INTEGRATION OF OLED LIGHT SOURCE AND OPTICAL FIBERS ON A PDMS BASED MICROFLUIDIC DEVICE FOR ON-CHIP FLUORESCENCE DETECTION

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ABSTRACT

A detection device is proposed with an integrated light source based on Organic Material. The microfluidic channels are fabricated using PDMS material, with also an inlet channel where an optical fiber is inserted and put close to the microfluidic channel. This fiber is then plugged to a PMT to analyze the fluorescent emission. Measurements were carried out with several concentrations of Rhodamine B, from 1 to 100 μM. The output voltage shows a linear response versus the dye concentration, but the results also exhibit problems that should be solved in order to improve the chip sensitivity.

Keywords: OLED, fluorescence spectroscopy, PDMS, lab-on-a-chip

INTRODUCTION

The Lab-on-a-chip concept that corresponds to the complete integration onto the microchip of all the elements required to perform a biochemical analysis, has been studied for many years. Efforts were done in order to reduce the size, and also to improve the efficiency of such integrated devices using various techniques and materials. Actually, many basic processes have been successfully miniaturized like μ-PCR, μ-CE... But the detection element is still a challenging part of the lab-on-a-chip. Several methods have been reported based on fluorescence spectroscopy, with optical fibers [1], integrated waveguides [2] or an optical fiber coupled with an integrated photodetector [3]. But all these devices still need a light source. Then an Organic Light Emitting Diode (OLED) is proposed as an on-chip light source. The design and fabrication processes of the OLED and the Poly(Di-Methyl)Siloxane chip are first briefly detailed. Then the results with Rhodamine B fluorescent dye are reported with concentrations ranging from 1 to 100 μM.

FABRICATION PROCESS

Starting from a glass substrate pre-coated by a uniform Indium Thin Oxide layer (thickness around 150 nm), the ITO layer (transparent lower electrode) is first patterned using conventional lithography method. The substrate is then introduced inside an Organic Molecular Beam Deposition system (OMBD). The desired organic materials

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(α-NPD and Alq) are successively deposited by thermal evaporation through the same square shadow mask. The sample is then moved to another chamber for the Lithium Fluoride (0.5 nm) and Aluminium (120 nm) deposition through a different shadow mask in order to obtain the device shown in Fig. 1 [4].

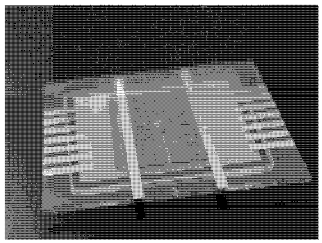


Figure 1. *Photo of the device, with encapsulation system to protect the Organic Materials from O_2 contamination*

To fabricate the PDMS chip [4], a mold master made of a thick negative photoresist called SU-8 is used. After mixing the PDMS solution with a curing agent (ratio 1:10), the gel is poured over the mold master and baked for 2 hours at 65 °C. The PDMS layer is peeled off, and bonded onto a thin glass substrate after Oxygen plasma for 10 seconds. This PDMS layer as shown in Fig 2 (on the left side) includes two kinds of channel: the microfluidic channel where the sample solution will be introduced and the fiber inlets where the 105 μm core optical fiber will be inserted.

DESIGN OF THE STRUCTURE

The two free glass surfaces are juxtaposed and aligned so the OLED is enlightening the microfluidic channel in front of the fiber. The optical fiber is plugged to a Photo-Multiplier Tube to analyze the light power collected by the fiber.

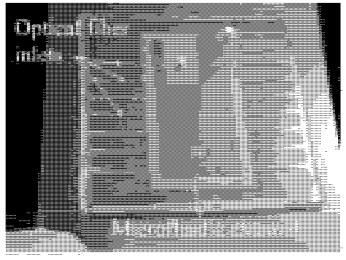
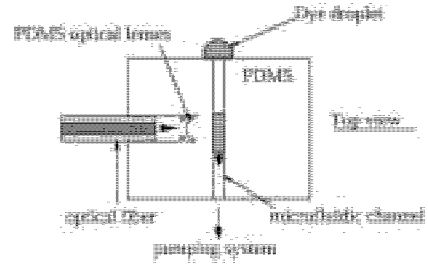


Photo of the PDMS layer bonded onto a glass substrate



PDMS layer design with the optical fiber inserted into a channel very close to the microfluidic channel

Figure 2. *Fabrication of the PDMS microfluidic device*

The OLED exhibits a wide light spectrum centered on 510 nm that matches the excitation wavelength of Rhodamine B fluorescent dye. In order to prevent the dye absorption by PDMS, a system as described in Fig. 2 was set. At one end of the microfluidic channel, 4 μl of dye is introduced while a pumping system is working on the other side. By this

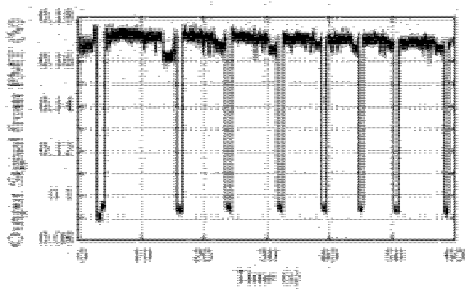
technique, the fluorescent solution and the PDMS layer facing the optical fiber are in contact during around 1 second, and reduce drastically the absorption phenomenon.

RESULTS ANS DISCUSSION

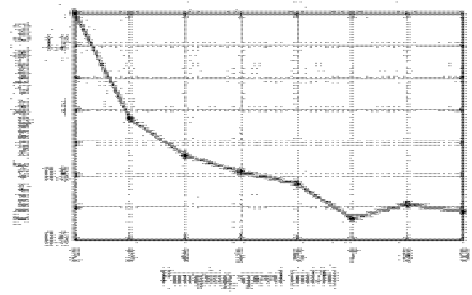
In order to minimize the contact between PDMS and Rhodamine B, first measurements were performed with water introduced inside the microfluidic channel. On the left part of Fig. 3, the PMT output voltage exhibits strong variation even if the liquid flowing inside the microchannel doesn't exhibit any fluorescent property. The OLED – fiber coupling (around 0.17 V) corresponds to a real direct coupling, but also to the light that is reflected by the PDMS-air interface due to the refractive index mismatch, especially at the top of the microfluidic channel. When water is introduced, this index mismatch is reduced so a larger amount of light is transmitted through the PDMS layer. Then this light power is no longer collected by the fiber and it leads to a decrease of the output signal (first peak in Fig. 3, around 0.09 V). When the microfluidic channel facing the optical fiber is filled with water, the intensity of the OLED – fiber coupling is reduced so that the output voltage of the PMT also decreased. The period of time the microfuidic channel is filled with water, and so the width of those negative peaks, is then directly dependant of the pumping speed. By increasing the pumping speed, the peaks width decreases and the contact between the PDMS material and the Rhodamine B droplet is minimize.

On the right part of Fig. 3 are plotted the sample time checking versus the pumping speed, with a behavior similar to 1/x function. In order to decrease the time contact below 1 second, the 4 ml/h pumping speed was chosen for our experiments.

The results with dye are presented in Fig. 4 that depicts the output signal of PMT when several samples were flowing inside the microfluidic channel. Different solutions were introduced sequentially into the microfluidic channel: water, 1, 5, 10, 25, 50, 75 and 100 μM Rhodamine B dye diluted into Carbonate buffer solution, and water.



PMT output signal with water flowing inside the microfluidic channel and various pumping speed



Time of sample illumination in front of the fiber versus the pumping speed

Figure 3. *Calibration measurements with water*

When the sample containing fluorescent dye is flowing inside the microchannel, the previously described effect is combined with the fluorescent light emission from the dye. Depending on the dye concentration, the output signal varies and the differences between this level and the reference one are summarized in Fig. 4.

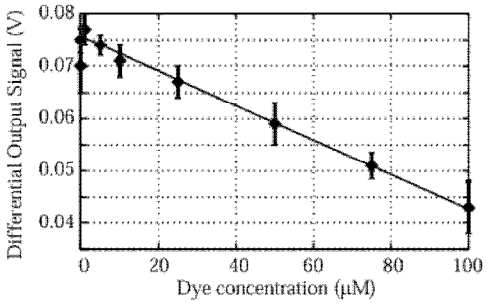


***Figure 4**. Differential output signal of PMT versus the concentration of Rhodamine B dye diluted into Carbonate buffer solution*

The output voltage versus the dye concentration exhibits a linear dependence with concentration varying from 1 μM to 100 μM. But the error bars are quite large and cannot allow precise measurement and efficiency concentration determination from a sample. These error bars, coming from a non-flat and non-stable signal, can be attributed to the measurements systems, with non-uniform concentration inside the measured droplet. Due to the pumping system, some droplets remained inside the fluidic channel after a test. By introducing a new sample inside the microchannel with a different concentration, the two solutions mixed and the concentration inside the plug became non-uniform.

But in case of capillary electrophoresis, these problems should disappear and yield an efficient measurement method with integrated light source.

CONCLUSION

A new detection device based on fluorescent spectroscopy, with an on-chip light source and a fiber connected to a PMT was proposed and tested. The studied design exhibits a strong OLED-Fiber coupling, but measurements were carried out with several dye concentrations, from 1 to 100 μM. This technology is promising, but the design should be optimized in order to decrease the noise level, and thus enhance the measurement sensitivity and accuracy.

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