Design, Integration and Performance Evaluation of Optical Detection Elements for Miniaturized Biochemical Devices

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Optical detection is still the most widely used detection method in miniaturized devices for chemical analyses or biomedical applications (micro-Total Analysis Systems, Lab-on-a-Chip systems). In particular, fluorescence detection is very popular due to the excellent limits of detection achievable. This is often a challenge because of the small detection volumes in most biochemical microdevices. However, alternatives such as absorbance detection, which is much more universal in its applicability, and chemiluminescence, which does not require an external light source, are very attractive as well.

Fabrication techniques from the telecommunication industry can readily be adopted to make waveguides for chemical sensing [1,2]. However, new recipes needed to be developed to fabricate waveguides, which are transparent in the visible and the UV range of the optical spectrum, as these wavelengths are particularly important for chemical applications. We have developed UV-transparent planar waveguides to deliver and collect light at various places on a microchip, allowing for a number of specialized detection geometries. Figure 1 shows several waveguides designed to interface with a microfluidic channel arranged in a U-shape. This detector arrangement allows for very long absorption pathlengths, which helps increase the detection sensitivity of the device. A different use of waveguides is shown in Figure 2, where a multitude of waveguides resulting from a 1x128 splitter is placed alongside a fluidic channel. Such a layout can be applied to the measurements of velocities of beads or cells. The performance of these designs is discussed in terms of their detection efficiency and their suitability for the intended application. Design limits and possible solutions are evaluated.

For light detection directly on the chips back-side contacted photodiodes have been incorporated. By implementing photodiodes on the back-sides (i.e., away from the side where the light is generated) the electrical and fluidic access and the packaging of the chip is simplified (see Figure 3). The fabricated photodiodes were tested in a biochemical microdevice, where an enzyme reactor and a fluidic mixer were integrated to perform a series of chemical processes producing light as a by-product. The amount of this chemiluminescent light, which is proportional to the amount of analyte molecules present, was measured using the integrated photo-diodes. The challenges of the fabrication process and the performance of the device are discussed.

Finally, a device was designed, where fluidic channels, waveguides and photodiodes were integrated on the same substrate. Deliberately inserted grooves into the waveguide structures led to the coupling of light into the silicon substrate towards the back-side photodiodes.

Special attention has been paid to process procedures, since aligning the fabrication conditions for waveguides and photodiodes is a challenging task. First performance tests of the fabricated devices will be presented and the possibilities for improved designs will be discussed.

References:

[1] P. Friis, K. Hoppe, O. Leistiko, K. B. Mogensen, J. Hübner, J. P. Kutter
Applied Optics, 40, 2001, p. 6246
[2] J. Hübner, K. B. Mogensen, A. M. Jorgensen, P. Friis, P. Telleman, J. P. Kutter
Review of Scientific Instruments, 22, 2001, p. 229

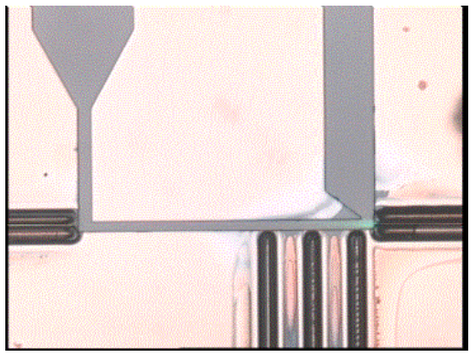

Figure 1: Waveguides at various positions interfacing to a microfluidic channel arranged in a U-shape.

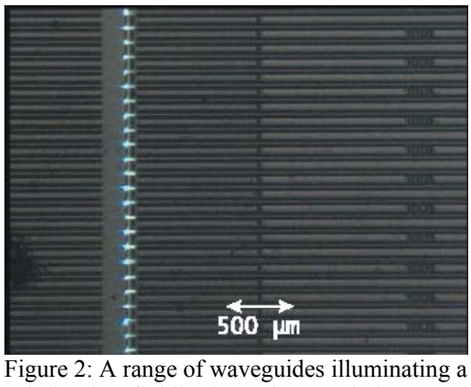

Figure 2: A range of waveguides illuminating a dye solution in a fluidic channel at regularly spaced intervals

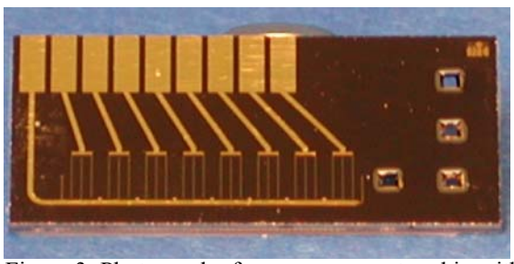

Figure 3: Photograph of an enzyme reactor chip with back-side contacted photodiodes. The photodiodes, the electrical connectors and the fluidic through-holes can be seen.