Extended Abstracts of the 2013 International Conference on Solid State Devices and Materials, Fukuoka, 2013, pp830-831

G-2-5

Organic Optoelectronic Platform for Droplets Actuation and Cells Manipulation

Tung-Ming Yu[1], Po-Chen Shih[2], Ming-Huei Liu[3], Long Hsu[1] and Cheng-Hsien Liu[2*]

[1] National Chiao-Tung Univ.
1001 University Rd., Hsinchu 30010,Taiwan
[2] National Tsing-Hua Univ.
No. 101, Section 2, Kuang-Fu Road, Hsinchu 30013, Taiwan
Phone: +886- 3-5715131 E-mail: pcshih@mx.nthu.edu.tw
[3] Sinonar Corp.
8 Prosperity Road, Hsinchu Science Park, Hsinchu, 30078, Taiwan

Abstract

This paper reports the organic optoelectronic platform which integrates optoelectrowetting (OEW) and optoelectronic tweezers (OET) by spin-coating titanium oxide phthalocyanine (TiOPc) as a photoconductive layer for realizing the manipulation of cells and the actuation of droplets in a single chip.

1. Introduction

This paper reports the organic optoelectronic platform which integrates optoelectrowetting (OEW) and optoelectronic tweezers (OET) by spin-coating titanium oxide phthalocyanine (TiOPc) as a photoconductive layer for realizing the manipulation of cells and the actuation of droplets in a single chip. The equivalent circuit models of this platform are established and simulated for indicating the operation regions of OET and OEW under the frequency modulation. We demonstrate two kinds of operation methods: (1) Stromal cells in a droplet are concentrated by OET force with inverse strip-shaped optical patterns and the applied electrical signal in the high frequency range. (2) Droplets are actuated by OEW force with square-shaped optical patterns and the applied electrical signal in the low frequency range.

S. K. Fan et al. group establish identical and dielectric-coated electrodes of dielectrophoresis (DEP) and electrowetting on dielectric (EWOD) in a single chip to achieve the concentration of Neuroblastoma cells in an EWOD-actuated droplet by applying appropriate electrical signals with different frequencies on these electrodes [1]. J. K. Valley et al. present the united platform which uses the a-Si (amorphous silicon)-based OEW structure to manipulate HeLa cells and droplets by controlling image-induced virtual electrodes and modulating the frequencies of electrical signals [2]. In our previous researches, TiOPc-based OET and OEW devices have been respectively developed [3, 4]. Now we demonstrate the concentration of Stromal cells and the actuation of droplets in the TiOPc-based optoelectronic platform with frequency-modulated OET and OEW.

2. Results

The setup of the platform shown in Figure 1 includes a LCD projector, optical lens module (L1, L2 and M1 parts), a microscope and a CCD camera. Optical images are produced from the projector and transmitted though optical lens module onto the device. The function generator and the AC signal amplifier are used to generate the frequency-modulated electrical signals for OET and OEW operations.

Figure 2 shows the structure of the platform and related equivalent circuit models in different operation conditions. TiOPc, SU-8 and Teflon, from bottom to top, are spin-coated on the bottom ITO glass with the thickness about1.5μm, 1μm, and 20nm respectively. The top ITO glasses are spin-coated with 20nm Teflon. A droplet including cells is rested with the spacer (~50um) in between. Figure 2(a) shows initial condition. Major voltage drops across the TiOPc layer when no light illumination and the applied electrical signal at the low frequency. Neither OET nor OEW phenomenon happens. Figure 2(b) shows OEW mode. In the low frequency range, the SU-8 layer has the higher impedance to result in most voltage drop across it in the light illuminating location. The square-shaped virtual electrode induces electrowetting force to drive a droplet. Figure 2(c) shows OET mode. In the high frequency range, most voltage concentrates on a droplet in the image pattern due to the higher impedance of the liquid layer. The strip-shaped virtual electrodes generate DEP force on cells. According to equivalent circuit models of OEW and OET, the changes of $V_{Insulator}$ (voltage across the insulator) and V_{water} (voltage across the liquid layer) varying with frequencies are simulated in Figure 3 to distinguish OEW and OET regions.

Figure 4 (a)-(d) show that a droplet containing microparticles is trapped and moved by the square-shaped image with the voltage of 50V at 500 Hz. The velocity of the droplet movement is about 14μm/s. Figure 5 (a)-(d) show that Stromal cells experience positive DEP and are concentrated in the center of the picture by inverse strip-shaped images when AC signal (bias = 7.8V, frequency = 100kHz) is applied. The measured velocity of Stromal cells is about 3μm/s and OET force on cells is about 10 pN.

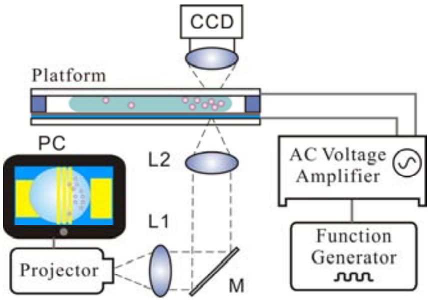


Fig. 1 Setup of the organic optoelectronic platform.

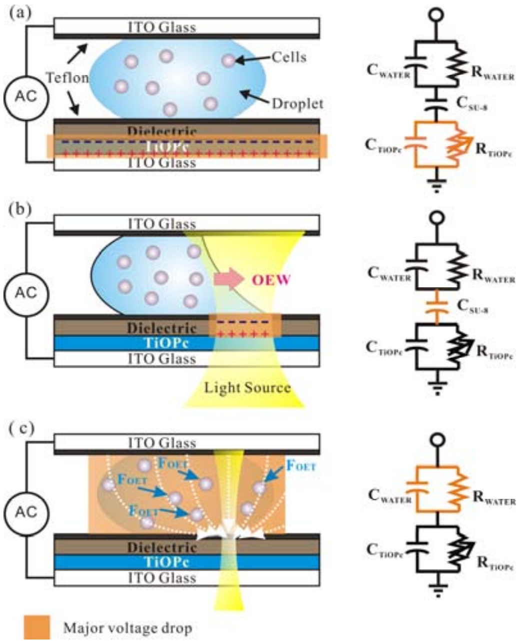


Fig. 2 Working principles of organic optoelectronic platform. (a) Initial condition; (b) OEW mode; (c) OET mode.

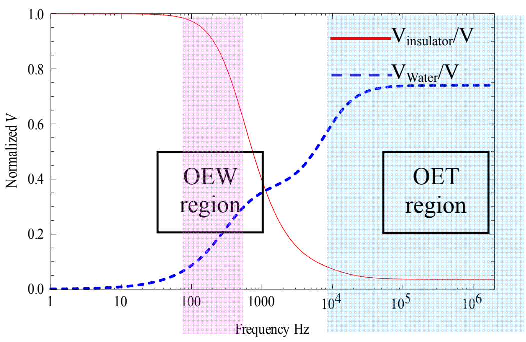
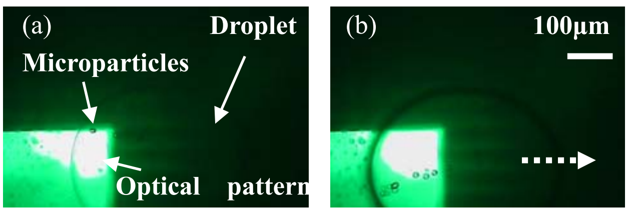


Fig. 3 In light illumination, OEW is the dominant force in the low frequency range (pink area). OET becomes the dominant force in the high frequency range (light blue area).



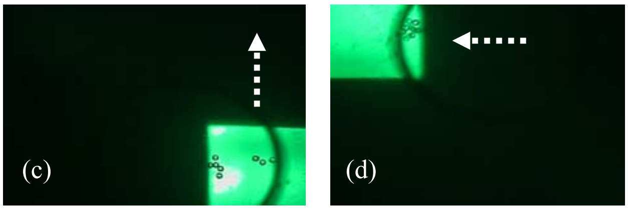


Fig. 4 (a)-(d) A droplet containing microparticles is trapped and moved in the direction of the optical pattern.

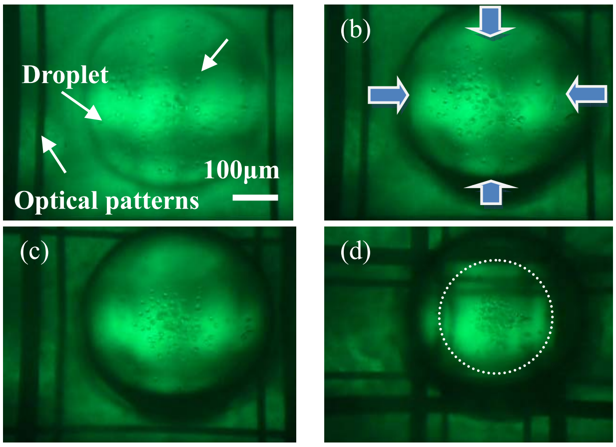


Fig. 5: (a)-(d) Stromal cells are concentrated by using inverse strip-shaped optical patterns moving from the edges to the center of the picture.

3. Conclusions

We have demonstrated that a droplet containing microparticles was trapped and moved by the square shaped image with the voltage of 50 V at 500 Hz. The velocity of the droplet movement is about 14μm/s. We also demonstrated that a droplet containing Stromal cells was trapped by inverse strip-shaped images with the frequency of 100kHz. The measured velocity of Stromal cells is about 3μm/s and OET force on cells is about 10 pN.

Acknowledgements

This research was supported by the National Science Council of Taiwan, under the grant NSC-98-2120-M-007-003. The authors would like to thank Sinonar Corp. (Taiwan) for providing TiOPc material and helping the fabrication.

References

[1] S. K. Fan et al.,*Cross-scale Electric Manipulations of Cells and Droplets by Frequency-modulated Dielectrophoresis and Electrowetting*, *Lab Chip*, **8**(2008)1325

[2] J. K. Valley et al., *A Unified Platform for Optoelectrowetting and Optoelectronic Tweezers*, *Lab Chip*, **11**(2011)1292.

[3] S. M. Yang et al., *Dynamic Manipulation and Patterning of Microparticles and Cells by Using TiOPc-based Optoelectronic Dielectrophoresis*, *Opt. Lett.*, **35**(2010)1959.

[4] T. M. Yu et al., *Integration of Organic Opto-electrowetting and Poly(ethylene) Glycol Diacrylate (PEGDA) Microfluidics for Droplets Manipulation*, *Sens. Actuators B*, (2011), In Press.