THIOL-ENE WAVEGUIDES AS PROMISING COMPONENTS OF OPTOFLUIDIC MICROSYSTEMS

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ABSTRACT
Fabrication of optical elements from inexpensive polymer materials using mass-production tools is a current challenge. In this paper, thiol-ene based polymer waveguides and their integration into microfluidic systems are presented. Due to physical properties of thiol-ene materials the waveguides can be easily sealed with a microsystem, and connected with optical fibers. The presented thiol-ene waveguide microsystem was used for determination of 4-methylumbelliferone showing good agreement with results obtained with the standard method using a spectrofluorimeter.

KEYWORDS
Thiol-ene, waveguide, optofluidics.

INTRODUCTION
Integration of cost-effective and suitable for mass production optical elements with microfluidics are a prerequisite for the successful development of various lab-on-a-chip systems and their commercialization [1].

Conventional optical fibers and waveguides are attractive due to their ability for guiding and focusing of light to measurement points, and efficient coupling to commercial light sources and detectors, thereby increasing the design flexibility [2]. However, many of the materials used for fabrication of optical waveguides (SU-8, PMMA, PC, COCs) exhibit a good transparency only in the visible range, or are costly and more challenging to work with (SU-8, glass) [3]. The efficiency and economy of the design and fabrication of optical waveguides can be considerably enhanced if ways to prepare optical elements from new types of materials are explored.

In this paper, we present thiol-ene polymers as promising materials for optofluidic applications. The thiol-ene reaction mechanism affords delayed gelation, low shrinkage, high conversion, and uniform crosslink densities resulting in the ability to obtain polymers with unique physical and mechanical properties. Moreover, thiol-ene polymers show good adhesion to other materials, good chemical resistance to organic solvents, and have high refractive index [4]. So far, thiol-ene-based polymers have been used in a number of ways to fabricate microstructures, and obtain various functional elements such as lenses, photonic crystals or dielectric layers [5]. Here, we extend this list by using thiol-ene-based polymers as integrated planar waveguides.

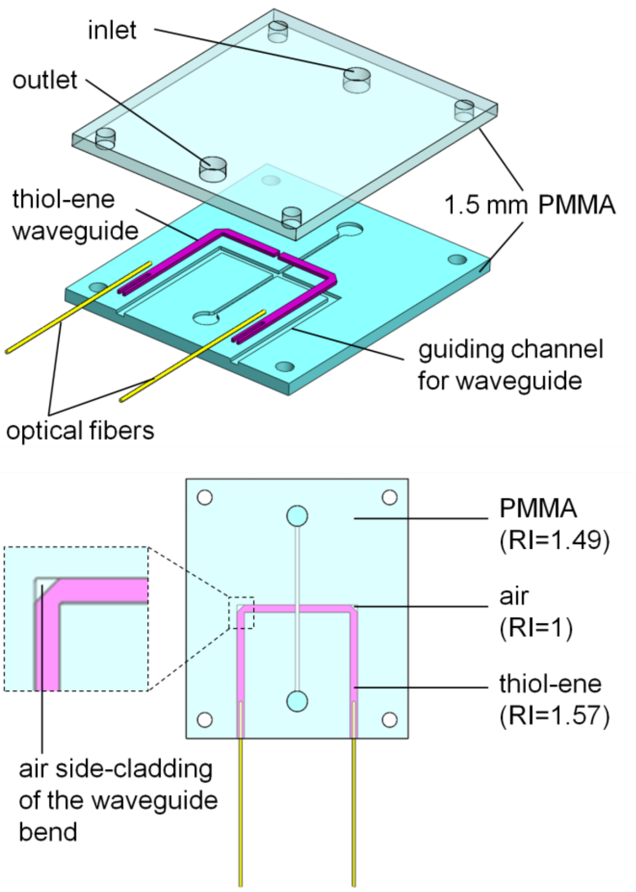

Figure 1. Schematic view of the PMMA microsystem with thiol-ene waveguides.

EXPERIMENTAL & RESULTS
1 mm wide and 500 µm high thiol-ene waveguides were fabricated using a PDMS mould. A stoichiometric mixture of "thiol" (pentaerythritoltetrakis(3-mercaptopropionate)) and "ene" (1,3,5-triallyl-1,3,5-triazine-2,4,6(1H,3H,5H)-trione) was poured into the mould, and cured by UV exposure for 4 min. Next, the waveguides were manually inserted into the guiding microchannels of a simple PMMA system (Figs. 1 and 2). After thermal bonding of a lid (85ºC), the system was perfectly sealed and no leakage through the waveguide guiding channels was observed even for flow rates of 100 µL/min.

The waveguides of the microsystem could easily be connected to an external light source via optical fibers inserted into integrated coupling structures. 90-degree waveguide bends utilizing air as side-cladding enables a significantly improved transmission of the excitation light, while maintaining a small footprint of the device.

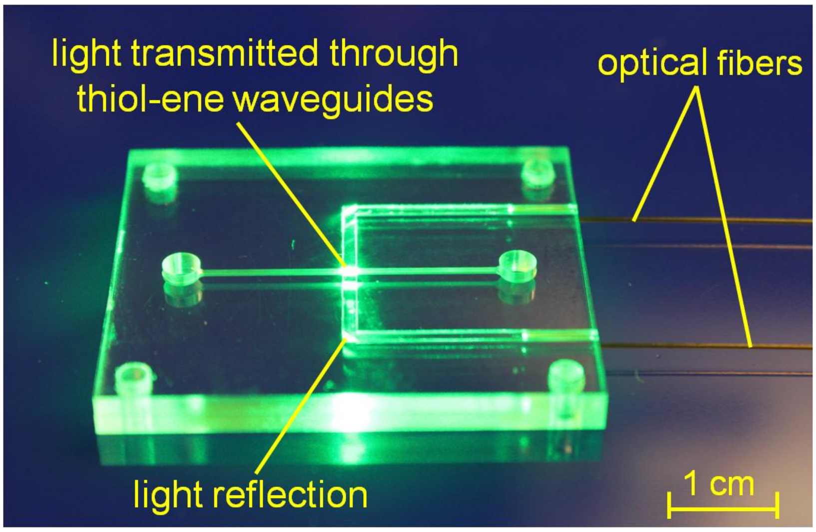

Figure 2. Photograph of the microsystem.

The thiol-ene waveguide microsystem connected to a LED and a PMT was validated by measurements of fluorescence from a deprotonated form of 4-methylumbelliferone (λ_{ex}=365 nm, λ_{em}=445 nm), which is commonly used for kinetic investigation of enzyme activity. The detection limit using the presented setup is quite low (LOD=650 nM) (Fig. 3), and, comparing with the LOD of the standard method using a very sensitive spectrofluorimeter and a 1cm x 1cm quartz cuvette (10 nM), demonstrates the potential of thiol-ene-based waveguides as promising optical components. They are attractive due to their easy manipulation, fabrication, sealing within a microdevice, simple connection with optical fibers, and the further possibility of tuning different properties such as stiffness (reduced if the thiol component is used in excess) or a broader wavelength range using appropriate thiols and enes (Fig. 4).

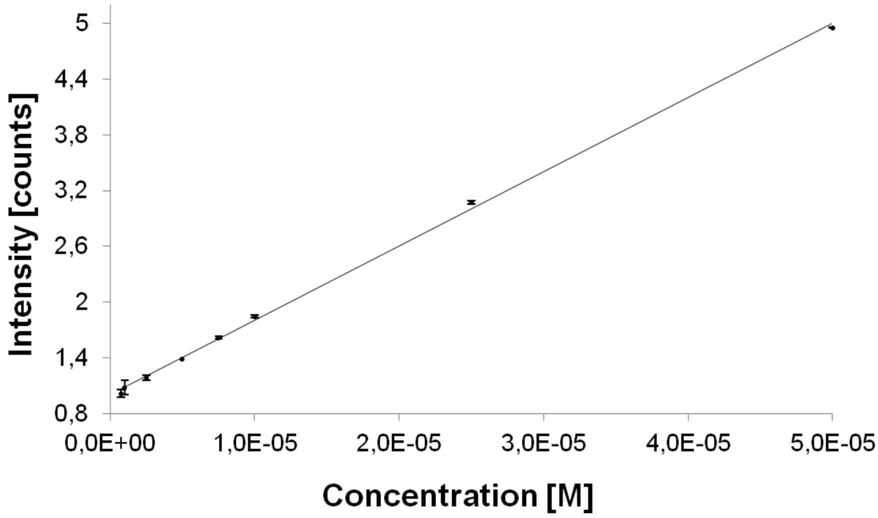

Figure 3. Calibration curve of a deprotonated form of 4-methylumbelliferone using the presented PMMA system with thiol-ene waveguides (LOD=650 nM).

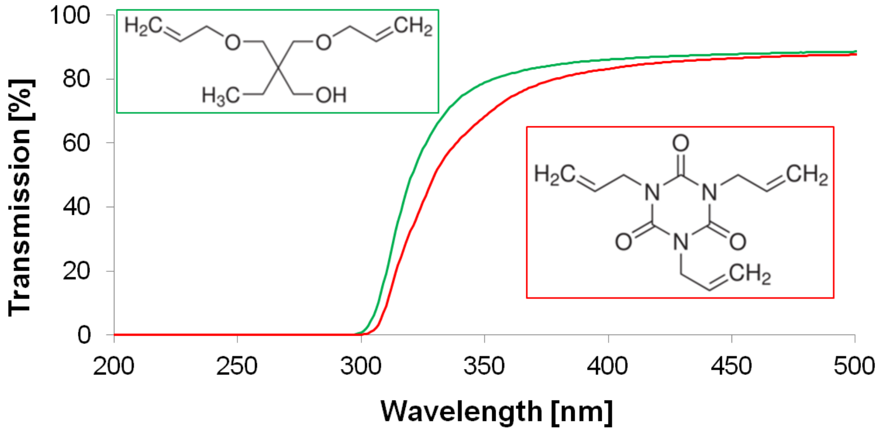

Figure 4. Optical transmission spectra of 5 mm thick blocks prepared from a stoichiometric mixture of pentaerythritoltetrakis(3-mercaptopropion ate) with: trimethylolpropane diallyl ether (green curve) and 1,3,5-triallyl-1,3,5- triazine-2,4,6 (1H,3H,5H)-trione (red curve).

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