Monolithically integrated photonic lab-on-a-chip platform for biological applications

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Optical Transducer Issues

• Difficult integration of all optical and electrical components on the same chip

• Need for external optical components
   Bulky set-ups (portability issues)
   Expensive experimental set-ups
   Need for alignment (tedious process, takes time)

Solution: Monolithic integration of all passive and active optical components on the same Si chip
Optoelectronic Platform Concept

- LED
- $\text{Si}_3\text{N}_4$ WG
- PD
- spacer
- top cladding layer

- PCT WO2007/074348
Optoelectronic Platform Concept

Light Source (LED): Reverse biased avalanche diode

Spectral response: VIS-NIR (>450nm)

<table>
<thead>
<tr>
<th>Item</th>
<th>Maximum Rated Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Dissipation</td>
<td>150mW</td>
</tr>
<tr>
<td>Current</td>
<td>10mA</td>
</tr>
<tr>
<td>Reverse Voltage</td>
<td>15V</td>
</tr>
</tbody>
</table>

• Reverse breakdown voltage: \(~30V @ 25^\circ C\)

• Reverse dark current: \(\leq 2pA\)

• Measured Photocurrent: \(<700pA (\text{mm long WGs, monomodal in the vertical direction, multimodal in the horizontal direction})\)

• Capacitance: \(~2pF \text{ for } 400\times400\mu m \text{ pads}\)

Output Spectrum: 3hrs continuous operation. Recorded by QE65000 cooled spectrometer.
Integrated Optoelectronic Platform Advantages

- All active (LED, PD) and passive (Waveguides) optical components on the same chip
- Multiple transducers on the same chip
- Standard Si processing
- Very small size (depends on the sensor principle of operation)
- Potential integration of read-out electronics on the same chip

Integrated Optoelectronic Platform Applications

- OptoElectronic
- OptoElectroMechanical
Monolithically integrated interferometric biochips for label-free early detection of Human diseases (PYTHIA)

PYTHIA Objectives

• Broad Band Mach-Zehnder Interferometry: Proof of concept
• Arrays on a chip with wafer scale encapsulation
• Real-time label-free monitoring of biochemical reactions with high sensitivity and dynamic range
• Generic platform for portable diagnostic tools for early detection of diseases (Antibody assay (free and bound PSA- for prostate cancer), Oligonucleotide based detection (MEN2, RP))

WO/2009/115847: “Monolithically integrated physical chemical & biological sensor arrays based on broad-band Mach-Zehnder Interferometry”

www.pythia-project.eu
PYTHIA partners

A multidisciplinary team of eight partners (4 SMEs, 2 research centers, and 2 university departments) from six EU countries with complementary skills.

NCSR ‘Demokritos’, Greece
Optoelectronic sensor chip fabrication & functionalization

PhoeniX BV, Netherlands
Optical sensor simulation and design

LioniX BV, Netherlands
Optical sensor chip fabrication

Jobst Technologies GmbH, Germany
Microfluidics & encapsulation

Jagiellonian University, Poland
Sensor surface characterization

VTT, Finland
Read-out electronics and measuring system

Biogenomica SA, Greece
Biochip & system evaluation

University College London, UK
Biochip & system evaluation
10 label-free all Si-based monolithically-integrated optical transducers on a single-chip

- chip length = 9.25 mm, width = 4 mm
- die size ~40mm$^2$
- ~150 dies/wafer (4”)

Integrated Photo-Electro-Mechanical Transducer

**Optical cantilevers:**
- Miniaturized devices
- Very high sensitivity, Very good LOD
- Arrays of cantilevers on the same chip
- External light source and detector

**The Solution:**
- Integrated Light Source
- Integrated Photodetector
- Planar Waveguides

**The Concept:**
- The light travels through the cantilever

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“A Monolithic Photonic Microcantilever Device for in-Situ Monitoring of Volatile Compounds”
Conclusions

Monolithically integrated platform that combines light source (VIS/NIR), planar waveguides, photodetector

TRULY INTEGRATED PHOTONIC LoC
Various Transduction Principles have been explored:
  Mach-Zehnder Interferometer
  Cantilever
  Others are in progress.....................

CHARACTERISTICS
✓ Label-free detection
✓ Array of sensors on the same chip
4th Workshop on MultiAnalyte BioSensing Devices

Where: Athens, Greece
When: 7-8 September 2011

Abstract Submission Deadline: April 15, 2011
Notification of Acceptance: May 27, 2011
Early Registration Deadline: June 10, 2011

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