Production Processes for Micro Optics - Enabler for Energy Efficient Lighting

Mimomems Strategic Workshop
Sinaia Romania

October 11, 2009

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Market for Micro Optics
Production of Micro Optics
Exemplary Process Chain "FlexPAET"
Summary and Outlook

We operate a quality management system certified according to DIN ISO 9001:2000.
**Micro Optics – Market Overview**

- Automotive Lighting
- Metrology and Security
- Ambient Lighting
- Industrial Production
- Medical Technology
- Consumer Electronics
- Aviation

**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

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**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
**Development Steps for Micro Optics**

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

**Simulation**

**Mastering**

**Combination**

**Mass production**

**Source:** Contrast Optical Design Inc., Fraunhofer IPT

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**Two Worlds of Mastering Processes**

- Lithography-based processes
- Micro machining

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

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**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)

Development Steps for Micro Optics

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

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

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 metallic copies.
- Production wear resistant moulds for further mass production.
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

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

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**FlexPAET - 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.
- **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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**Summary 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