Production Processes for Micro Optics - Enabler for Energy Efficient Lighting

Mimomems Strategic Workshop
Sinaia Romania

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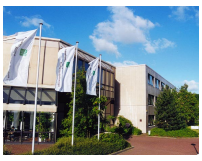
Fraunhofer IPT

WZL RWTH AACHEN

Content

- Fraunhofer IPT
- Market for Micro Optics
- Production of Micro Optics
- Exemplary Process Chain “FlexPAET”
- Summary and Outlook

The Fraunhofer Institute for Production Technology IPT



Executive Director
- Prof. Fritz Klocke

Board of Directors
- Prof. Fritz Klocke, Prof. Christian Brecher, Prof. Robert Schmitt, Prof. Günther Schuh, Prof. Andre Sharon

Activities
- Process Technology
- Production Machines
- Production Quality and Metrology
- Technology Management

Affiliated Organization
- Fraunhofer Center for Manufacturing Innovation CMI Boston, USA

We operate a quality management system certified according to DIN ISO 9001:2000.

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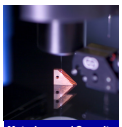
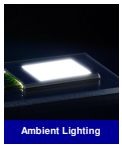
Micro Optics – Market Overview


Automotive Lighting


Metrology and Security


Ambient Lighting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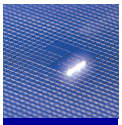

Industrial Production


Medical Technology


Consumer Electronics


Aviation

Source: Hella GmbH,

Micro Optics – Lighting Applications

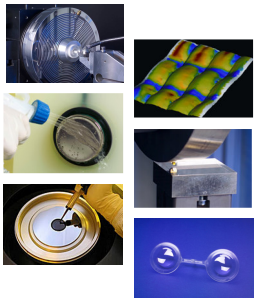
Main reasons for growing demand for micro optics in lighting applications

- Energy efficiency
  - Trend towards LED-Technology forced by politics
  - A significant part of energy losses in lighting applications results from inefficient optics (e.g. diffusing screens, light leakages, insufficient directing of light)
- Design aspects
  - Growing demand for sophisticated lighting solutions for indoor and outdoor applications

Source: Frankfurter Rundschau, ecue control GmbH

Content

Demands for the Production of Micro Optics

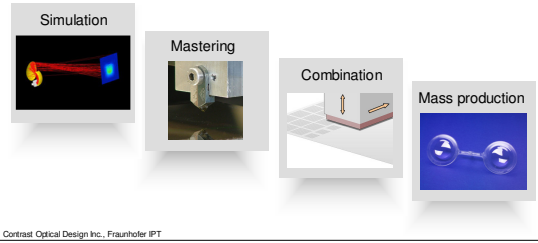


- Multiple production technologies need to be linked
- Cost efficient and scalable production capacity range from prototypes to mass production
- Flexible, semi automated production equipment
- Multi disciplinary optimisation of process steps required

Source: Fraunhofer IPT, Temicon GmbH

Development Steps for Micro Optics

- The development of micro optics requires efficient combination of several disciplines



Source: Contrast Optical Design Inc., Fraunhofer IPT

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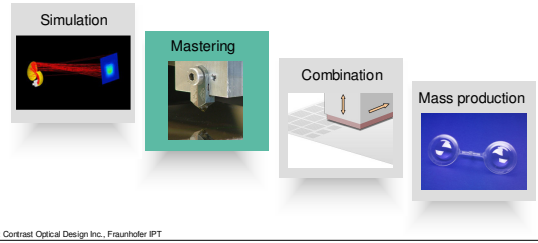
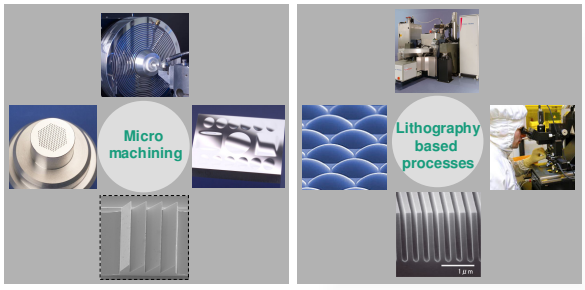


Source: Contrast Optical Design Inc., Fraunhofer IPT

Two Worlds of Mastering Processes

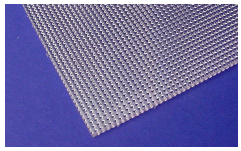


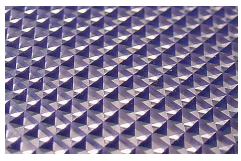
Source: Fraunhofer IPT, NTT Advanced Technology, Temicon GmbH, Süss GmbH

Micro Machining World: Prototyping of Pyramid Structures

Geometry:
- Pitch: 2 mm
- Angle: 90 °
- Height: 1 mm
- Workpiece: 140 x 140 mm²

Process:
- Spindle rotation: 1200 rpm
- Feed: 150 mm/min
- Cutting depth: 1,5 mm

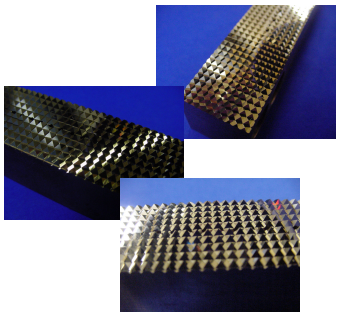




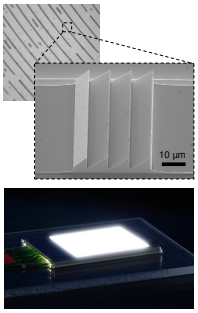
Micro Machining World: Pyramid Structures in Brass

Geometry:
- Pitch: 2 mm
- Angle: 90 °
- Height: 1 mm
- Workpiece: 155 x 20 mm²

Process:
- Spindle rotation: 1000 rpm
- Feed: 30 mm/min
- Cutting depth: 1,2 mm



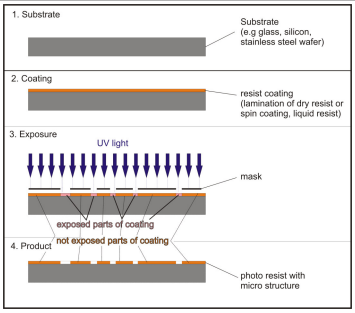
Micro Machining World: Blazed Gratings



- Production of micro structures (blazed gratings) with structure width < 10 µm by diamond turning
- Production of stamp tools (40 x 40 µm²) or direct structuring surfaces by Fast-Tool-Servo
- Application in light guiding foils in lighting and display technology
- Process optimisation and advanced process know how necessary
- Development of highly dynamic ultra precision axis necessary

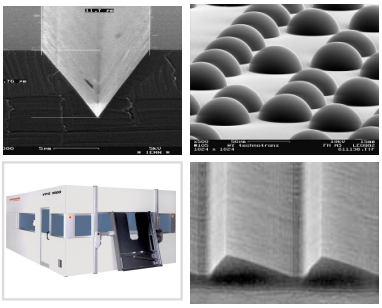
Lithography World

- Lithography based processes have been developed mainly for binary structures
- Entire process chains have been optimised for special high volume applications (e.g. DVD production, chip production)
- Characteristics
  - High resolution (down to 20 nm structure size)
  - High aspect ratio



Litographic 3D Patterning

- Adaption for optical applications
  - Large area applications (e.g. laser lithography process on areas > 1m²)
  - 3D-micro manufacturing (e.g. reflow processes, grey scale lithography, anisotropic etching)



Source: Temicon Gmbh, Teledyne LLC, Aristotle University of Thessaloniki

Development Steps for Micro Optics

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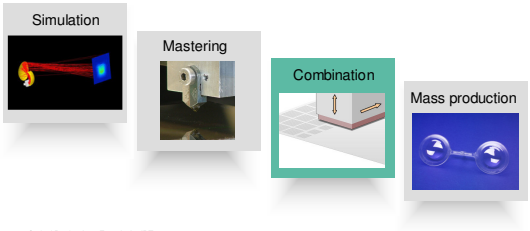
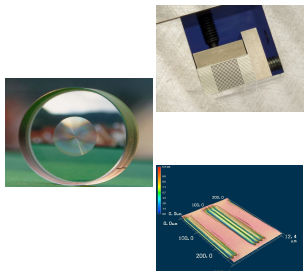


Source: Contrast Optical Design Inc., Fraunhofer IPT

Connecting Two Worlds: Combination Processes

- Components or technologies of the mastering processes can be recombined in a flexible way
- Structural dimensions and work piece dimensions not necessarily need to be in a certain relation
- Combination can be done by
  - mechanical combination
    - e.g. assembly of galvanic masters
  - sequential processing
    - e.g. laser beam lithography on diamond machined surfaces
  - replicating combination
    - e.g. step and repeat hot embossing



Source: Fraunhofer IPT, Fraunhofer IOF

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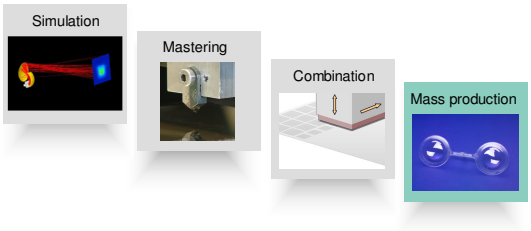
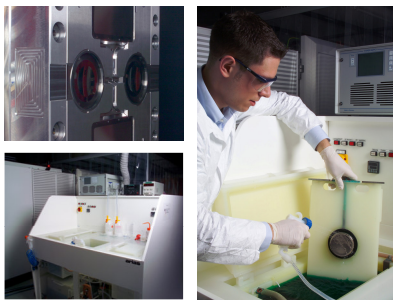


Source: Contrast Optical Design Inc., Fraunhofer IPT

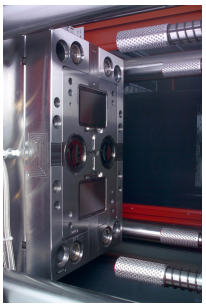
Key Process for Mass Replication - Electroforming

- Replication of master geometries by electroforming
- Electroforming enables the economic application of cost intensive mastering processes due to the possibilities of making high quality metalic copies
- Production wear resistant moulds for further mass production



Source: Fraunhofer IPT

Mass Production: Injection Moulding and Hot Embossing



Injection Moulding

- Medium to high volume production of polymer optics
- Simulation and iterative process optimisation enable highly accurate replication
- Multi material processes
- Substitution of assembly processes possible
- Highly automated systems available

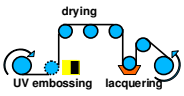
Hot Embossing

- Very high replication quality
- Prototypes till medium batch size

Source: Fraunhofer IPT

Roll-to-Roll Embossing

- High volume production of optical components
- Accurate replication of structural details
- Little supplier market for the technology
- Promising technology for low-cost production of micro optical components



Source: 3M / Vikuiti

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FelxPAET - Introduction

FlexPAET
- Flexible Patterning of Complex Micro Structures using Adaptive Embossing Technology

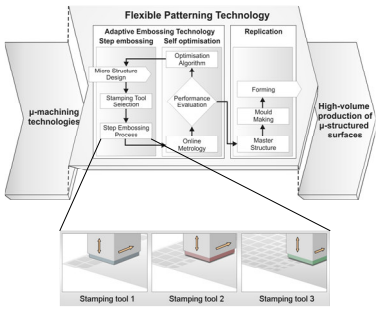
Project Goal
- Development of a production chain using
  - micro embossing
  - surface structuring and
  - mass replication

  for the production of large area micro structured optical components

Project Start
- October 2008

Project Duration
- 3 Years

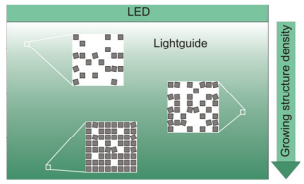
EU Project - FlexPAET

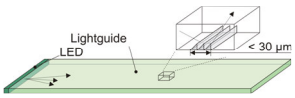


- **Adaptive Embossing Technology**
  - Flexible
  - Self-optimising fabrication
  - Large area micro structured surfaces
- **Step embossing:** Master structures will be manufactured directly into thermoplastic substrates by step and repeat embossing
- **Self optimization:** In-situ metrology to analyse the optical performance of the master substrate
- An **optimisation algorithm** will determine necessary rework substrate
- **Replication Process:** Master will be used to produce a mould – galvanic process
- **Forming:** Moulds will be used for replication

Lightguide Design

- Lightguide bases on a structured plate or film
- Structural elements are blazed gratings with sizes in the range of few microns
- High energy efficient lightguides need optimal adapted structure density and 3-dimensional patterns
- A back light unit contains several million grating pixels





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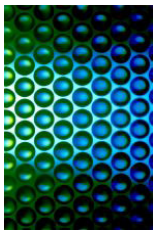
Summery and Outlook



- Excellent market opportunities for the design and production of micro optics.
- Growing demand for lighting applications.
- Flexible, semi automated production equipment is needed.
- Linking and optimising existing technologies is most important for the economic production of micro optics.

Source: Süss GmbH