High-throughput Droplet Sensing Platform for Pharmaceutical and Bioengineering Applications Using Microwave Technology

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Droplet-based microfluidic technologies are uniquely suited for applications requiring highthroughput processing of large numbers of detection or sensing tasks. Potential applications can be found in cell discrimination/morphology, intracellular content analysis, detection of bioassays, antibody screening and digital PCR. The development of new techniques for the detection and manipulation of individual droplets at high frequencies is of great importance in the sense of improving capabilities of droplet-based microfluidic devices for high-throughput screening technology. Although optical methods are available for this task, they are bulky and expensive. On the other hand, microwave technology, as a versatile non-optical method, employs a scalable and cost-effective sensing mechanism without chemical modification or physical intrusion. In this work, we demonstrate a high-throughput droplet-based microfluidic system integrated with a new developed microwave custom circuitry. The system is able to detect individual nanoliter-sized droplets and their content. We utilized a very cost-effective and flexible printed circuit board technology for our custom microwave circuitry, which is very compatible to point-of-care applications as well. The circuitry is consisted of surface mount components and is able to generate microwave signal and measure the response of the sensor (reflection coefficient of sensor) in a very fast manner. This design eliminates the need for a VNA. The microwave sensor is a small resonator accumulating electromagnetic energy into a small gap enabling the differentiation between materials with different electrical properties (i.e. permittivity, conductivity). When microchannel is aligned with the resonator, and droplets passing above the capacitive region causes changes in the capacitance and shifts in the resonance frequency. Every specific droplet exhibits a characteristic signal depending on its electrical properties. Since the resonance frequency relies on the liquid properties, this shift is used to sense the presence of a single droplet and its content. We confirmed that the system has detection limit of several kilohertz (kHz) itself, and in the experiments we reached droplet generation rates over 3.3 kHz. We present here a fast, novel and label-free

microwave based approach to detect droplets and sense their contents. This novel microfluidic system might potentially be used as a coulter counter and content analysis in many bioengineering applications.