3D INTEGRATION OF MICROLENSES TO REALIZE A LOW-POWER AND HIGH-SENSITIVITY OPTICAL DETECTION SYSTEM FOR A DISPOSABLE LAB-ON-A-CHIP

Sung-Il Chang and Jun-Bo Yoon

Korea Advanced Institute of Science and Technology (KAIST), Korea

ABSTRACT

A new optical detection system consisting of 3D-integrated microlenses, reflector, and LED was proposed and realized. The microlenses were fabricated with 3D diffuser lithography and PDMS replication method. The propsed optical system showed 3 times better sensitivity than the conventional planar optical detection system did.

Keywords: Diffuser lithography, Microlens, Optical detection system

1. INTRODUCTION

As a need for self-diagnosis and point-of-care increases remarkably, researches on a very cheap, but highly sensitive disposable lab-on-a-chip are being accelerated. Among them, it has been one of the key issues to integrate a low-power and high-sensitivity optical detection system into a lab-on-a-chip. As a result, microlenses have been widely utilized to focus and intensify an excitation light and an emitted fluorescence light [1-5]. However, more sophisticated design of the microlenses to gather as much light as possible is imminent for the extremely low-power optical detection system. Furthermore, the integration of various microlenses having their own functions has been overlooked in the previous works, while the importance of the microlens itself has been recognized.

In this paper, we proposed an integrated optical detection system suitable for a cheap and low-power disposable lab-on-a-chip, based on a powerful fabrication technology of versatile microlenses that we have developed recently.

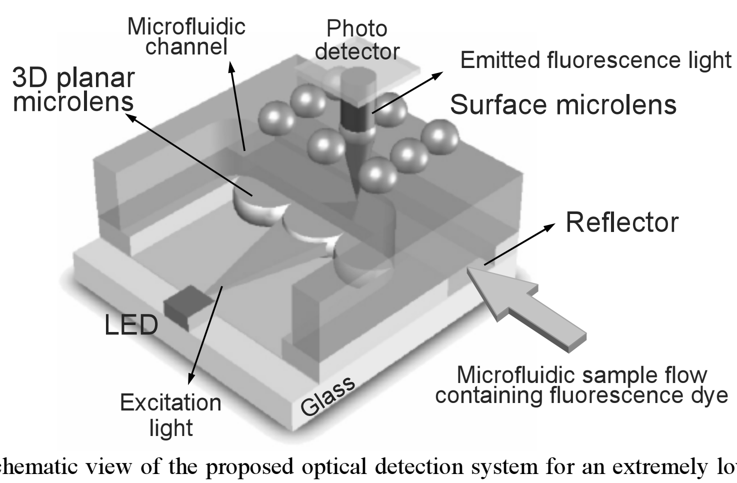

Figure 1. Schematic view of the proposed optical detection system for an extremely low-power and low-cost disposable lab-on-a-chip

2. RESULTS AND DISCUSSION

Figure 1 shows a schematic view of the proposed detection system. The proposed 3D planar microlens having a rounded sidewall collects the weak excitation light from common LED into a focal point to maximize its intensity. Through an elaborate design of the microlenses, the excitation light is focused on the focal point of the surface microlens so that the emitted fluorescence light may be collected to the photodetector through the surface microlens with a high efficiency. Moreover, the reflector reflects the downward fluorescence light to the surface microlens to enhance detection sensitivity.

Figure 2 shows the fabrication process. The photoresist molds for the microlenses and the microfluidic channel were formed by using novel 3D diffuser lithography [6-7] and their cross-sectional SEM images were shown in Fig. 2(a) and (b), respectively. We replicated the molds with PDMS and bonded with each other. Finally, PDMS peel-off from the molds was followed by bonding it on a slide glass coated with a gold reflector. SEM photographs of the fabricated detection system and the microlenses are shown in Fig. 3.

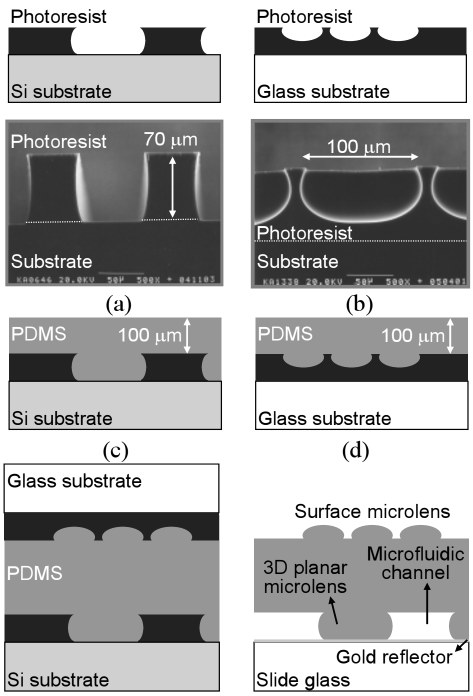

Figure 2. Fabrication process of the integrated optical detection system. (a)(b) Photoresist mold formation by using a 3D diffuser lithography. (c)(d) PDMS spin coating (e) PDMS bonding and curing (f) PDMS peel-off and bonding on a slide glass coated with a gold reflector

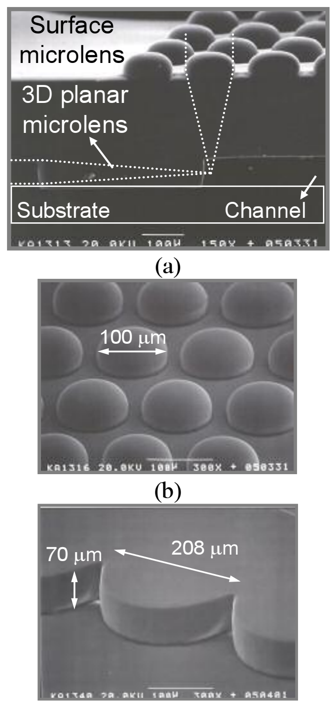

Figure 3. (a) Cross-sectional SEM photograph of the fabricated detection system. The expected paths of lights were also shown with dotted lines. Enlarged photographs of the (b) surface microlens and (c) 3D planar microlens

For the characterization of the fabricated system, we used 10^{-3} M Rhodamine fluorescence dye solution in ethanol ($\lambda_{excitation}$=525 nm $\lambda_{emission}$=555 nm) and an epoxypackaged green LED excitation source which is as cheap as $0.35. Microscope photograph in Fig. 4 shows the emitted fluorescence light through the surface microlens.

We obtained the excellent optical spectrometer measurement results showing that the proposed system enhanced the intensity of the emitted fluorescence light about three times as shown in Fig. 5. Furthermore, we also measured the intensity of the fluorescence light with different LED powers to test the minimum power required to the system. Even at the low consumed power of 7 mW (generally used LED consumes several tens to hundreds of mW), we could distinguish the fluorescence light from the background noise.

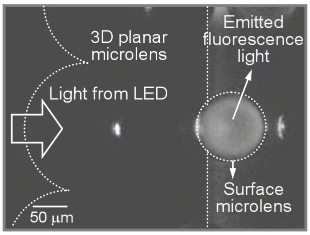

Figure 4. Microscope photograph showing the emitted fluorescence light through the surface microlens when an LED was used for an excitation source

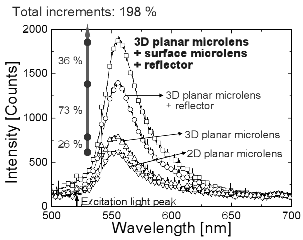

Figure 5. Optical spectrometer measurement results of the fabricated optical detection system with the integrated microlenses and the reflector.

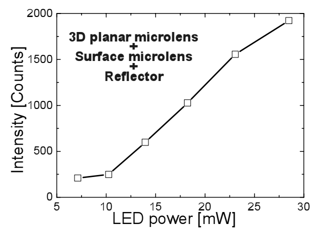

Figure 6. Intensity of the fluorescence light with different powers consumed by LED.

3. CONCLUSIONS

To summarize, we greatly enhanced sensitivity of the low-power disposable lab-on-a-chip more than three times by using the inexpensive LED light source and the 3D integrated microlenses combined with the reflector. This work will help the realization of the very low-cost biochips for various biomedical purposes.

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