Integration of excimer laser micromachining in a biomedical sensor microfabrication process

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• Measurement principle
• Micromachining of capillary structures by excimer laser
• Microfabrication of the biochip by replication
• Experimental validation
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Introduction

MID*-based smart homecare diagnostic network

Inexpensive compact diagnostic tool for body fluid assays (≈100€)

* MID → “Mobile Internet Devices” (PC tablets, smart-phone, ...)

Lab-on-chip

Lab-on-chip
Low-cost homecare diagnostic tool
First proof-of-concept prototype
Diagnostic tool layout

- Biochip
- CMOS
- USB port
- Readout box
- Polarizer
- Bandpass filter
- LED
1. Biochip optical readout principle

Sensing area structure based on SPR (Surface Plasmon Resonance)

- SPR detection format: Functionalized gold layer
- LSPR detection format: Functionalized gold nanoparticles
2. Biochip optical readout principle

SPR = Surface Plasmon Resonance

Change of the refractive index of the liquid or analyte surface binding events shift the resonance dip in the reflectivity spectrum.

\[
\int_{\lambda_1}^{\lambda_2} I(\lambda) \, d\lambda
\]
Biochip design

- Sensor inlet
- Sensing area
- Output prism
- Input prism
- Capillary pump

$\mu$-pillars structure machined by excimer laser
Microfluidic capillary structure

Machined by excimer laser

Measured by interferometric profilometry
Implementation of the microfluidic capillary structure.

1. Direct laser writing of the mask (DWL150 from Heidelberg)

2. Excimer laser micromachining system
   Mask projection technique
   (Optec, B)
Implementation of the microfluidic capillary structure.

Excimer laser micromachining system used at CSL: mask projection technique

- Demagnification: X10 or X16 (ratio between size on mask and on part)
- Wavelength: 193 nm (ArF), pulse duration: 5 ns
- Laser energy: 16 mJ/pulse, repetition rate: 1 - 300 Hz
- Optical resolution: 1.5 µm
- Beam size: 2.5x2.5 mm² on mask
- Masks: structured metallic sheet or metal on quartz
- Materials: polymer, ceramic, glass, ...
Implementation of the microfluidic capillary structure.

Excimer laser machining

200 µm

$\phi_{\text{pillars}} = 25 \, \mu m$

Pillars machined in PMMA

STEP & REPEAT PROCESS FROM BASIC PATTERN ON MASK

(~ 0.25 s for 1 pattern with 25 µm depth)
Implementation of the microfluidic capillary structure.

Excimer laser machining

\[ \phi_{\text{pillars}} = 50 \ \mu m \]

STEP & REPEAT PROCESS FROM BASIC PATTERN ON MASK

10 \mu m square pillars
Implementation of the microfluidic capillary structure.

1. Direct laser writing of the mask for μ-pillars

Chrome-on-quartz masks

2. Excimer laser machining

Original chip in PMMA

3. Replication Master generation

Metallic insert

4. Hot embossing

PMMA embossed chip

5. Metrology
Implementation of the biochip optical part

Step 1: Nickel-mould template fabrication

- Transfer of the commercial prisms into an imprint
  
  ![Diagram of transfer process]

- Metal layer vacuum deposition

- Electroplating of Nickel

- Nickel-mould template
Step 2: Replication of the prism coupler by hot embossing

PMMA substrate

Nickel-template

Step 3: Sensing area coating (Gold, 50nm) and functionalization

Step 4: Association of the biochip with a 0.5-mm thick PMMA cover slab
Experimental validation: SPR sensogram

Signal, [RU]

Time, [s]

Water, n=1.330

Water-glycol solution (WGS), n=1.340

Sample injection

Refractive index resolution, $\delta n \approx 1.0 \cdot 10^{-4}$ [RIU]
Concept goals and key features

Biochip concept

- Integrated architecture
- Low cost (fabrication by replication)
- Easy use
  - Optical coupling without matching liquid
  - Passive capillary pumping (without an external pump)

Laser micro-machining of capillary structures

- Excimer mask projection technique is efficient for 10 – 50 µm pillars structures
- Flexible technique (different design can be quickly performed and tested), but requires a dedicated mask

Outlook for CSL

- Design and prototypage of microchip integrating optics, SPR and microfluidics
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