Radio Frequency Resonator for Continuous Monitoring of Microfluidic Droplet Size Dispersity

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Abstract

INTRODUCTION

Droplet microfluidic systems are gaining a lot of importance in several areas of biology and chemistry because they are allowing new methodologies with greater controllability and more accuracy than traditional methods [1], [2]. In such systems, micro-droplets are used as a platform to carry out biological assays or chemical micro-reactions in a confined and controlled space[3], [4]. Microfluidic chips also allow the integration of electrical, optical, thermal, and other sensing systems for monitoring purposes as well as the integration of post-processing steps (i.e. external energy inputs) such as confined UV light exposure, localized heaters and cooling systems, etc.

Coulter counters that make use of radio frequency signals[5] or impedance measurements [6], have shown the integration of electronics with these microfluidic systems. RF resonators are another example of a sensor used to differentiate fluids with different relative permittivity such as glucose, water and alcohol[7]. Our work on a crude-oil water-cut sensor based on a T-resonator in a microfluidic device, showed frequency shifts up to 50MHz for only a 5% change in water concentration.

In this work, we use a RF T-resonator in order to monitor stable droplet generation in a parallel system. In these devices, many droplet generators are operating simultaneously to scale up the volume production of such droplet-based microfluidic systems[8]. In these parallel systems, it is important to control the dispersity in droplet size across the different generators to ensure a low coefficient of variation and uniform droplet production. Since the relative permittivity of water and common oils used in microfluidics differs considerably, an RF resonator can be used to detect small changes in the droplet trains that containing larger or smaller droplets, and therefore detect any malfunction in the generators.

USE OF COMSOL MULTIPHYSICS®

COMSOL Multiphysics® is used to model the system in three-dimensional space as shown in Figure 1. The T-resonator is placed on top of the microfluidic channel containing the fluids and a ground plate is connected underneath. Then we make use of the electromagnetic waves module

provided by COMSOL Multiphysics, in order to measure the s-parameters of the given signal at a range of frequencies varying from 1GHz to 10GHz.

RESULTS

Our simulation results show a large frequency shift (~ 4Ghz) when liquids with different relative permittivities are passed through the channel. These results are very promising towards implementing an RF system for continuous monitoring of droplet size dispersity. Our simulations are going to take into account the contributions of the permittivities of oil and water volumes in order to estimate the complex relative permittivity of the microfluidic channel itself.

CONCLUSIONS

We have successfully demonstrated an RF resonator, in which a frequency shift in the S21 parameter depends on the relative permittivity of the material flowing in the channel. Then we have proposed to use this feature as a sensor to monitor parallel systems of microfluidic droplet generation.

Reference

1] A. B. Theberge, F. Courtois, Y. Schaerli, M. Fischlechner, C. Abell, F. Hollfelder, and W. T. S. Huck, “Microdroplets in Microfluidics: An Evolving Platform for Discoveries in Chemestry and Biology,” Small, vol. 49, pp. 5846–5868, Mar. 2010.
[2] H. Song, D. L. Chen, and R. F. Ismagilov, “Reactions in Droplets in Microfluidic Channels,” Angew. Chem. Int. Ed., vol. 45, no. 44, pp. 7336–7356, Nov. 2006.
[3] D. Conchouso, E. Rawashdeh, D. Castro, A. Arevalo, and I. G. Foulds, “Optimized Channel Geometry of a Flow-Focusing Droplet Generator for Parallelization.,” presented at the Proceedings of the 2013 COMSOL Conference, Rotterdam, 2013.
[4] D. Conchouso, E. Al Rawashdeh, A. Arevalo, D. Castro, and I. G. Foulds, “Simulation of a 3D Flow-Focusing Capillary-Based Droplet Generator,” Proceedings of the 2013 COMSOL Conference.
[5] D. K. Wood, S. H. Oh, S. H. Lee, H. T. Soh, and A. N. Cleland, “High-bandwidth radio frequency Coulter counter,” Appl. Phys. Lett., vol. 87, no. 18, p. 184106, 2005.
[6] S. Zheng, M. Liu, and Y.-C. Tai, “Micro coulter counters with platinum black electroplated electrodes for human blood cell sensing,” Biomedical Microdevices, vol. 10, no. 2, pp. 221 –231, Sep. 2007.
[7] J. Shao, G. Manandhar, B. Arigong, and H. Zhang, “Dual-band microwave device for sensing dielectric property changes in microfluidic channels,” Microw. Opt. Technol. Lett., vol. 54, no. 12, pp. 2691–2694, Sep. 2012.
[8] D. Conchouso, D. Castro, S. A. Khan, and I. G. Foulds, “Three-dimensional parallelization of microfluidic droplet generators for a litre per hour volume production of single emulsions,” Lab on a Chip, vol. 14, no. 16, pp. 3011–3020, 2014.

Figures used in the abstract

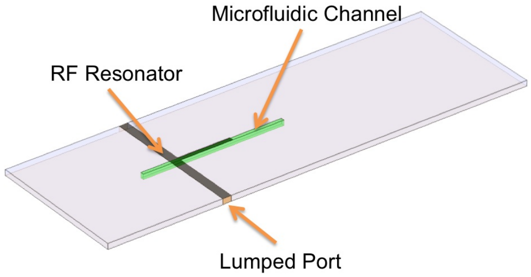

Figure 1: Figure 1 Microfluidic RF Resonator for continuous monitoring of droplet size dispersity. The channel is made out of three PMMA thin sheets that are thermo-compression bonded, and the resonator is was inkjet printed on top of the chip using conductive Ag.

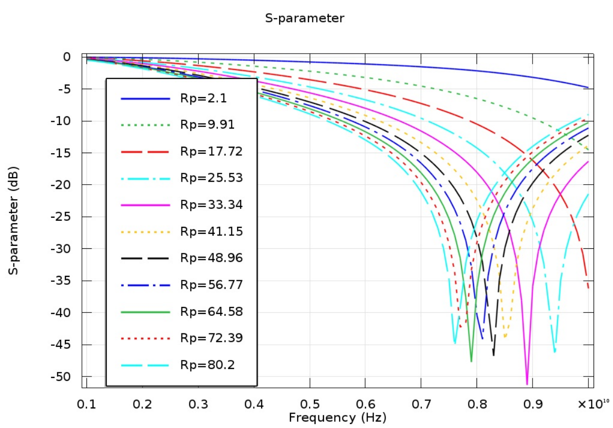

Figure 2: Figure 2 Frequency response. The graph shows the S21 parameter across the RF T-resonator for a range of different fluids with relative permittivities varying from pure oil values (2.1) to pure water values (80.1). The shift in the frequency is used to detect any change in the system.

Figure 3

Figure 4