Research Cluster Advanced Manufacturing in Photonics Industries

Open Proposal for the

Innosuisse Call „Digitalisation – Advanced Manufacturing“

NTB
Interstaatliche Hochschule
für Technik Buchs

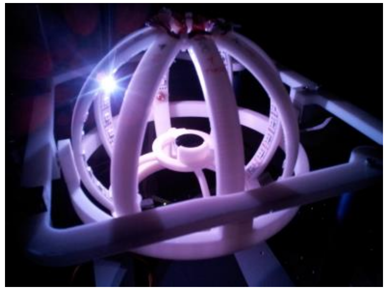
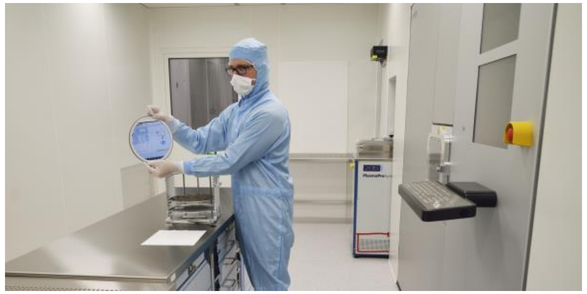
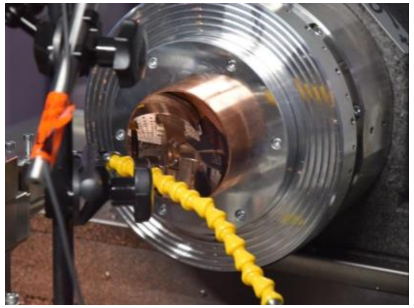
FHO Fachhochschule Ostschweiz

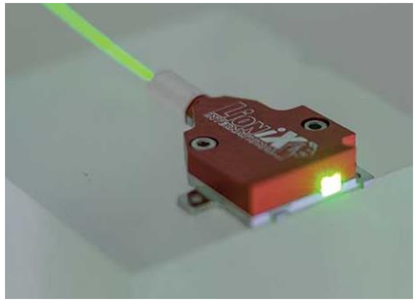
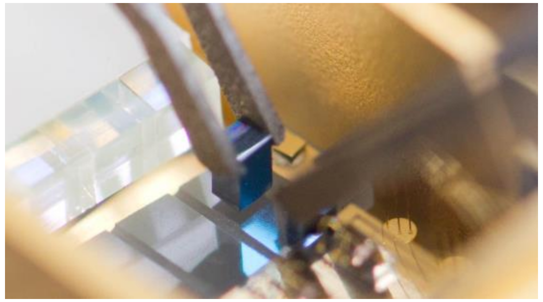
NTB
Interstaatliche Hochschule für Technik Buchs
FHO Fachhochschule Ostschweiz

Cluster Projects with High Visibility in Advanced Manufacturing

Match Making Event in Buchs

25 companies
50 participants

andreas.ettemeyer@ntb.ch

Overview of Project Proposals

NTB
Interstaatliche Hochschule für Technik Buchs
FHO Fachhochschule Ostschweiz

Mechanical Manufacturing

1. High precision moulds and dies
2. Medical disposable sensors

Laser Manufacturing Techniques

1. Selective Laser Micro Manufacturing

Packaging of photonic systems

1. Handling concepts
2. Standardized correction elements
3. Precision assembly of miniaturized objectives
4. Alternative bonding techniques

Surface Optimization

1. Laser Polishing

Cleaning in photonic production

1. New approaches for optics cleaning (processes)
2. Process control in optics cleaning (analytics)

andreas.ettemeyer@ntb.ch

thomas.liebrich@ryhsearch.ch

Manufacturing of high-precision moulds and dies

Mass production is mainly based on forming → Moulds and dies lay the cornerstone in the production chain

Market trends:

- Higher complexity (integration of additional functionality)
- Increasing variety
- Miniaturisation of components

Problems:

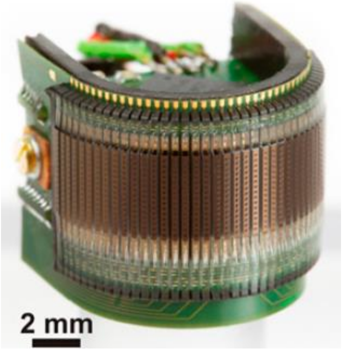
- Manufacturing processes of moulds are expensive and time consuming
- Combination of macro- and micro-cosmos

Applications:

- Optical industry, i.e. lenses for AR / VR googles, LiDAR sensors, structural colours for displays, security coding, healthcare or wearables
- Semi-conductor industry, i.e. wave guides, micro-systems, voice processing, artificial intelligence

Aspherical lenses
[www.jenoptik.com]

Mixed reality headset
[www.digitec.ch]



Miniature curved
artificial compound
eyes [Floreano et al]

thomas.liebrich@ryhsearch.ch

Manufacturing of high-precision moulds and dies

Overall goal:

Development of **economic and reliable process chains** for volume and cost effective **manufacturing in Switzerland** of parts made of metals, glass and polymers by using high-precision moulds and dies

1. *Technical and economic comparison of different manufacturing technologies for moulds (18 months)*

development of manufacturing technologies for moulds

- Metal-cutting machining: diamond machining
- Laser machining: ablation, polishing
- Lithography / etching / UV-LIGA

} and combinations of these technologies

2. *Development of specific process chains for manufacturing high-precision optical components like lenses for AR / VR glasses*

Advantage: all steps of the complete process chain are available in ‘little big country’ Switzerland

Industry / company-specific requirements to be treated in separate projects

thomas.liebrich@ryhsearch.ch

Manufacturing of high-precision moulds and dies

Deliverables:

- Identification of actual state-of-art, its deficiencies and possible improvements
  (for the manufacturing as well as for the metrology)
- In particular, the capability of combining metal-cutting processes like diamond machining with lithographic processes like nano-imprint for manufacturing high-precision moulds shall be investigated

Benefit for companies:

- Evaluation of state-of-art for relevant manufacturing technologies for mould fabrication
- Forecast about future state-of-art and its requirements (i.e. machinery, production environment, cleaning stations, …)
- Government-funded (InnoSuisse) preliminary work within this project, which allows in subsequent projects the development of specific processes for industries' requirements
- Compact project due to limited project duration
  => Subsequent project will also start within reasonable time
- Possibility to benefit from as many project partners from industry as possible due to reduced cash fee

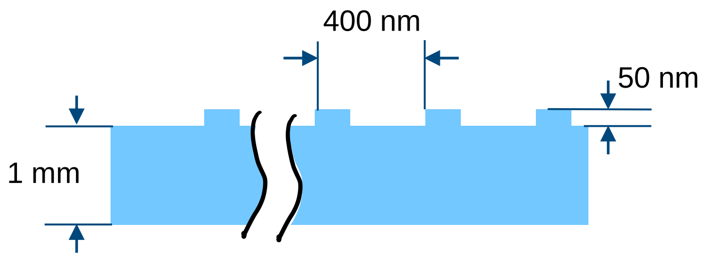
michael.marxer@ntb.ch

NTB
Interstaatliche Hochschule für Technik Buchs
FHO Fachhochschule Ostschweiz

Sensors from Polymer Components with Precision Micro Structures

Actual Situation

- Core compontents of medical sensors are made from glass



Problems

- Difficult manufacturing
- Costs too high
- Processes too slow
- Cleaning problematic

Goals

- Cost reduction
- From glass to polymer → disposables
- Small manufacturing tolerances
- Increased manufacturing speed
- Reliable processes for micro structures
- Manufacturing in Switzerland

Questions

- Which materials?
- Interface material - tool?
- Which manufacturing processes?
- Quality control, (In-Situ) measurement?
- Stability of processes?
- economics?

michael.marxer@ntb.ch

NTB Interstaatliche Hochschule für Technik Buchs
FHO Fachhochschule Ostschweiz

Sensors from Polymer Components with Precision Micro Structures

Consortium / Main Topics / Status

- Industry
  - Main industry partner (Sensor manufacturer, known)
  - NN manufacturer micro tools (open)
  - NN micro injection mold service (open)
  - NN manufacturer of base material (open)
- Research
  - NTB production metrology (known)
  - NTB Micro / Nanotechnology (tribology, structuring, chemistry, known)
  - RhySearch (manufacturing of micro moulds, known)
  - NN polymer injection molding technology (in discussion, open)

Data

- Project volume: ca. 600 000 CHF
- Duration: 18 Months

Results

- Prozess chain for polymer components with precision micro structures
- Manufacturing technology to produce moulds for micro injection compoments
- Measurement techniques for process control and verification

Overview of Project Proposals

NTB
Interstaatliche Hochschule
für Technik Buchs
FHO Fachhochschule Ostschweiz

Mechanical Manufacturing

1. High precision moulds and dies
2. Medical disposable sensors

Laser Manufacturing Techniques

1. Selective Laser Micro Manufacturing

Packaging of photonic systems

1. Handling concepts
2. Standardized correction elements
3. Precision assembly of miniaturized objectives
4. Alternative bonding techniques

Surface Optimization

1. Laser Polishing

Cleaning in photonic production

1. New approaches for optics cleaning (processes)
2. Process control in optics cleaning (analytics)

andreas.ettemeyer@ntb.ch

roelene.botha@ntb.ch

NTB Interstaatliche Hochschule für Technik Buchs
FHO Fachhochschule Ostschweiz

Femtosecond Laser-Induced Micromanufacturing in Optical Glasses

Goal

Exploration of femtosecond laser-induced microfabrication technology for industrial applications in optical glasses.

Topic (I) – 3D microstructures manufacturing

- High integration density becomes more and more important in industrial applications
- femtosecond selective laser-induced etching (SLE) is one such technique to produce 3D in optical materials

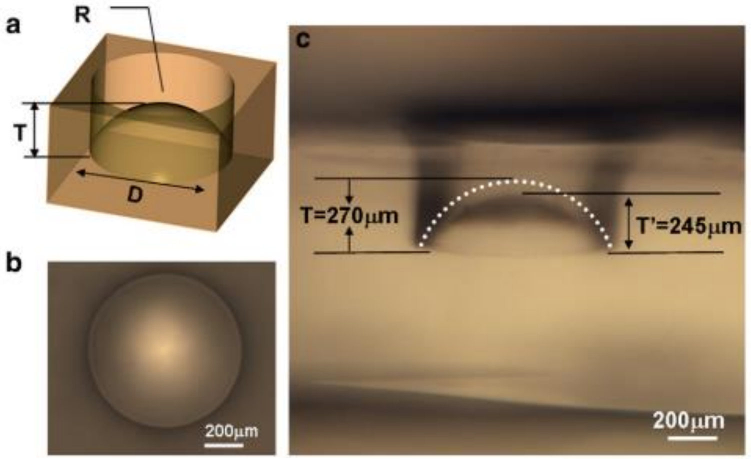
Applications:

μ-fluidics, optical elements, optomechanics, …

Challenges:

surface roughness
=> *reason for laser polishing initiative*

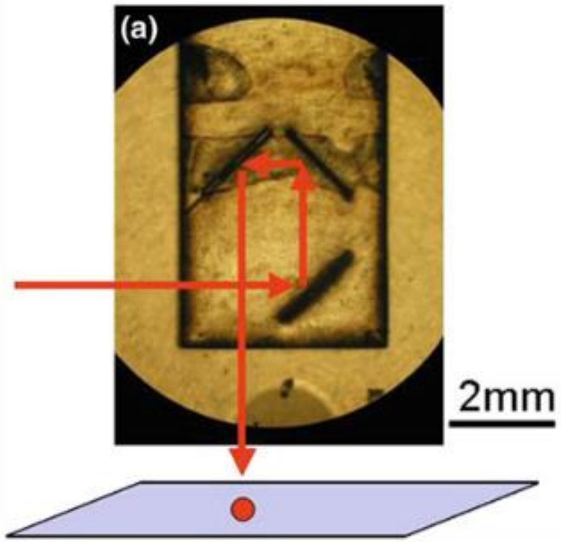
microlenses



Qiao, Lingling; He, Fei; Wang, Chen; Liao, Yang; Cheng, Ya; Sugioka, Koji et al. (2011): Fabrication of a micro-optical lens using femtosecond laser 3D micromachining for two-photon imaging of bio-tissues. In Optics Communications 284 (12), pp. 2988–2991. DOI: 10.1016/j.optcom.2011.01.082.

Comment!
Polishing post process needed to reduce roughness:
Reason for laser polishing initiative of NTB

microoptics



Sugioka, Koji; Cheng, Ya (2014): Femtosecond laser 3D micromachining for microfluidic and optofluidic applications. London: Springer (SpringerBriefs in applied sciences and technology).

roelene.botha@ntb.ch

Femtosecond Laser-Induced Micromanufacturing in Optical Glasses

Topic (II) – Femtosecond written waveguides

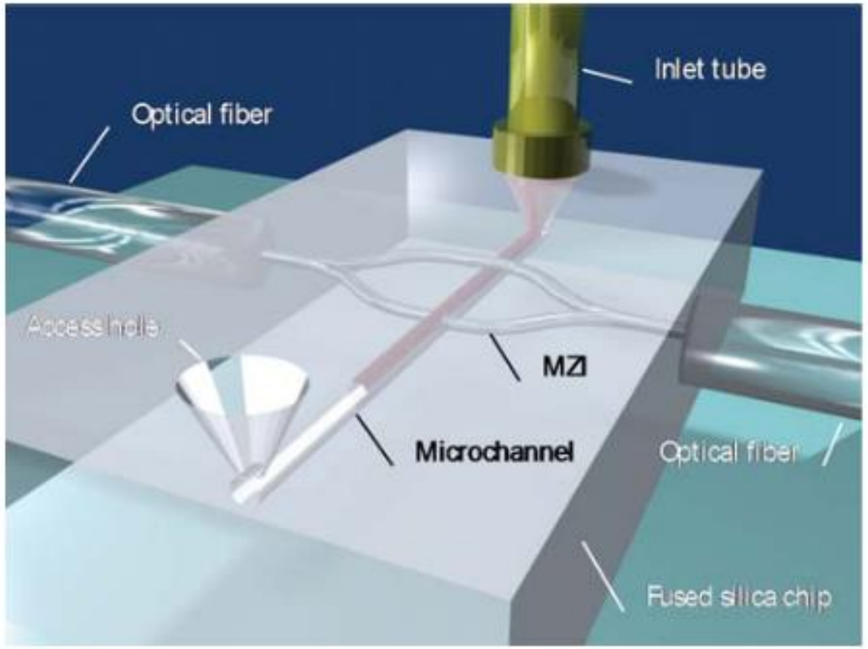
- Same laser system can be used to write waveguides
- Combination of 3D microstructures with waveguides

Applications:

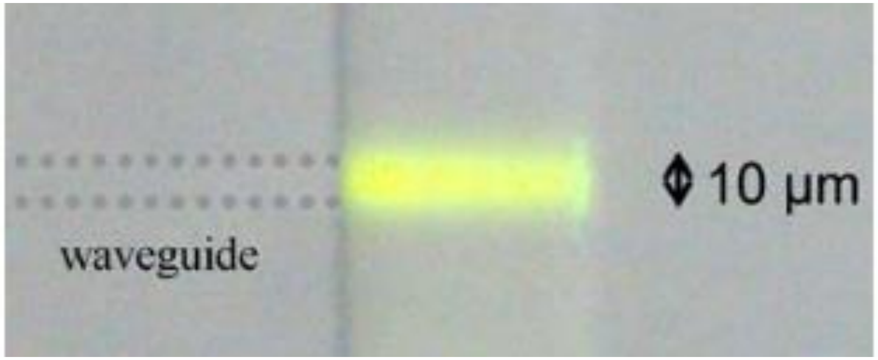
optical sensors, coupling elements, routing of signals

Challenges:

attenuation of waveguides



Crespi, Andrea; Gu, Yu; Ngamsom, Bongkot; Hoekstra, Hugo J. W. M.; Dongre, Chaitanya; Pollnau, Markus et al. (2010): Three-dimensional Mach-Zehnder interferometer in a microfluidic chip for spatially-resolved label-free detection. In Lab on a chip 10 (9), pp. 1167–1173. DOI: 10.1039/b920062b.



Martinez Vazquez, Rebeca; Osellame, Roberto; Cretich, Marina; Chiari, Marcella; Dongre, Chaitanya; Hoekstra, Hugo J. W. M. et al. (2009): Optical sensing in microfluidic lab-on-a-chip by femtosecond-laser-written waveguides. In Analytical and bioanalytical chemistry 393 (4), pp. 1209–1216. DOI: 10.1007/s00216-008-2399-8.

roelene.botha@ntb.ch

NTB
Interstaatliche Hochschule für Technik Buchs
FHO Fachhochschule Ostschweiz

Femtosecond laser-induced micromanufacturing in optical glasses

Resources: 1.5 man year

1.5 man year

Topic (I) - Selective laser-induced etching of glass devices

- Cylindrical lens array (industrial partner ☑)
- Light weight structures (potential partner ☑)
- …

Topic (II) - Femtosecond laser-induced waveguides

- Waveguides (industrial partner ☑)
- Fiber coupling element (industrial partner ☑)
- …

Materials (project)

- Fused silica
- Borosilicate (Eagle XG, BF33, BK7)
- High index material (e.g. LAH53)

Deliverables

Technology platform for industrial products

- design rules
- starting point for bilateral Innosuisse projects after the cluster project
- technology applied on industrial use cases

Estimated budget

- **Human Resources (3MJ):** ca. 450’000.- (Innosuisse funding)
- **Material costs:** 25’000.- (substrates, chemicals, substrates holders, …)
- **Facilities:** 30’000.- (Slit extension for WGs in FS, Characterisation set-ups)

Cluster Goal:
> 4 industrial partners
~ 11 kCHF cash for each partner

Overview of Project Proposals

NTB
Interstaatliche Hochschule für Technik Buchs
FHO Fachhochschule Ostschweiz

Mechanical Manufacturing

1. High precision moulds and dies
2. Medical disposable sensors

Laser Manufacturing Techniques

1. Selective Laser Micro Manufacturing

Packaging of photonic systems

1. Handling concepts
2. Standardized correction elements
3. Precision assembly of miniaturized objectives
4. Alternative bonding techniques

Surface Optimization

1. Laser Polishing

Cleaning in photonic production

1. New approaches for optics cleaning (processes)
2. Process control in optics cleaning (analytics)

Laser Polishing Technology for Optics Manufacturing

Availability of high power laser opens chance for manufacturing of small optical components with high precision and efficient material processing

- Enables new markets and applications (e.g. aspheres, free forms)
- Leads to increased demand for optical high power components

Challenges for surface tolerances:

- Improve existing processes
- Invest into new manufacturing and measuring techniques

“Optics systems must not only offer greater precision and higher tolerances but also better transmission with fewer wavefront errors” – Photonics Spectra, October 2018

roelene.botha@ntb.ch

Laser Polishing Technology for Optics Manufacturing

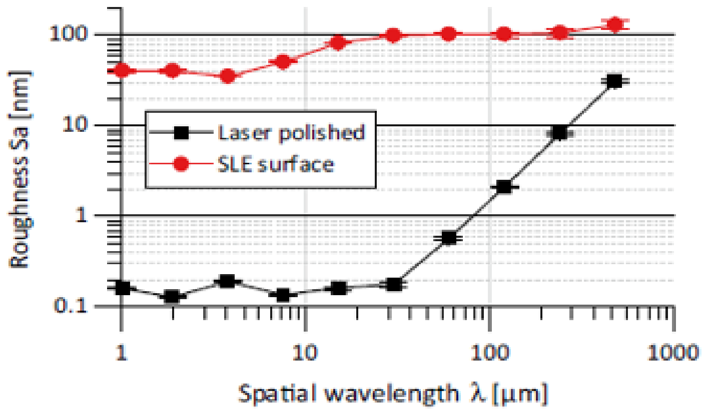
Laserbased polishing will enable faster production cycles of standard optics components and free form optics in higher numbers

By laser polishing:

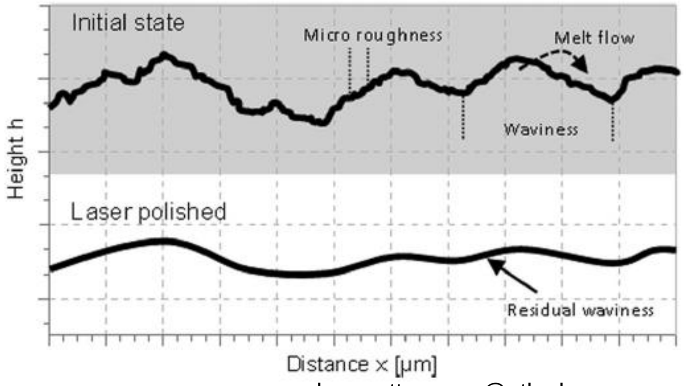
- Roughness can be reduced to 0.2 nm[1]:
- Error correction with laser polishing: Laser Beam Figuring (LBF) required[2]:

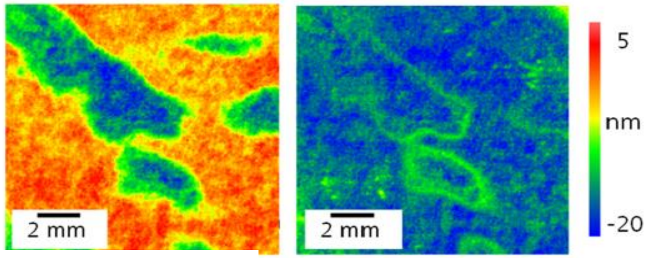
Vor (rechts) und nach (links) CO_2 Laser Politur

[1] Weingarten et al., Microfluid Nanofluid (2017)



[2] Weingarten et al., J. Laser Appl. 29 (2017)





Mechanisch poliert
Laser Beam Figuring

Laser Polishing Technology for Optics Manufacturing

Large variety of optical components

- No «one-for-all-solution» possible for laser polishing
- Develop general polishing procedure for fused silica
- Adopt to specific needs in second step

Advantages of laser polishing

«Disruptive» technological progress

- Of strategic importance for all optics manufacturers

High initial technological risk

- *Innosuisse* Clusterproject as first step to computer integrated laser polishing process
- In following steps technology can be adopted to specific requirements

roelene.botha@ntb.ch

NTB
Interstaatliche Hochschule für Technik Buchs
FHO Fachhochschule Ostschweiz

Laser Polishing Technology for Optics Manufacturing

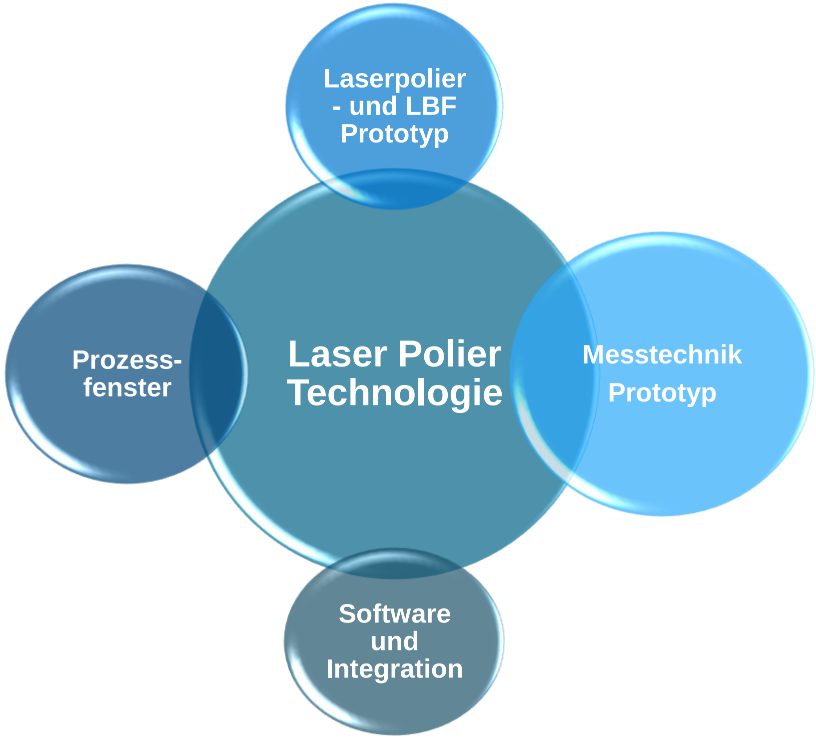
Development of Proof-of-Concept-Prototypes, which improve micro roughness and accuracy of optical free forms from fused silica in iterative steps.

Prototypes

- are functional and ready for future integration
- Will be manufactured in the following projects with a computer integrated laser polishing process

Vorgesehene Deliverables:

1. Prototypsystem zum Laserpolieren und LBF
2. Prototyp-Messsystem zur Bestimmung der Rauheit und des Formfehlers (Passfehlers) der Glasoberfläche vor- und nach polieren
3. Prozessfenster für die Laserpolieren und LBF vom QuarzglasSystem Integration Software



Overview of Project Proposals

NTB
Interstaatliche Hochschule für Technik Buchs
FHO Fachhochschule Ostschweiz

Mechanical Manufacturing

1. High precision moulds and dies
2. Medical disposable sensors

Laser Manufacturing Techniques

1. Selective Laser Micro Manufacturing

Packaging of photonic systems

1. Handling concepts
2. Standardized correction elements
3. Precision assembly of miniaturized objectives
4. Alternative bonding techniques

Surface Optimization

1. Laser Polishing

Cleaning in photonic production

1. New approaches for optics cleaning (processes)
2. Process control in optics cleaning (analytics)

andreas.ettemeyer@ntb.ch

thomas.gischkat@rhysearch.ch

NTB Interstaatliche Hochschule für Technik Buchs
FHO Fachhochschule Ostschweiz

Cleaning 4.0: New Approaches for Optics Cleaning

Subject: optimize the cleaning process with innovative elements and investigate its influence on optical coating quality

duration: 18 Months

Motivation:
- cleaning is a key element in the process chain
- varying cleaning quality and increasing requirements
- large optimization potential in the field of cleaning

Goal: investigation of existing techniques (e.g. US-Frequency, chemicals, drying, …) and innovative techniques (drying, post treatment, in-situ modification of cleaning detergences, …) on the optical performance (quality of surface, LIDT, scattering, …)

thomas.gischkat@rhysearch.ch

NTB Interstaatliche Hochschule für Technik Buchs
FHO Fachhochschule Ostschweiz

Cleaning 4.0: New Approaches for Optics Cleaning

description:
- build up of model cleaning set-up at NTB/RhySearch
- Automatization / in-situ Eingriff einbauen 4.0
- Untersuchung zum Einfluss der Parameter (z.B. US-Frequenz, Chemie, …)
- Trocknungsalternativen
- Nachbehandlung

Benefit:
- Untersuchung zu neuen Reinigungsmethoden unter Laborbedingung
- Verbesserung der Reinigung
- kurze Wege zur Analytik (LIDT, CRD, TS, EDX, …)
- kurze Wege zur Beschichtung (DIBS, MS, MoCVD, …)
- Zur Verfügung für Servicereinigung (Anlagenbauer, Laserbauer, …)

Partners:
- UCM (main industry partner, known)
- coating partner (application, open)
- Supplier of chemicals (open)

Cleaning 4.0: New Approaches for Optics Cleaning

Follow up: machine learning project in combination of this project and manufacturing project, e.g.

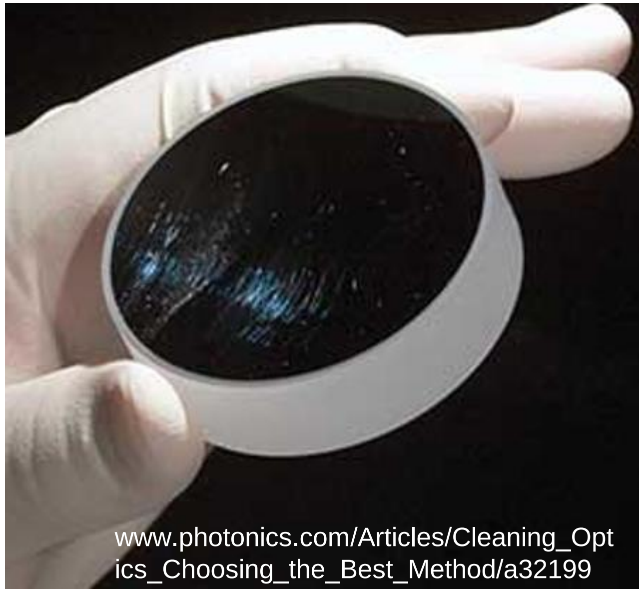
- in-Situ process control recognizes the change of pH value and chemical composition
- innovative process techniques can stabilize the chemistry in advance of the next processing step
- automatic extension of regeneration time, if particle load increases

roelene.botha@ntb.ch

Process Control in Optics Cleaning

Challenge Cleaning in Optics Industry

- Different substrate geometries lead to complicated handling
- Different materials of glas and polymer, coated, not coated, sensitive surfaces, …
  → different chemical stability
- Manual handling of specimen → added source of contamination



www.photonics.com/Articles/Cleaning_Optics_Choosing_the_Best_Method/a32199

Very small contaminations can lead to severe problems with optical coatings

- Requires analytic techniques, which are expensive and difficult to implement
- Not all dirt is visible during visual inspection before coating

roelene.botha@ntb.ch

NTB
Interstaatliche Hochschule
für Technik Buchs
FHO Fachhochschule Ostschweiz

Process Control in Optics Cleaning

Process control after cleaning:

- Dark field microscopy, contact angle measurement, white light interferometr, lens,…

During cleaning process: control of systems parameter

- Particle counting in liquids
- conductivity

➡ *More information about state of the system available!*

roelene.botha@ntb.ch

NTB
Interstaatliche Hochschule für Technik Buchs
FHO Fachhochschule Ostschweiz

Process Control in Optics Cleaning

- **Approaches in semiconductor manufacturing, e.g.**
  - UV and NIR absorption spectroscopy for in-line, real time inspection of different chemicals, gas chromatography MS, analysis of metallic contamination, conductivity, resistance, IR multiple internal reflection spectroscopy (IR-MIRS),…

→ Actual as is state is not directly applicable for optics cleaning

Goal of project: Development of new measuring strategies to guarantee high process stability of cleaning in optics manufacturing.

Overview of Project Proposals

NTB
Interstaatliche Hochschule für Technik Buchs
FHO Fachhochschule Ostschweiz

Mechanical Manufacturing

1. High precision moulds and dies
2. Medical disposable sensors

Laser Manufacturing Techniques

1. Selective Laser Micro Manufacturing

Packaging of photonic systems

1. Handling concepts
2. Standardized correction elements
3. Precision assembly of miniaturized objectives
4. Alternative bonding techniques

Surface Optimization

1. Laser Polishing

Cleaning in photonic production

1. New approaches for optics cleaning (processes)
2. Process control in optics cleaning (analytics)

andreas.ettemeyer@ntb.ch

dietmar.bertsch@ntb.ch

Packaging of Photonic Systems

Topic 1: Handling/positioning concepts for photonic systems in low and medium numbers

- Number of pieces (100 … 2000 /a)
- evaluation of total system (Blister, little handling effort,…)

Topic 2: Design of standardised correction elements for photonic systems

- For integrated CMOS
- For optical systems

Topic 3: Concept for precision assembly of miniaturized objectives (accuracy micrometer)

Topic 4: investigation of alternative bonding techniques for precision assembly of photonic systems

- Bonding with controlled gas
- Reactive foils
- Low temperature soldering

dietmar.bertsch@ntb.ch

Cluster Project Packaging of Optics Systems

Consortium:

- Main industry partner (from optics or assembly)
- Assembly partner
- Systems manufacturer
- Adhesive / material provider

Research:

- NTB (manufacturing Lithography, MEMS / Packaging)
- Rhysearch (Precision manufacturing)
- CSEM Alpnach (packaging)
- Others

Data:

- Project sum: ca. 700’000 CHF.-
- Duration of project: 18 Months

Results:

- Process chain for manufacturing of high precision systems
- Bonding technique of components without «gas materials»
- Measuring technique for process control

dietmar.bertsch@ntb.ch

Cluster Project Packaging of Optics Systems

Exact Positioning

- Pick and place automat
- Active alignment
- Stabilized environment
- Dosing / dispensing systems
- Delivery / blister
- Design of components
- Fixation tools
- Bonding techniques

Bonding Techniques

- Optical quality
- Stress in the system
- Operation temperatures
- Additionals processes (coating)
- Thermal expansion
- Dosing functionality
- Long timer stability
- Without outgasing

Fixation

- Planar technology / 3D handling
- Mechanical forces
- High accuracy by masks or active alignment
- 3D positioning required (2, 3, 4 axes)?
- Design of mounting system

Partner

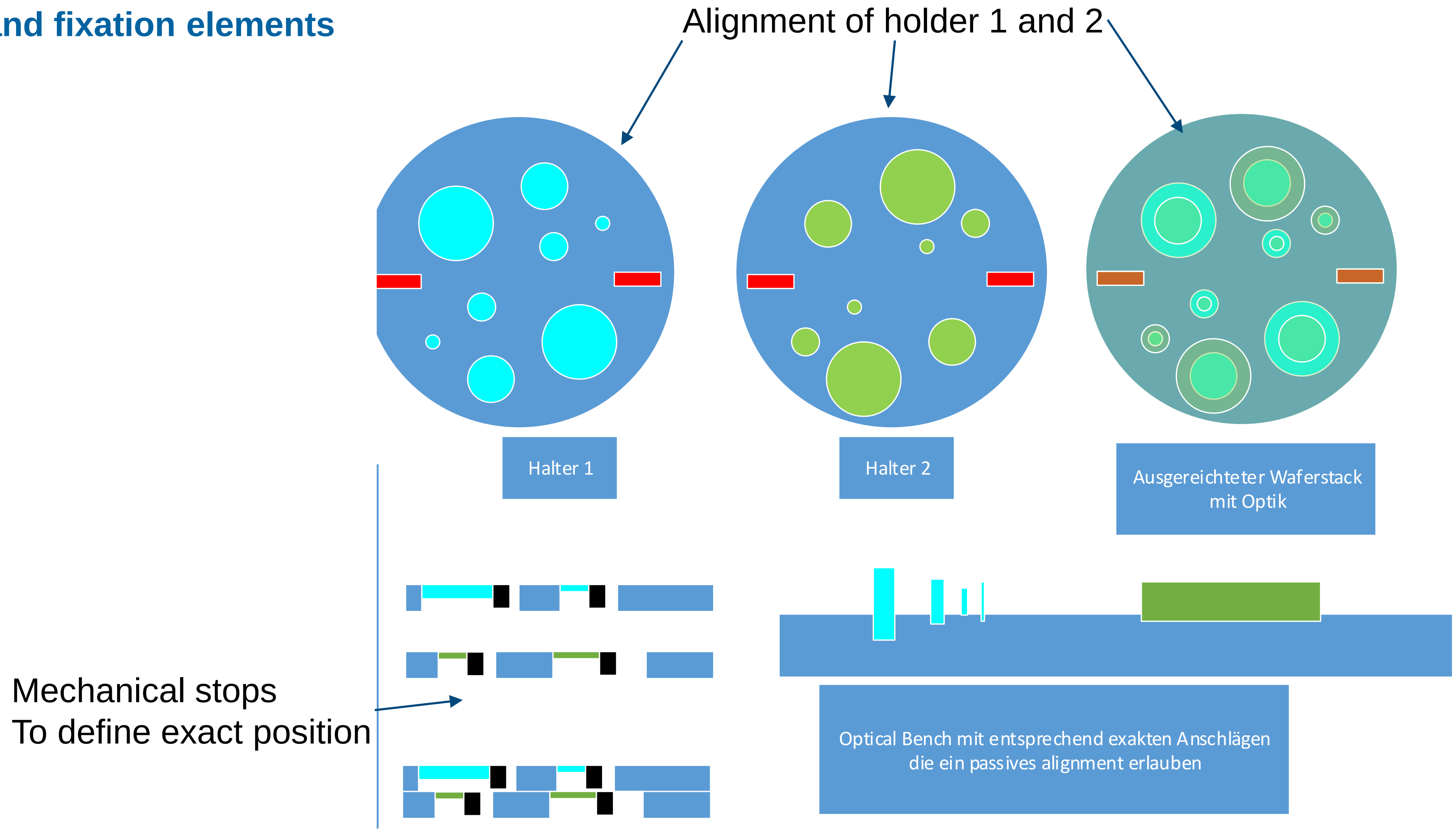
- Assembly (known)
- Optics manufacturer (discussion)
- System integrator (known)
- Supplier of adhesives (known)
- User of actual inquiry (open)

dietmar.bertsch@ntb.ch

NTB Interstaatliche Hochschule für Technik Buchs
FHO Fachhochschule Ostschweiz

Cluster Project Packaging of Optics Systems

Manufacturing of positioning and fixation elements



NTB
Interstaatliche Hochschule für Technik Buchs
FHO Fachhochschule Ostschweiz

Summary

Mechanical Manufacturing

1. High precision moulds and dies
2. Medical disposable sensors

Laser Manufacturing Techniques

1. Selective Laser Micro Manufacturing

Packaging of photonic systems

1. Handling concepts
2. Standardized correction elements
3. Precision assembly of miniaturized objectives
4. Alternative bonding techniques

Surface Optimization

1. Laser Polishing

Cleaning in photonic production

1. New approaches for optics cleaning (processes)
2. Process control in optics cleaning (analytics)

andreas.ettemeyer@ntb.ch

Proposal Cluster all Project Concepts two Few Big Clusters

Manufacturing Techniques

- High precision moulds and dies (RhySearch + Partners)
- Medical disposable sensors (NTB+ Partners)

Laser Polishing (NTB + Partners)

Selective Laser Manufacturing

- SLM (NTB + Partners)

Packaging of photonic systems

1. Handling concepts
2. Standardized correction elements
3. Precision assembly of miniaturized objectives
4. Alternative bonding techniques

Cleaning in photonic production

1. Processes (Rhysearch + Partners)
2. Analytics (NTB + Partners)

Proposal Cluster all Project Concepts two Few Big Clusters

NTB
Interstaatliche Hochschule
für Technik Buchs
FHO Fachhochschule Ostschweiz

Process Closed Loop Control (Empa + Partners)

Manufacturing Techniques

- High precision moulds and dies (RhySearch + Partners)
- Medical disposable sensors (NTB+ Partners)
- Fire and Forget → BFH + Partners
- Laser Polishing (NTB + Partners)

Selective Laser Manufacturing

- SLAM (CSEM + Partners)
- SLM (NTB + Partners)

Packaging of photonic systems

1. Handling concepts
2. Standardized correction elements
3. Precision assembly of miniaturized objectives
4. Alternative bonding techniques

Cleaning in photonic production

1. Processes (Rhysearch + Partners)
2. Analytics (NTB + Partners)