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OPTIMAL "all-in-one" laser lithography technology and applications

PRESENTED BY ELENA TURCO, JOANNEUM RESEARCH

DATE: 17TH NOVEMBER 2026 – BRUSSELS

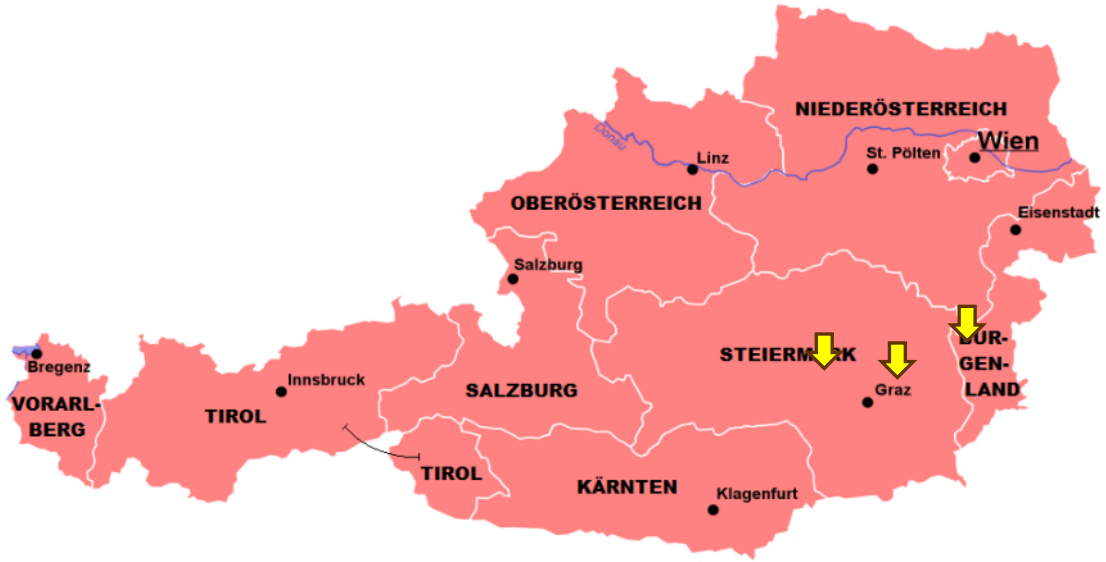
Joanneum Research - MATERIALS

Institute for Sensors, Photonics and Manufacturing Technologies

3 Laboratories in Austria

- Weiz
- Niklasdorf
- Pinkafeld

~ 80 Employees



Hybrid Electronics and Patterning

Laser and Plasma Processing

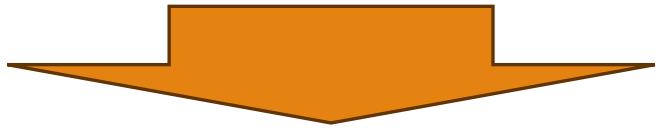
Smart Connected Lighting

Light and Optical Technologies

Sensors and Functional Printing

OPTIMAL – challenges and motivation

- Limited depth of structures.
- Limited area over which structures can be produced with current systems.
- Low processing speeds and process efficiency (materials waste, energy consumption).
- High power consumption for laser interference lithography with gas lasers.
- Multiple steps and expensive processes requiring samples shipment for the development of high complexity hierarchical multifunctional structures.



Increased thickness of photoresists & “all-in-one” laser lithography platform with 2000 cm^2 area and implementation of AI aided virtual photomasks

OPTIMAL project - overview

Start date: 01/10/2022
End date: 31/03/2027

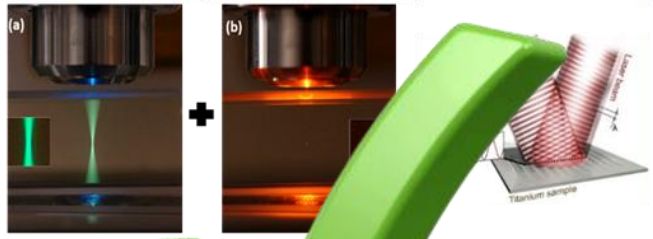
Project team:

JOANNEUM RESEARCH MATERIALS
JOANNEUM RESEARCH LIFE
UNIVERSITÀ DI PARMA
SLOVAK CENTRE OF SCIENTIFIC AND TECHNICAL INFORMATION
UNIVERSITY OF ŽILINA
micro resist technology
DeltaPix - Discover the Details
Sony DADC
hypervision
BASF We create chemistry

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Laser lithography modules & processes

1Photon (1PL) Parallel patterning | 2Photon (2PL) Serial patterning | Laser interference lithography (LIL)



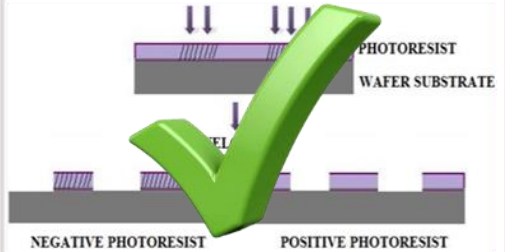
structures

All-in-one pl *a 2000 cm², Depth ≥ 150 µm, cm²/min, Critical dimension < 150 nm, Dimension 2.5D and 3D, hierarchical structures,* ***no post-processing****,* ***1st time right****, faster process.*

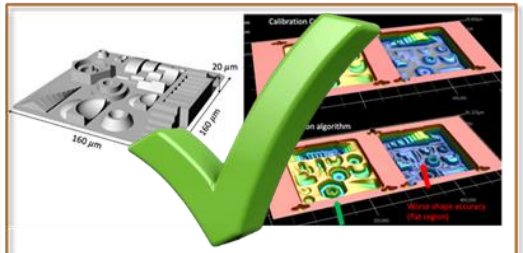
Quality monitoring



Photoresist materials



Virtual photomask



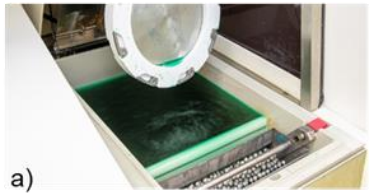
Sustainability assessment

- Required process itera om 5 to 2
- Higher writing speed
- Bigger substrate / a area
- Tailored re ns

Waste & rgy reduction

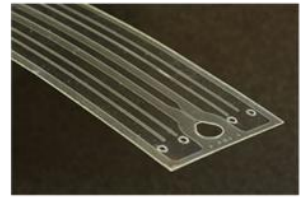
Applications

a) full-polymer micro lenses for industrial optics, b) hierarchical multifunctional drag reduction riblet structures for aviation, c) free-form lens arrays for high-end virtual reality displays and d) microfluidic hierarchical structures for lab on chip medical devices.


a)


b)


c)


d)

Photoresist materials

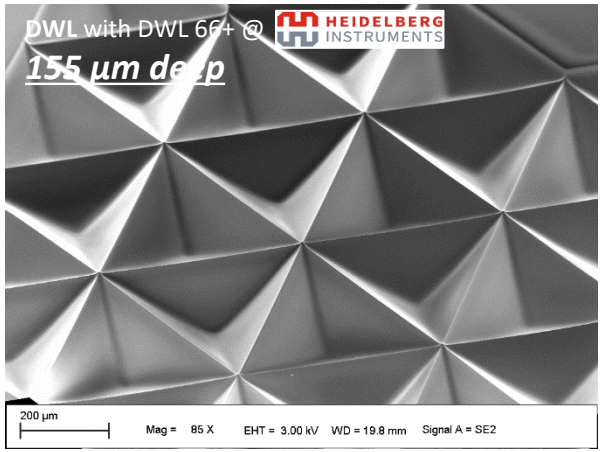
Positive resists for laser based gray scale lithography via 1PL & LIL:

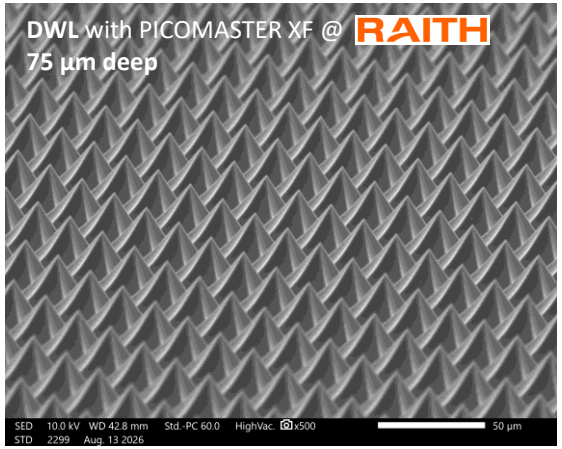
mr-P 22G up to 120 µm (single), 200 µm (double) film thickness; further reduced bubble formation during exposure; max. grayscale exposure depth of 160 µm successfully demonstrated, manageable grayscale working range ~ 140µm

Negative resists for laser-based lithography via 1PL & 2PL:

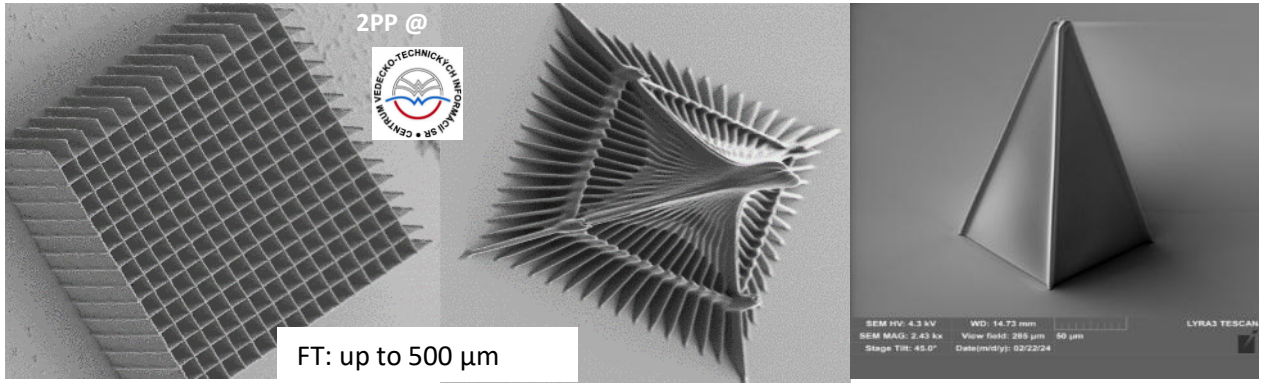
mr-DWL_100_HT_XP for a laser direct writing, up to 500 µm film thickness, high transparency, and UV sensitive until 405 nm

mr-P 22G





mr-DWL_100_HT_XP



All-in-one platform

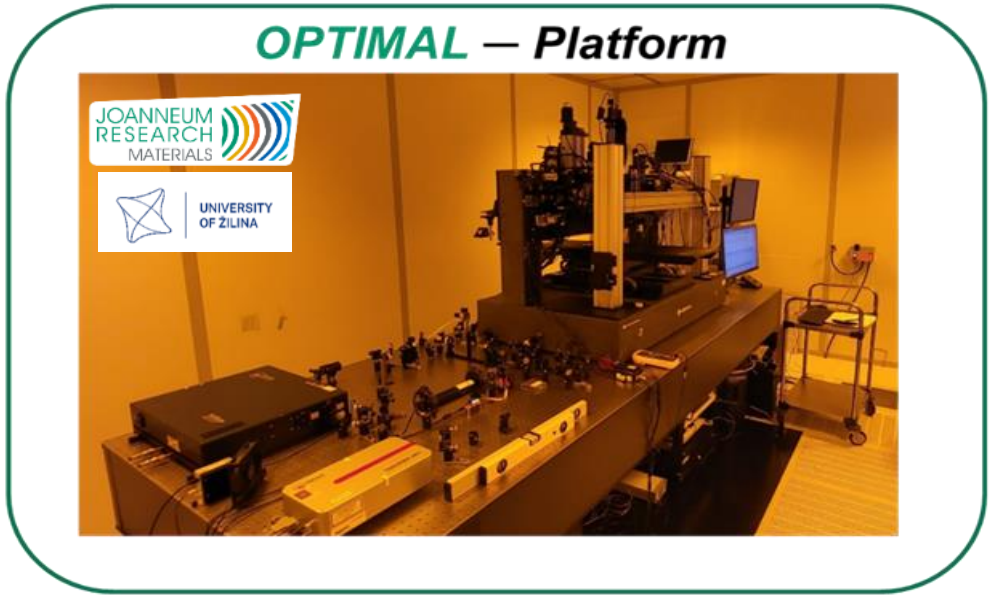
Located at Joanneum Research – MATERIALS institute in Weiz within a 40 m² yellow-light area (ISO 14644 **Class 6 cleanroom**).

The **serial** approach consists of one photon lithography (1PL) and two photon lithography (2PL), where the structure is written line by line. The **parallel** 1PL approach is including a spatial light modulator (SLM) and laser interference lithography (LIL), where a complete area is structured in one step.

The **quality control** system is composed by the alignment and pre-processing modules (focus-variation microscope system), the in-line monitoring modules (position-sensitive detector) and the off-line imaging system (bright and dark-field imaging contrasts).

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The **software module** consists of a self-learning algorithm in conjunction with a dedicated database, as well as the main control software.



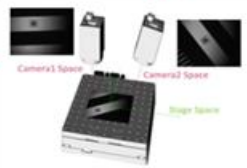
Writing modules

- One photon
- Two photon
- Laser interference lithography
- Parallel writing module via spatial-light modulator



Vision system

- Innovative dark-field and diffractive imaging
- Modules for fast focus determination and system calibration

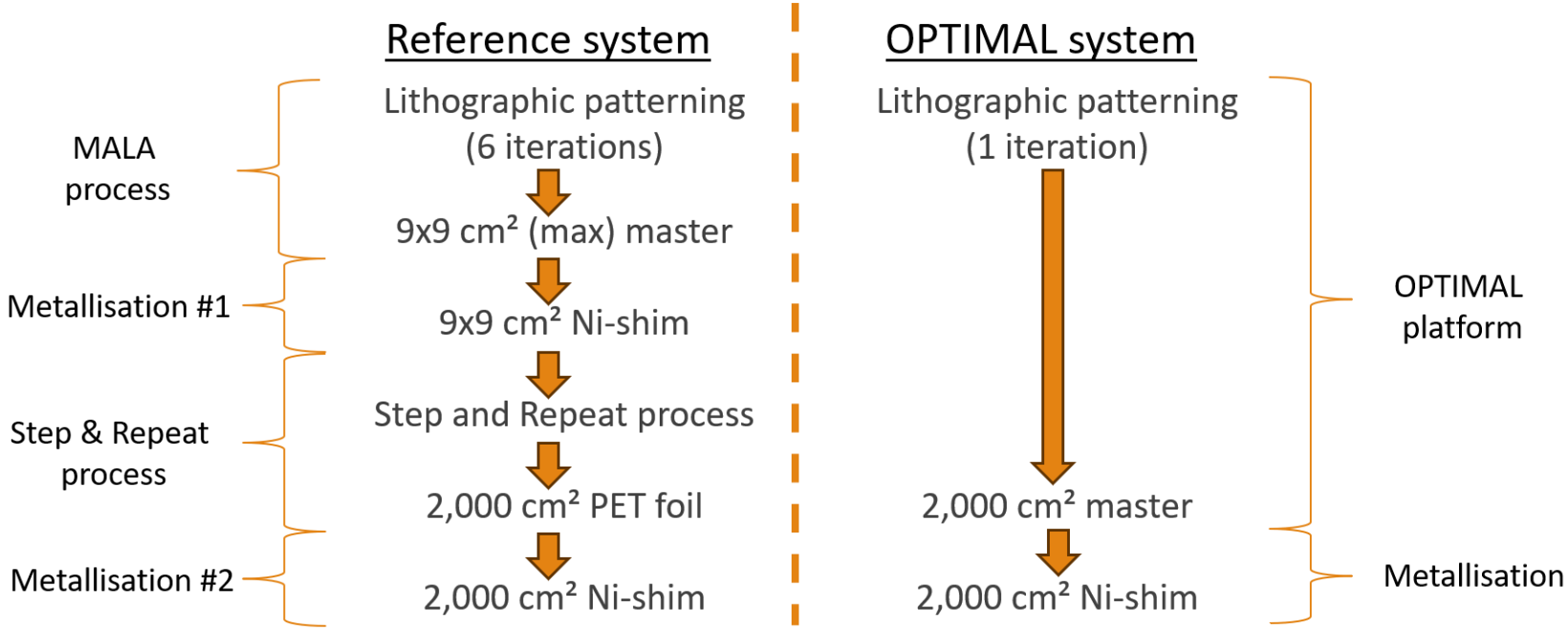


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Sustainability aspects

Comparison Reference system ↔ OPTIMAL system for production of 2000 cm² Ni shim

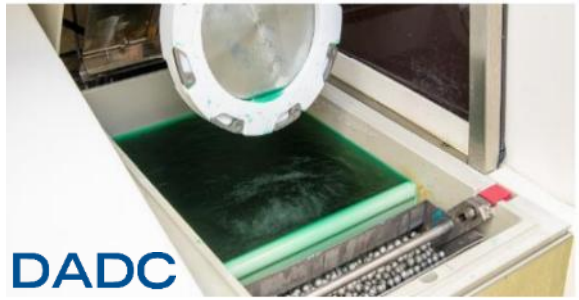
(MALA - JOR maskless laser system as „state-of-the-art“ reference process)



	Reference system (total)	OPTIMAL system (total)	Relative decrease by OPTIMAL
Process energy (kWh)	444	139	-69%
Processing time (h)	574	80	-86%
GWP total (kg CO_2e)	1079	122	-89%

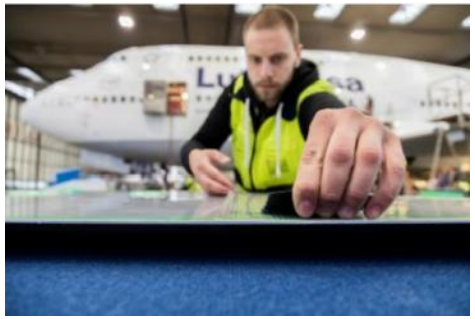
Applications and motivations

Full-polymer micro lenses for industrial optics aiming at replacing the current expensive diamond-milling technique



Sony DADC

Hierarchical multifunctional drag reduction riblet structures for aviation with additional functionalities produced at industrial level



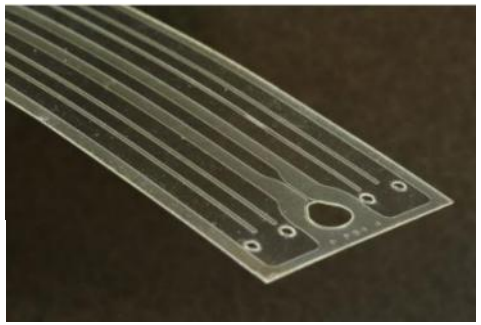
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Free-form lens arrays for virtual reality displays with increased efficiency by directing the light towards the eye pupil area (also in case of strabismus)



hypervision

Microfluidic hierarchical structures for lab on chip devices with complex microelement developed in one machine thus decreasing the time for production

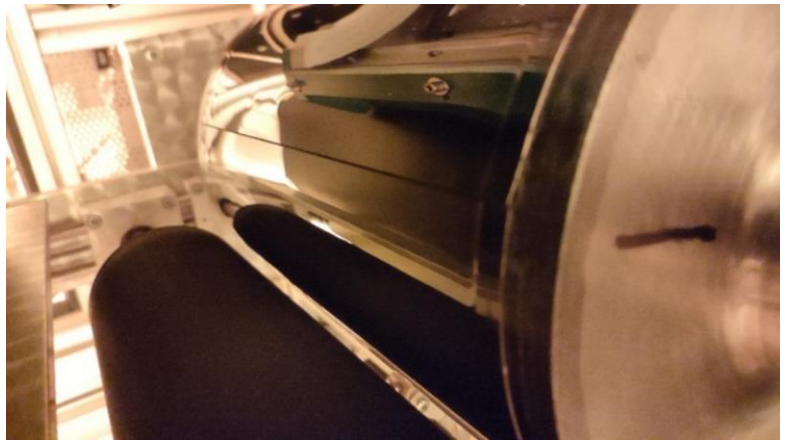


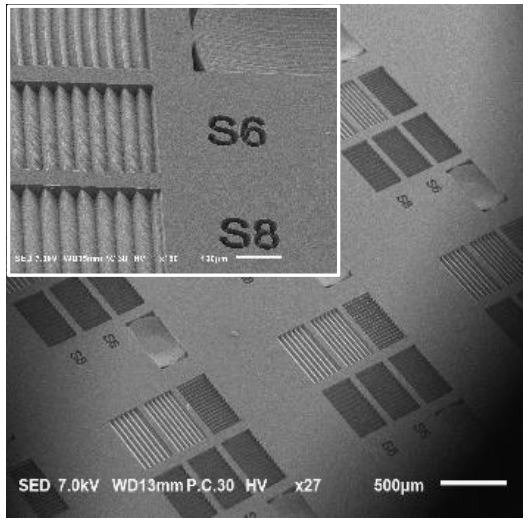
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Master and structures

63 x 28 cm Ni shim compatible with the R2R UV NIL process available at Joanneum

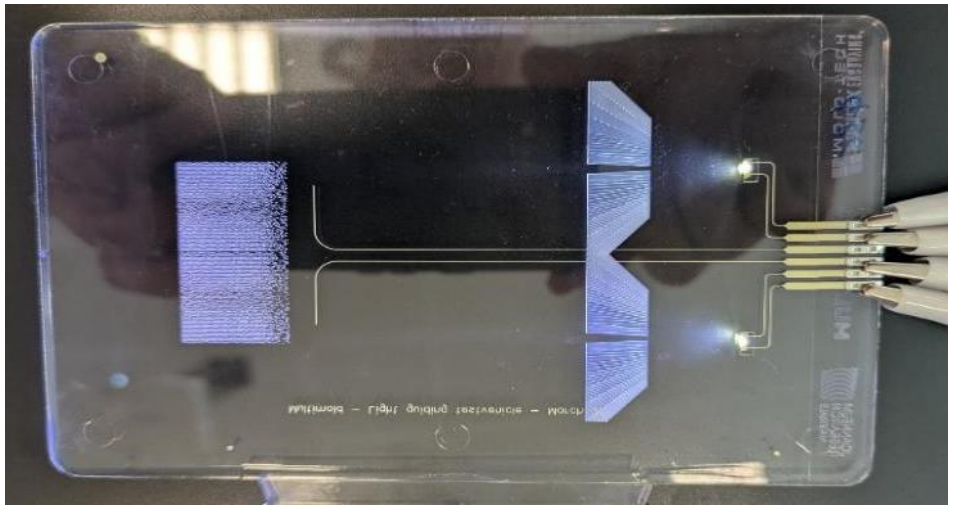






Injection molded light guiding microstructures (developed using OPTIMAL):

- Extended freedom in LED placement
- Improved optical design
- Management of light and heat distribution



Visit us at the LIMES booth to check the MULTIMOLD + OPTIMAL light guiding demonstrator!

Conclusions

The OPTIMAL project increase efficiency and yield by accelerating and upscaling the structuring process

- First time right fabrication of the required structures
- Lower resource consumption
- Waste reduction
- Lower CO_2 emissions
- Increased productivity
- Cost reductions

Thank you for your attention!

For more information,

Contact us: optimal@joanneum.at

Visit our website: https://www.optimal-project.eu/

Visit our LinkedIn account: https://www.linkedin.com/in/optimal-project-6b42812ba/

Visit our YouTube channel: https://www.youtube.com/watch?v=ijHFEzLJHyI

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