



MORPHOTONICS
Nanoimprint technologies



Applying a Display Manufacturing Mindset to High-volume AR Waveguide Production

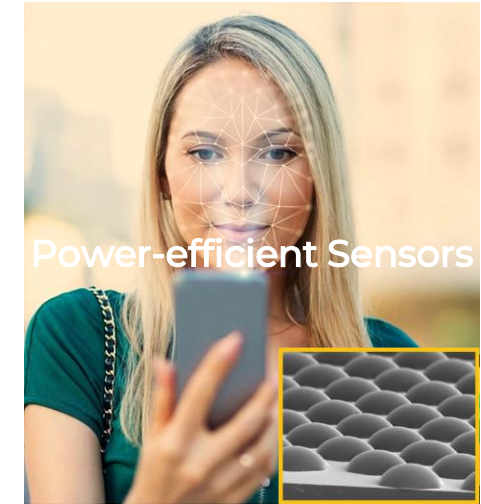
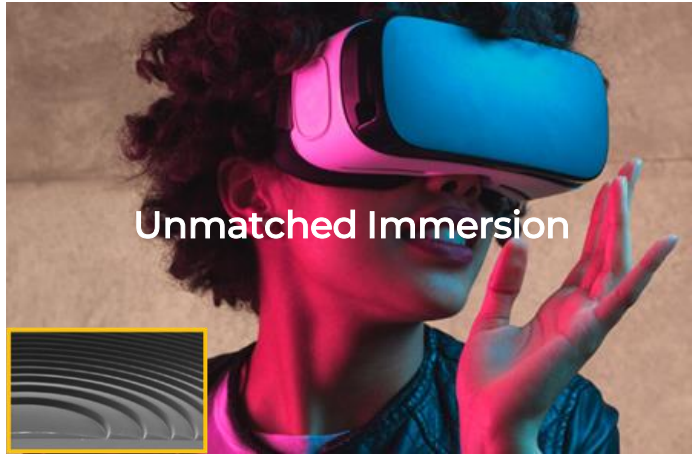
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Unprecedented visual experiences for the masses!



Design freedom to use **any micron/nano structures** for **high-volume products**
Key enabler is our large-area nanoimprinting technology!



Nanoimprint Technology Solutions

Business Scope

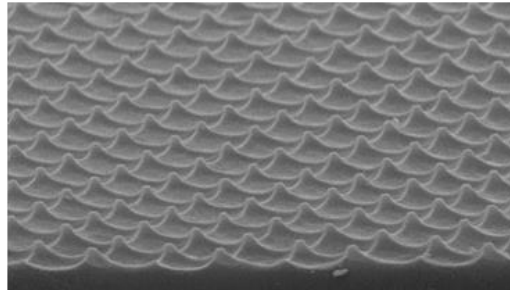
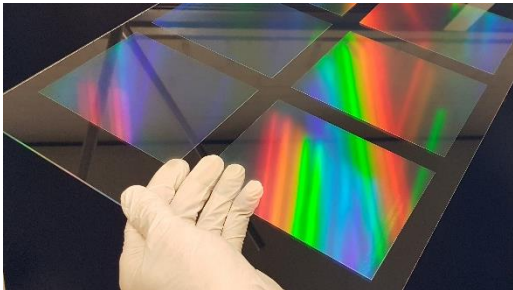
- **Problem:** Address the increasing demand (16% CAGR through 2027) of nanoscale surface customization for new visual experiences
- **Solution:** Deliver the ONLY imprinting solution for micro-nano structures, that allows design freedom for displays + high volume manufacturing

Background

- Founded in 2014. 40 Employees. 1000 m² cleanroom.
- IP: > 25 patents worldwide (5 patent families), 13 pending
- >20 tools sold worldwide, Roll-to-Plate (R2P) technology proven in production

Products & Platform Technology

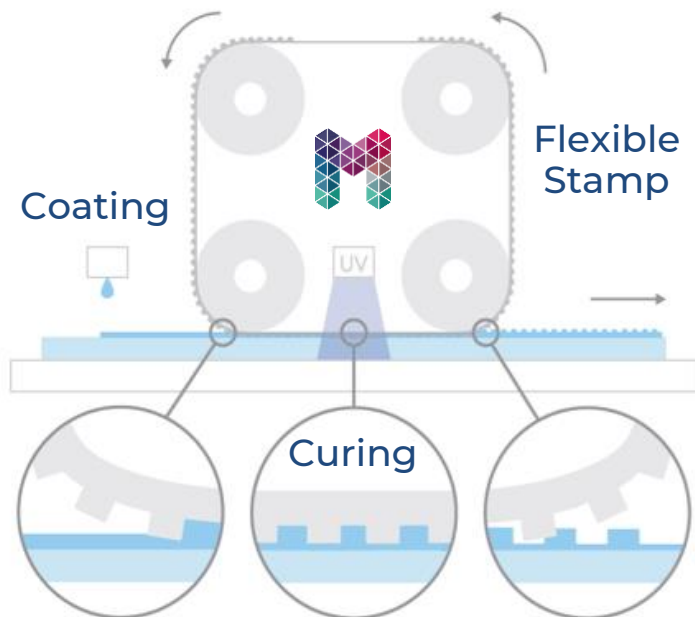
- Modular OEM platform approach from R&D to mass production;
- From sampling & master upscaling to turn-key production line
- Proprietary consumables: UV curable resins & flexible stamps





Large Area Nanoimprinting | Any Optics for Any Display

Roll-to-Plate (R2P) Nanoimprinting Technology



Any Optics:

Precise structures w/ feature sizes from 500 μm to 50 nm
Design freedom – Slanted, steep or high aspect ratio proven

Any Display:

Large-area replication up to 1.1 x 1.5 m², enabling high throughput for any display size

Position accuracy:

High replication fidelity w/ dimension stability in picometer range

High throughput:

Imprint cycle times < 2 minutes in mass production

Glass & Foil:

Rigid & flexible substrates, 100+ resin choices

Cost effective:

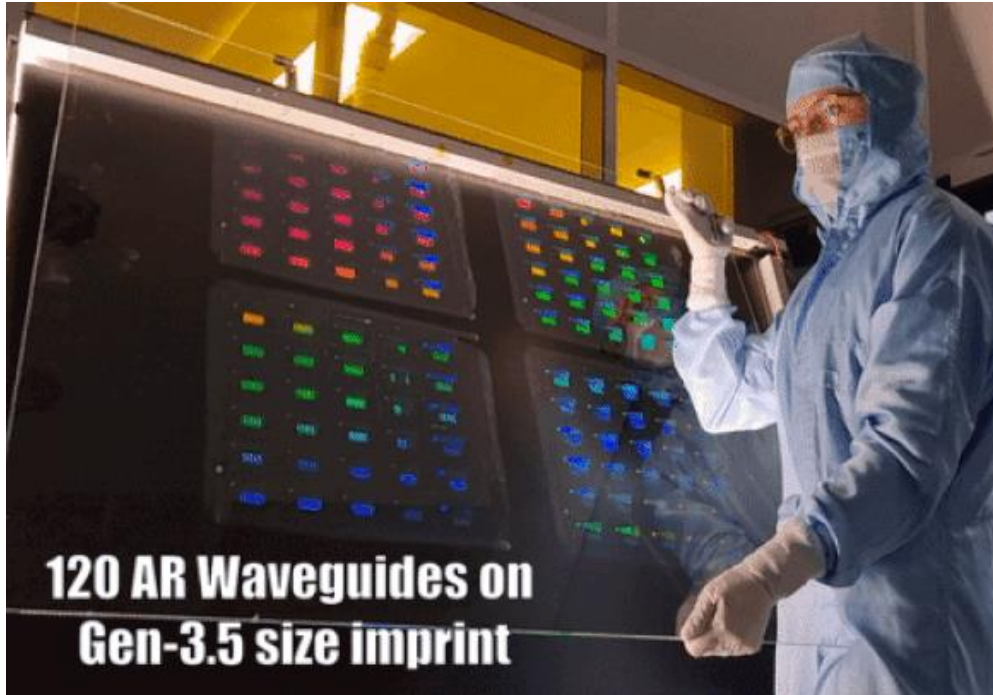
Stamp lifetime >1000x possible in mass production (texture dependent)
Minimal resin waste through active area control
Imprint cost < 0.5 USD/ smartphone product





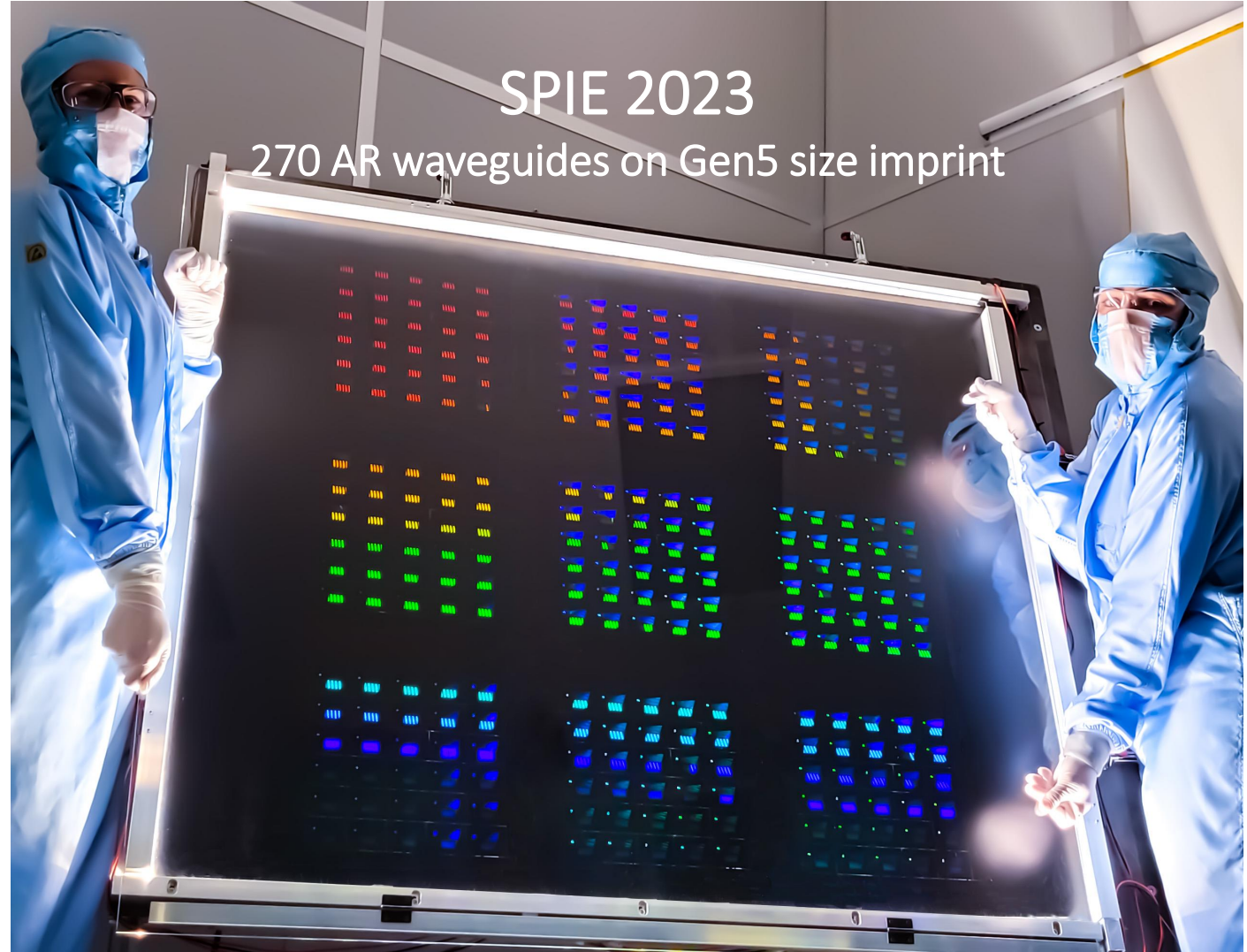
Pushing the boundaries of high-volume waveguide manufacturing

SPIE 2022



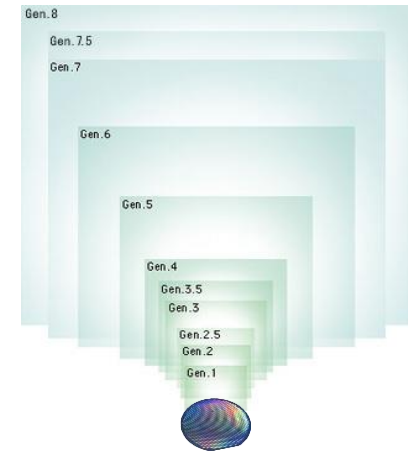
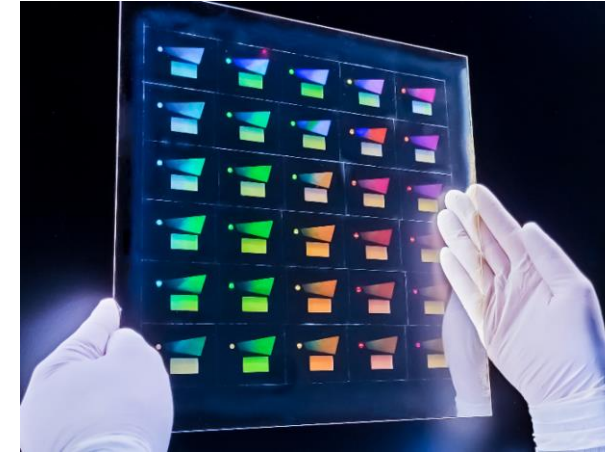
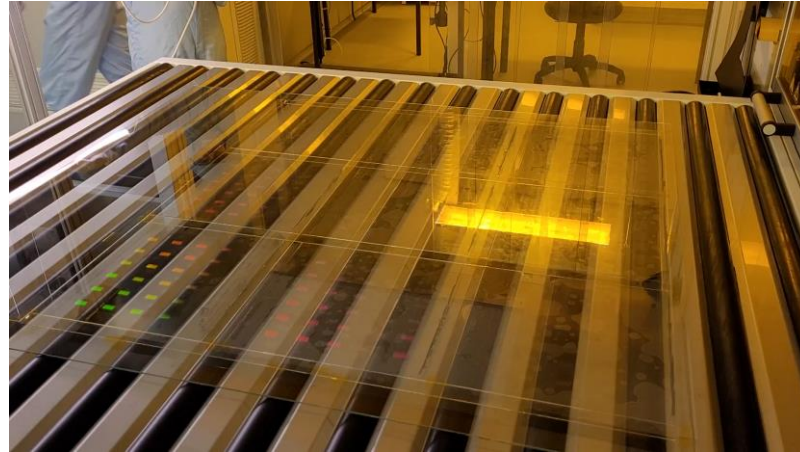
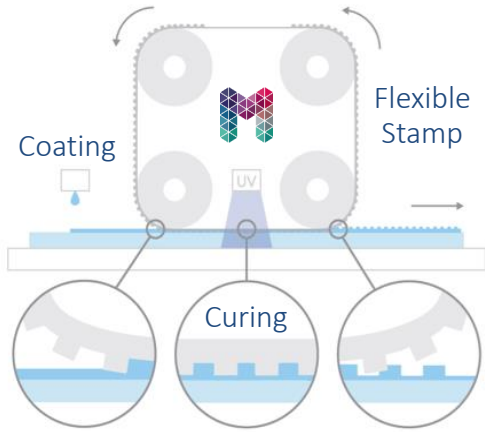
SPIE 2023

270 AR waveguides on Gen5 size imprint





Large-area nanoimprinting is key for high-volume waveguide production



- ✓ Roll-to-Plate nanoimprint technology using a uniform line pressure is scalable to larger areas
- ✓ Our solution follows display industry manufacturing logic
- ✓ Large substrates or multiple wafers are imprinted in one pass
- ✓ Use of dedicated proprietary flex stamp materials, in-house master-upscaling & process know-how



But... Quality before Quantity

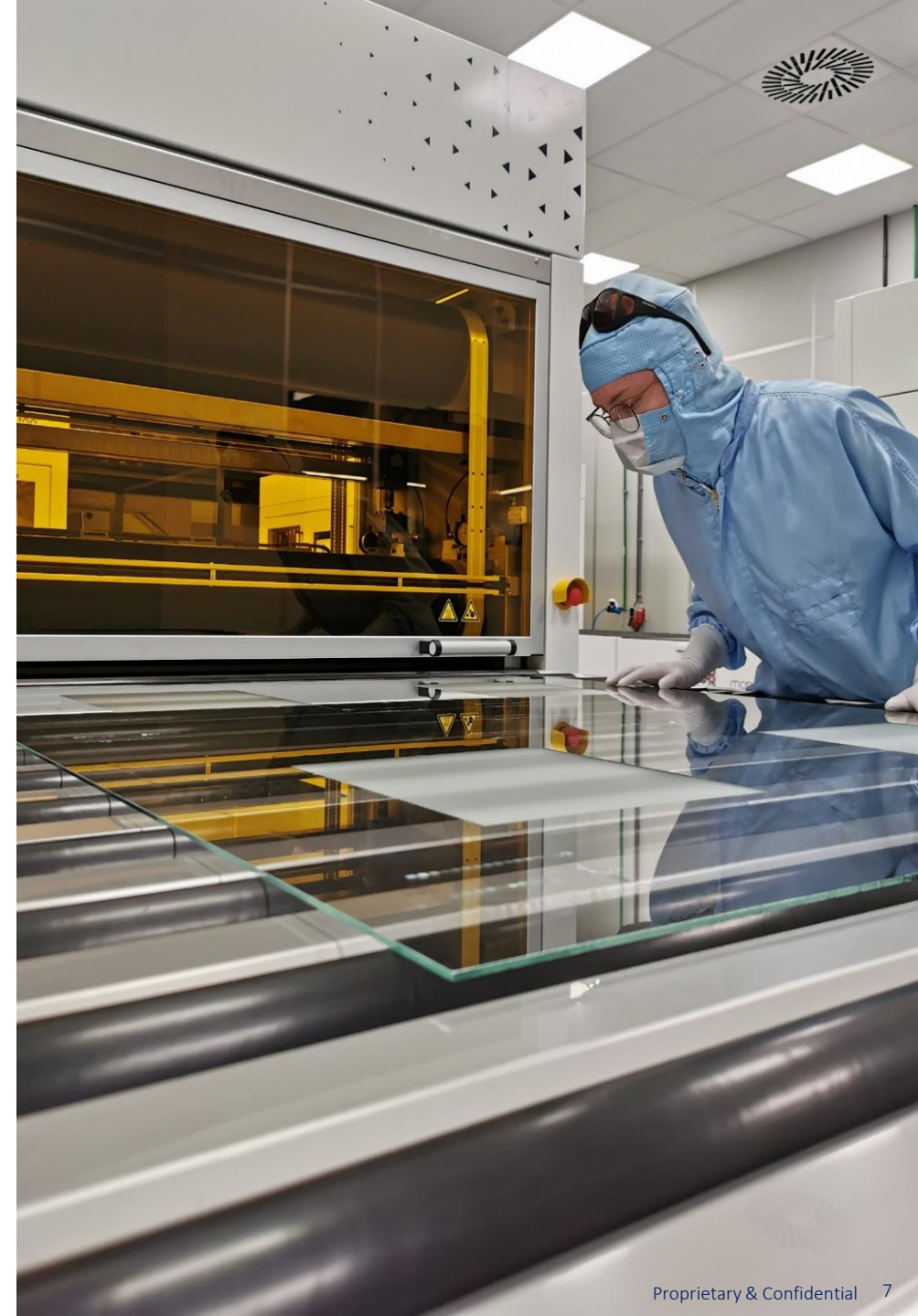
For AR to work, it is all about quality:

- Highest FOV
- Highest contrast
- Longest battery lifetime
- Lightweight attractive device

Preferably at affordable costs

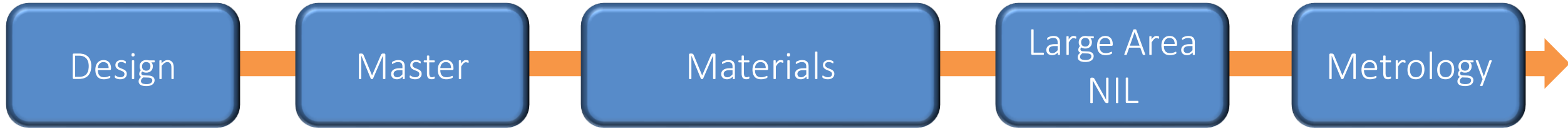
Large-area nanoimprint technology must provide:

- ✓ High replication quality across all manufacturing steps
Imprinted waveguide is true to the design & master
- ✓ Reproducible in high volume
- ✓ Uniform across large area

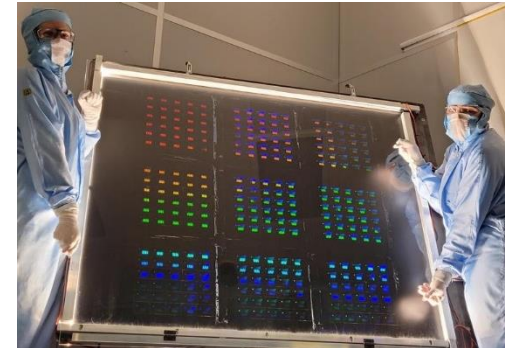
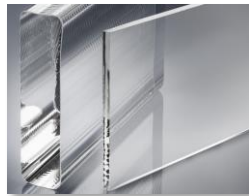
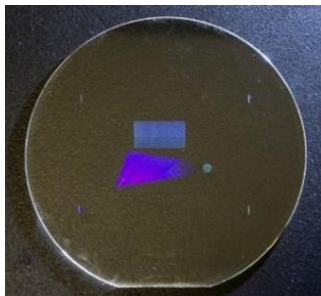
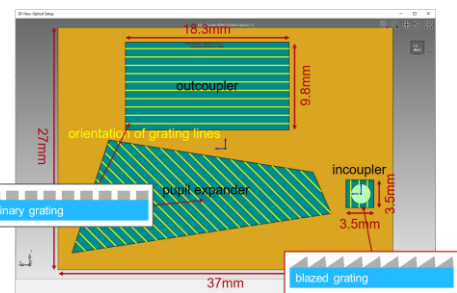




Demonstrating quality in all steps



Closed loop between design-mastering-imprinting-materials-testing is essential for successful product

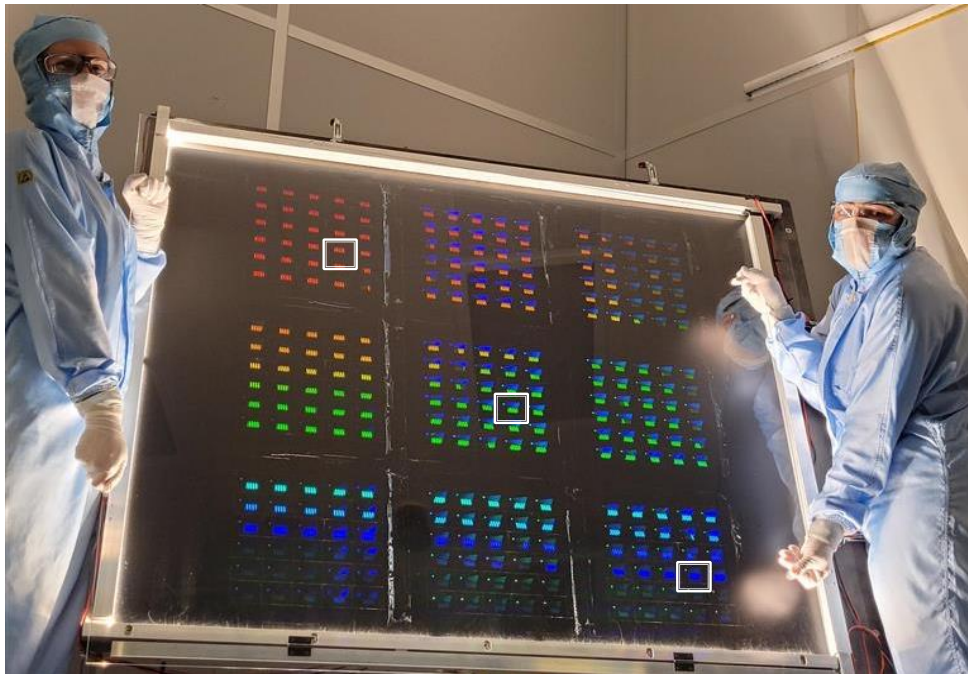




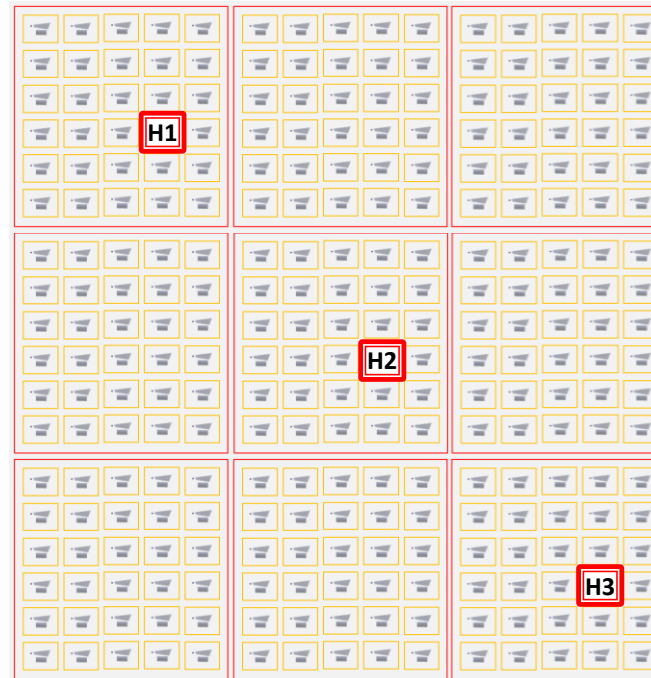
Replication quality

Replication quality tested for contrast, MTF, and pitch variation

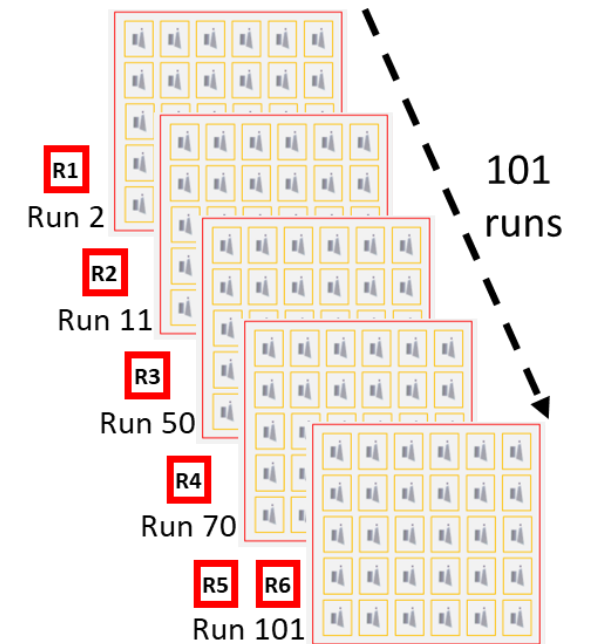
Each measured across the large imprint area & reproducibility tested for over 100 production runs



270 waveguides replicated GEN5 size



Homogeneity (named H1, H2 & H3)



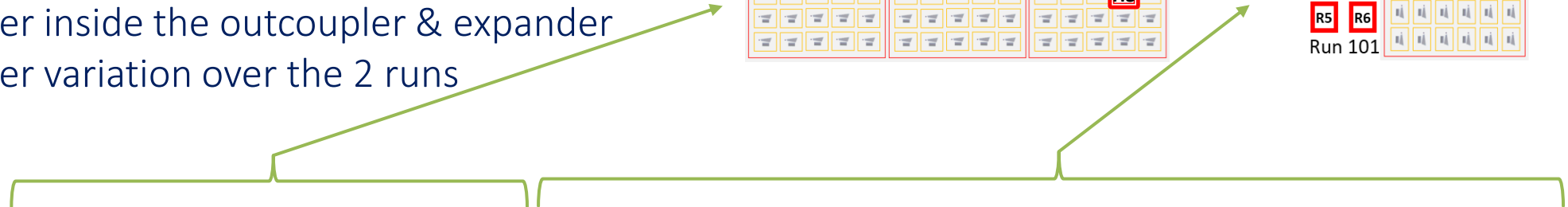
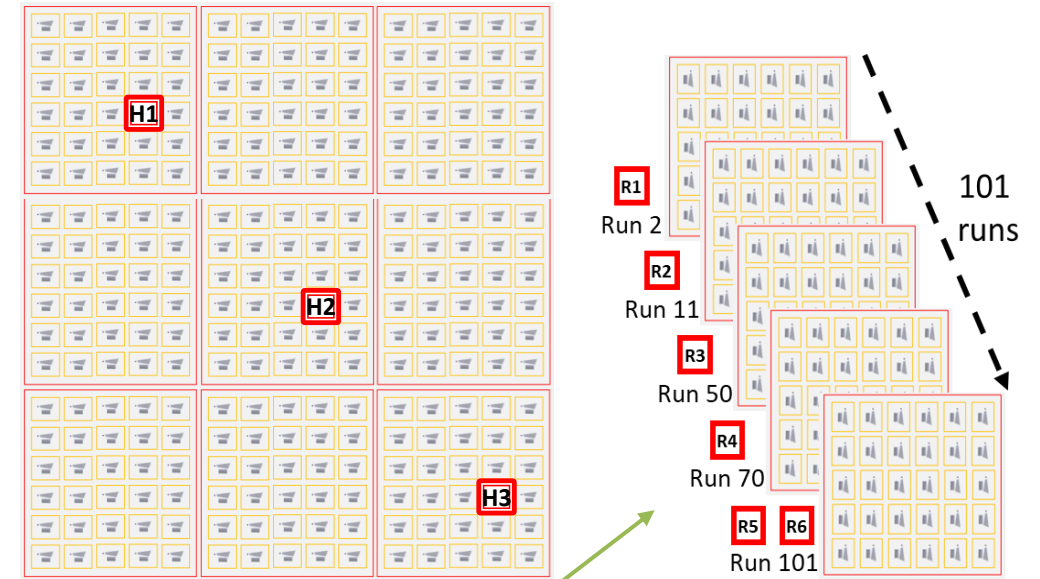
Reproducibility (named R1-R6)



Pitch uniformity

- Thermal, humidity & stretch changes well controlled, using High Dimension Stability flexible stamp (expansion of 5 $\mu\text{m}/\text{meter}$ per $^{\circ}\text{C}$)
- Measurement by Optofidelity using Littrow-diffractometer
- Waveguide track-pitch variation in 100 consecutive imprints:
 - <10 picometer inside the outcoupler & expander
 - <20 picometer variation over the 2 runs

Homogeneity (H1, H2 and H3) & Reproducibility (R1-R6) test waveguides



	Design	Master	H1	H2	H3	R1	R2	R3	R4	R5	R6
Incoupler	415 nm	414.971 nm	414.979 nm	414.972 nm	414.962 nm	414.972 nm	414.982 nm	414.954 nm	414.955 nm	414.962 nm	414.911 nm
Expander	293.45 nm	293.434 nm \pm 2pm (std.dev)	293.465 nm \pm 9pm (std.dev)	293.455 nm \pm 9pm (std.dev)	293.442 nm \pm 7pm (std.dev)	293.444 nm \pm 7pm (std.dev)	293.444 nm \pm 6pm (std.dev)	293.444 nm \pm 6pm (std.dev)	293.444 nm \pm 6pm (std.dev)	293.448 nm \pm 6pm (std.dev)	293.460 nm \pm 9pm (std.dev)
Outcoupler	415 nm	415.005 nm \pm 7pm (std.dev)	414.998 nm \pm 17pm (std.dev)	414.996 nm \pm 15pm (std.dev)	415.016 nm \pm 20pm (std.dev)	414.990 nm \pm 16pm (std.dev)	414.984 nm \pm 26pm (std.dev)	414.986 nm \pm 19pm (std.dev)	414.989 nm \pm 20pm (std.dev)	414.991 nm \pm 18pm (std.dev)	414.999 nm \pm 24pm (std.dev)



Residual layer thickness

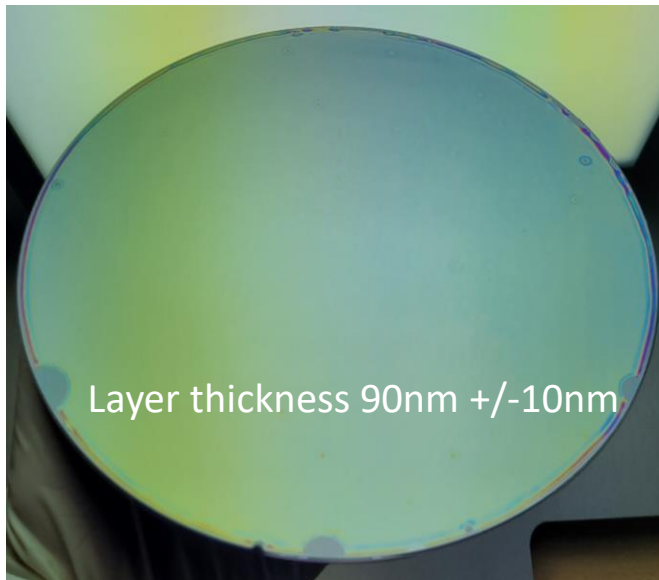
Waveguide demo

Waveguides have been designed with $4.6\ \mu\text{m}$ layer thickness. Variation in layer thickness on wafer with 30 waveguides is 5%, using the solvent free PixNIL SFT1 resin with viscosity of $570\ \text{mPas}\cdot\text{s}$.

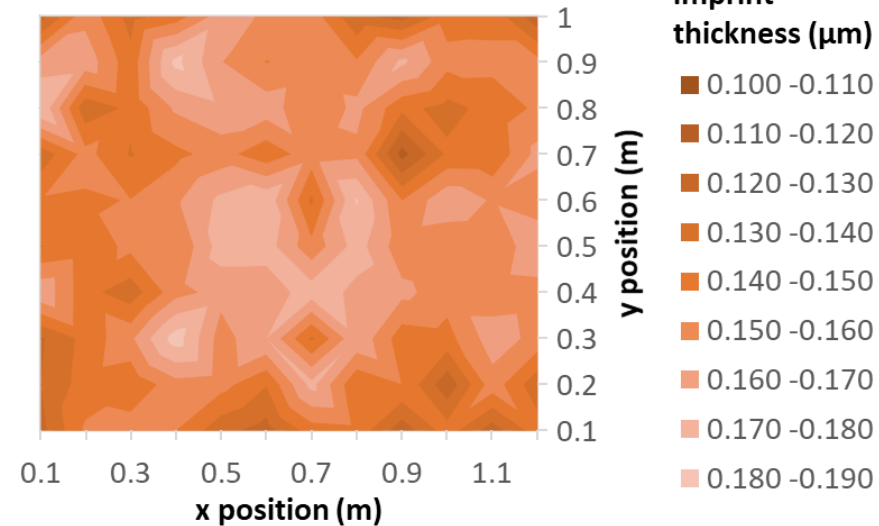
Layer thickness variations can be reduced by process modification

- Variation of $\pm 10\text{nm}$ have been achieved on 200mm wafer
- Variation of $\pm 35\text{nm}$ has been demonstrated for GEN5 surface

Both using low viscous solvent free resins



Residual layer thickness R2P imprint on 1.1x1.3 m



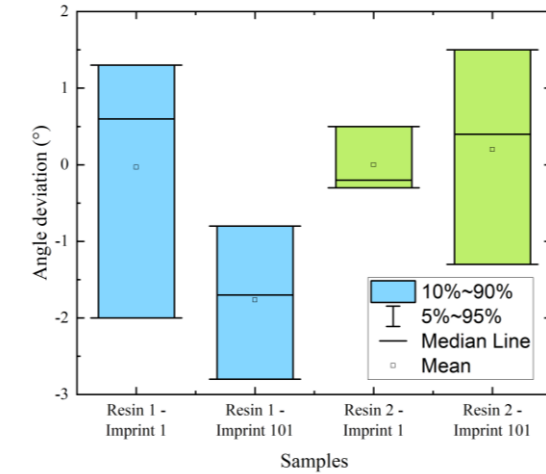
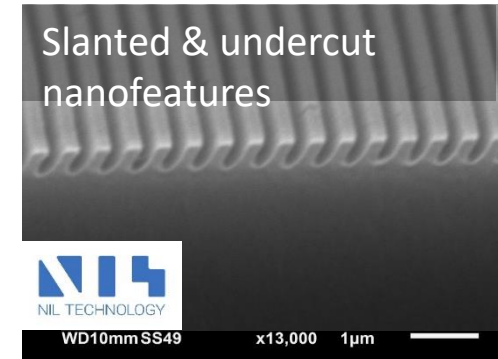


Complete design freedom for further process optimization

Material set can be tuned to replicate different textures from slanted nano-gratings to micron high Fresnel lenses

Slanted gratings for AR waveguides

- Replication of slanted gratings up to 50-deg demonstrated
- Stable replication quality re-using the flex stamp
 - No significant angle deviation after 101 imprints
- Replication of designs with different slanted gratings possible



Fresnel lenses for VR

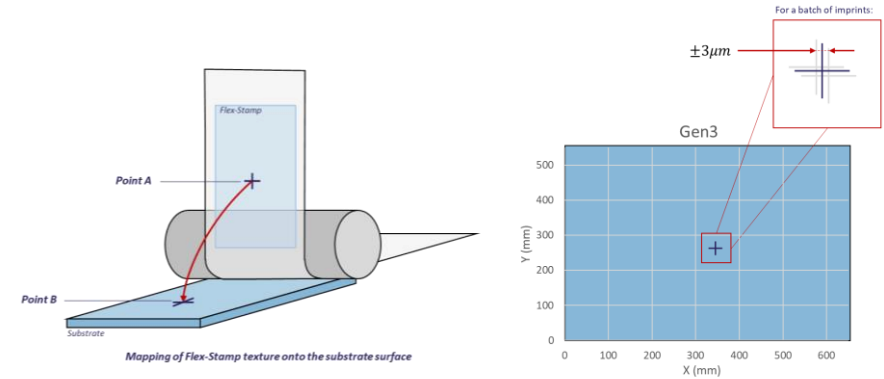
- Replication of micron steep slopes with varying slope orientation
- Well controlled resin shrinkage <6%



Based on work done together with Seisenbacher & Joanneum Research in EU Phabulous project

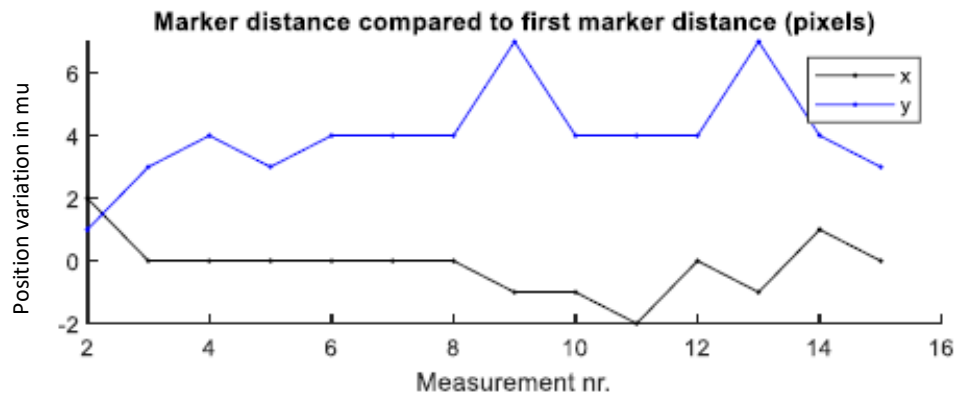


Aligned imprinting



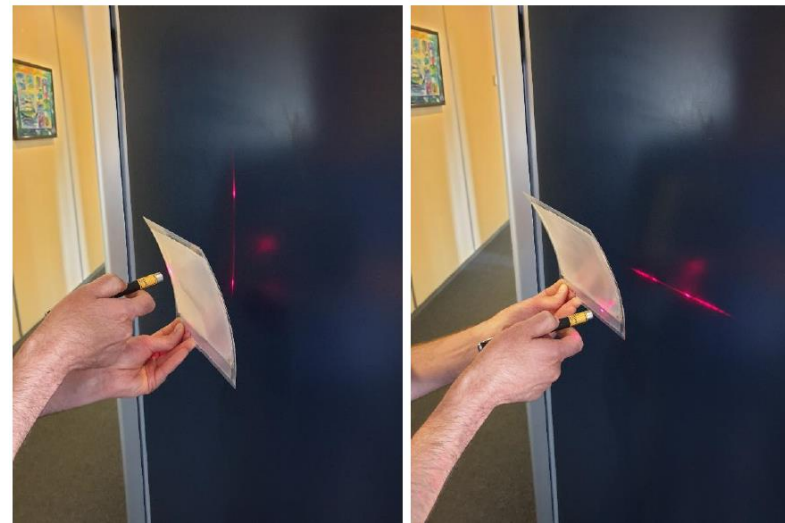
Morphotonics develops dedicated Portis X-NIL for aligned imprinting:

- Aligned imprinting at $\pm 3\mu\text{m}$ accuracy over full 600 x 600mm surface (incl. tilt)
- Enabling imprinting of dual sided AR waveguides



Position variation in run of 15 imprints (1pixel is 1 mu)

Effect of one direction prism imprint on laser light.



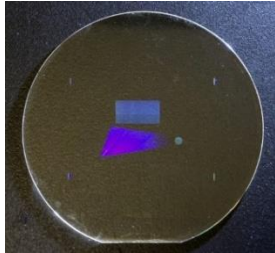
Resulting effect of the multi-layer imprint on laser light.



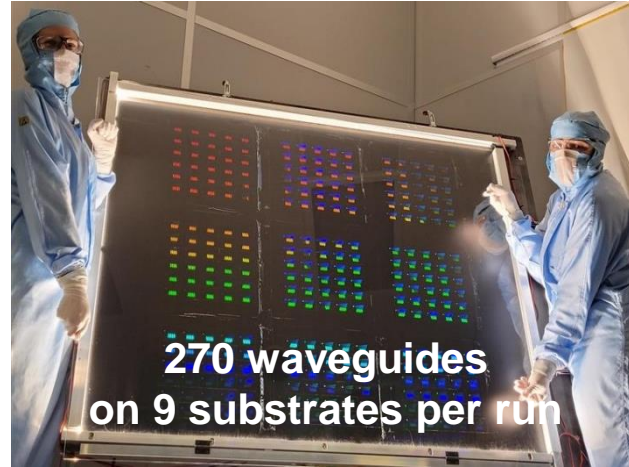


Large-area nanoimprinting is a viable AR waveguide manufacturing solution

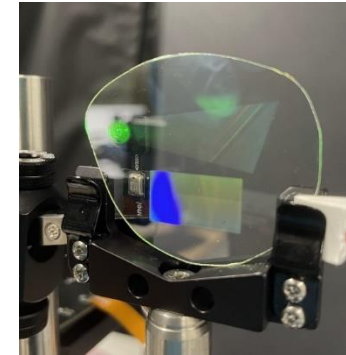
Single eyepiece
Master



R2P Imprint



Singulation to
single eyepiece



Visit us at Booth #201

- Any Optics:** Replication of different complex textures (slanted gratings, binary & blazed gratings, fresnel lenses)
- Any Display:** From AR glasses, automotive HUDs to smartwatches, tablets & TV size displays
- Any Size:** Production at GEN5 size (1.1x1.3m), imprinting on single or multiple substrates

Our large-area nanoimprint technology is already adopted by various display manufacturers for 3D, Anti Glare, and Augmented Reality applications



MORPHOTONICS

Nanoimprint technologies

Visit us:



May 23-25

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Special thanks to all our Morphotonics colleagues for their dedication & hard work and to our valuable partners LightTrans, NILT, Schott, Optofidelity, and Pixelligent