presentation was presented at EPIC Meeting on Wafer Level Optics 2019

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