ELECTRODE SPATIAL DESIGN FOR A NEW MICROFLUIDICS IMPEDANCE FLOW CYTOMETER

Ting-Wei Wu*, Chia-Hong Gao, Yi-Zhan Huang, Ting-Wei Lin and Chih-Ting Lin
Graduate Institute of Electronics Engineering, National Taiwan University, Taipei, Taiwan

ABSTRACT

In this paper, we present two new electrode spatial patterns identified for different applied ac operational frequency in our designed particle-analyzing device. To achieve effective particle analysis, 4 coplanar electrodes were designed and fabricated on glass substrates. 1 V ac signal is applied on one specified electrode to cause electrical field for impedance sensing. However, limited to non-ideal capacitive effect, there will be an constrained operational frequency range. Stray capacitance effect disturbs impedance analysis especially in high frequency domain where thwarts jobs for specifying cell types. Therefore, this work reports a new method for minimizing the effect by designing sensing electrode geometry.

KEYWORDS: Microfluidics, Impedance, Electrode Geometry, Flow Cytometry

INTRODUCTION

Impedance flow cytometry provides a convenient, fast and simple way to fulfill single cell analysis [1-2]. Such that Renaud et al proposed the first microfluidics-based impedance cytometer by classifying beads of 5, 8 µm at 1.72 MHz [2]. However, since the device is powered under an ac electric signal, there will be an operational frequency range constrained by double layer capacitance and stray capacitance effects. In our previous work reported at IMCS ’16 [3] and NEMS ’17 [4], this frequency range i.e. 1 MHz to 10 MHz has been specified on the basis of a developed-modified electrical model in our designed device. Some work has dealt with double layer effect by utilizing gold microelectrodes [1] and platinum electroplated ones [5]. However, high frequency area, which is important for exploring cell intracellular properties, has few methods to deal with stray capacitance deterioration. Extra inductor circuit with resonance frequency proposed by Wood et al. [6] has shown to improve its sensitivity. However, only one specific resonance frequency in their work is available instead of an adequate spectrum for high-frequency consecutive sensing. Also simultaneously extra circuit increases their complexity on cost and area. So, this work reports a new method for minimizing stray capacitance effect by designing sensing electrode geometry. Identical fabrication steps are utilized but with better sensitivity at a broader operational frequency range.

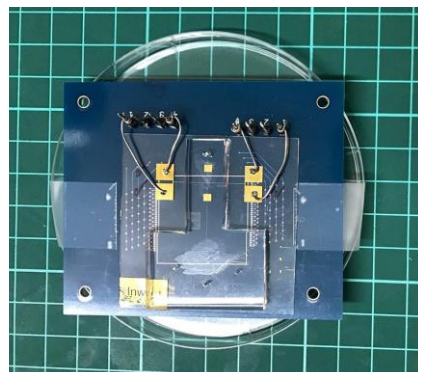
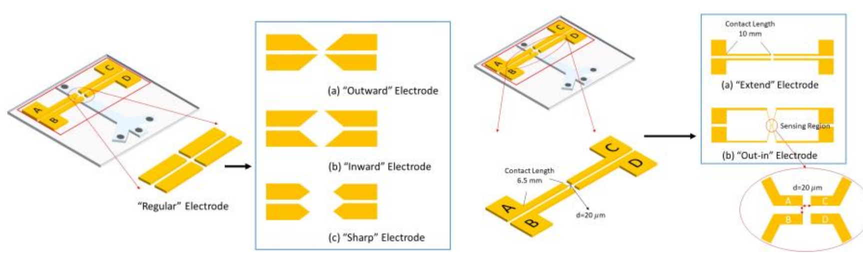


Figure 1: The real picture of the designed device.

EXPERIMENTAL

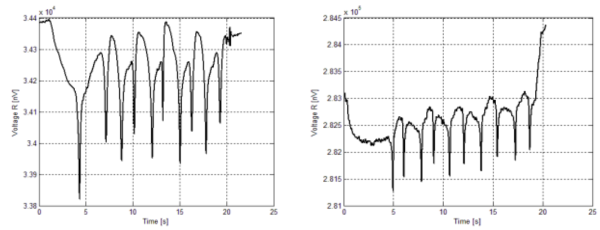
The fabrication process and experimental setup has been reported in previous works [3-4]. The real picture of device is shown in Figure 1. The polydimethylsiloxane (PDMS) channel is bounded on an oxygen-plasma treated glass substrate with 20 nm chromium and 50 nm gold sensing electrodes on it. To obtain particle size and position details, four electrodes are grouped as across (A-C) and neighbor (A-B) signal with electrode A applied by 1V signal. To further differentiate particle type, we propose new electrode design based on the previous one. Local variation and Contact length variation effects are defined for them shown in Figure 2. Local variation stands for the geometry variation on electrode’s sensing region. Tip effect is considered in this design to improve signal delivery theoretically. On



(a) *(b)*

Figure 2: Overall schematic of the device with (a) local sensing region variation and (b) specified contact length variation.

the other hand, contact length is defined to be the length where two electrodes' distance is 20 µm. Stray capacitance effect deteriorates failure of sensing especially when this length is considered large. Therefore new design is proposed hopefully to minimize the effect. Finaaly, 6 µm and 10 µm polystyrene beads are respectively injected into the microchannel upon these new designed electrodes. An example peak value of an impedance response could be experimentally shown using defined "Inward" and "Out-in" electrodes in Figure 3.

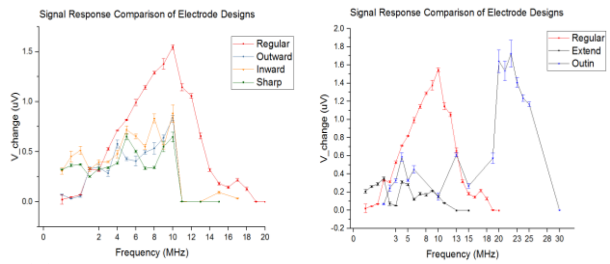


(a) (b)

Figure 3: Sample signal response of 10um beads (a) at 500kHz for "Inward" Electrode and (b) at 20MHz for "Out-in" Electrode.

RESULTS AND DISCUSSION

Employing the previous definitions of across signal throughout an operational frequency spectrum, Figure 4 indicates signal response distributions on each effect. Local variation effect shows good sensitivity of the electrode at frequency lower than 1MHz while contact length variation effect increases the ideal frequency range up to around 20-30 MHz. It shows the experimental results substantiate the new sensing electrode geometry's ability of extending the operational frequency range down to 300kHz and up to 30MHz and size differentiation. Non ideal capacitive effect is then testified to be alleviated by new electrode design. The proposed "Out-in" electrode will be able to implement bead type classification at further high frequency without disturbance of stray capacitance effect. Also the paper demonstrates the importance of electrode geometry on frequency selection of impedance cytometry.



(a) (b)

Figure 4. Signal Response Spectrum for (a) Local Variation Effect and (b) Contact Length Variation Effect.

CONCLUSION

In this work we show a high-frequency sensitivity dependence on new electrode geometry in particle-analyzing devices. Stray capacitance effect could be alleviated by introducing proposed "Out-in" electrode while another "Inward" electrode could reduce double layer capacitance effect in low frequency domain experimentally. In future work, "Inward" electrode could be used for bead size and position classification at low applied operational frequency while "Out-in" electrode for bead type differentiation at high frequency.

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REFERENCES

[1] H. E. Ayliffe, A. B. Frazier, and R. D. Rabbit, "Electric impedance spectroscopy using microchannels with integrated metal electrodes," *J Microelectromech Syst*, vol. 8, pp. 50-57.

[2] S. Gawad, L. Schild, and Ph. Renaud, "Micromachined impedance spectroscopy flow cytometer for cell analysis and particle sizing," *Lab Chip*, vol. 1, pp. 76-82, 2001.

[3] T.-W. Wu, C.-H. Kao, and C.-T. Lin, " Microfluidic Cell Counting Device Based on Impedance Analysis," *16th International Meeting on Chemical Sensors*, Jeju, Korea, Jul. 2016.

[4] T.-W. Wu, C.-H. Kao, and C.-T. Lin, "Impedance Spectroscopy for Microfluidic Particle-analyzing Device with Spatial-Coplanar Electrode Design,", *IEEE-NEMS '17*: Los Angeles, U.S.A, 2017.

[5] S. Zheng and Y.-C. Tai , "Human Blood Cell Sensing with Platinum Black Electroplated Impedance Sensor," *IEEE-NEMS '07*: Bangkok, Thailand, 2007.

[6] D. K. Wood et al, "High-Bandwidth Radio Frequency Coulter Counter," *Appl. Phys Lett*, vol. 87, no. 184 106.

CONTACT

* T.-W. Wu; phone: +2-3366-9603; r04943173@ntu.edu.tw