Active-matrix driven digital microfluidic system built on printed circuit boards

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Recently, digital microfluidics (DMF) are gaining increasing popularity in the field of biological and clinical applications [1]. In a typical DMF-based microreactor, micro- or nano-liter segmented liquids, in another word, droplets can be moved and split under electro-wetting on dielectric (EWOD) [2] and dielectrophoresis (DEP) [3] mechanism. The most outstanding advantages of digital microfluidic chips are the flexible sequences and the capability of conducting multiplex and parallel biochemical operations. At present, the digital microfluidic technology generally drives droplet in a passive one-to-one electrode-addressing manner, which limits the microfluidic chip application for the large-scale applications of chemical reactions and biological analysis in this field. In this study, we develop digital microfluidic chips driven by active electronic switching matrix, which may break the scale bottleneck for the application of digital microfluidic chips.

Our digital microfluidics system with active matrix electrodes is shown in Fig. 1. The digital microfluidics chip built on active matrix printed circuit board can locate any droplet in a large array, which fundamentally achieves the flexible control of droplets. Our proposed digital microfluidic system is composed of an active matrix DMF chip, a power supply, a multiple-channel input/output interface, an oscilloscope, and a video camera, and the system is controlled by a software developed by our research group. The digital microfluidic chips and peripheral electronic control hardware and software realized a parallel and continuous precise manipulation of multiple droplets in microliters. The architecture of an individual pixel is described in Fig. 2. The DMF chip is in a two-plate closed format. Its top plate is formed from an indium tin oxide (ITO)-coated glass, and then spin-coated with 50 nm Teflon-AF. The bottom plate, or electrode pads is formed from copper-coated substrate of a printed circuit board, coated with Parylene C and 50 nm Teflon-AF. A droplet is sandwiched between the two plates. Under the electro-wetting mechanism, the surface tension of the droplet decreases, and its contact angle becomes smaller upon activation by electric field. The change of contact angle caused an imbalanced surface tension, which drives the droplets to their target electrodes.

The movement of droplets are shown in Fig. 3. The DI water droplets can move in a pre-defined path (Fig. 3 (a)). Driven by the active matrix circuit, multiple droplets can be controlled simultaneously (Fig. 3(b)). The active matrix circuit can easily be extended to thousands of rows and columns, and thus can directly manipulate tens of thousands of droplets. Further, we conduct synchronized synthesis of peptide-based macrocycles, which greatly reduce the manpower, time and cost for large-scale and complex biological synthesis tasks. The features such as flexibility, reconfigurability and repeatability of the active matrix DMF chips can provide powerful large-scale sample preparation capabilities, which is strongly demanded in biomedical researches and applications such as genomics, proteomics and precision medicine.

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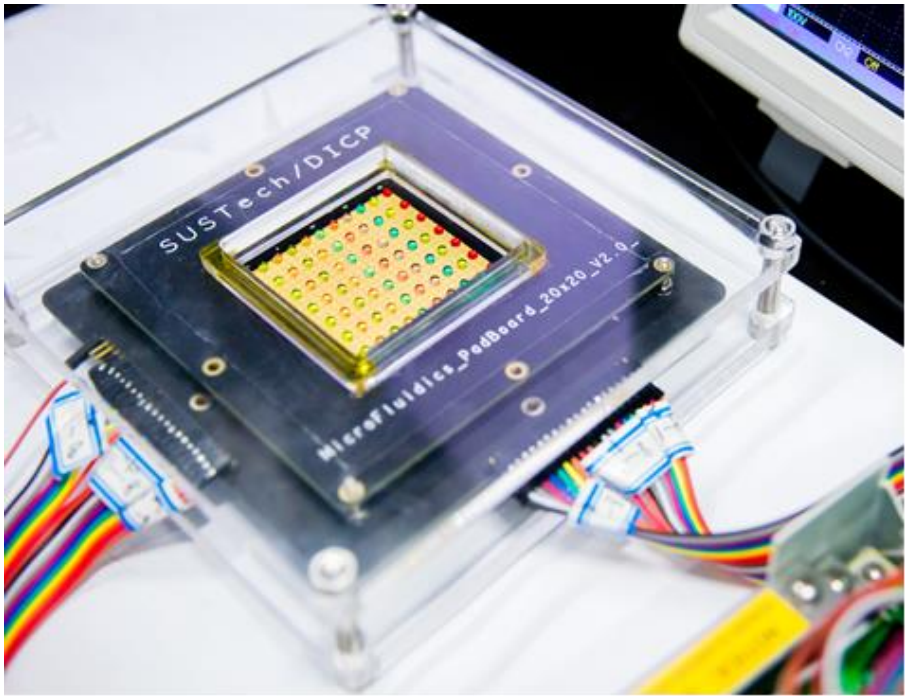

Figure 1. The digital microfluidic system driven by an active electronic switching matrix (jointly developed by SUSTech and Dalian Institute of Chemical Physics

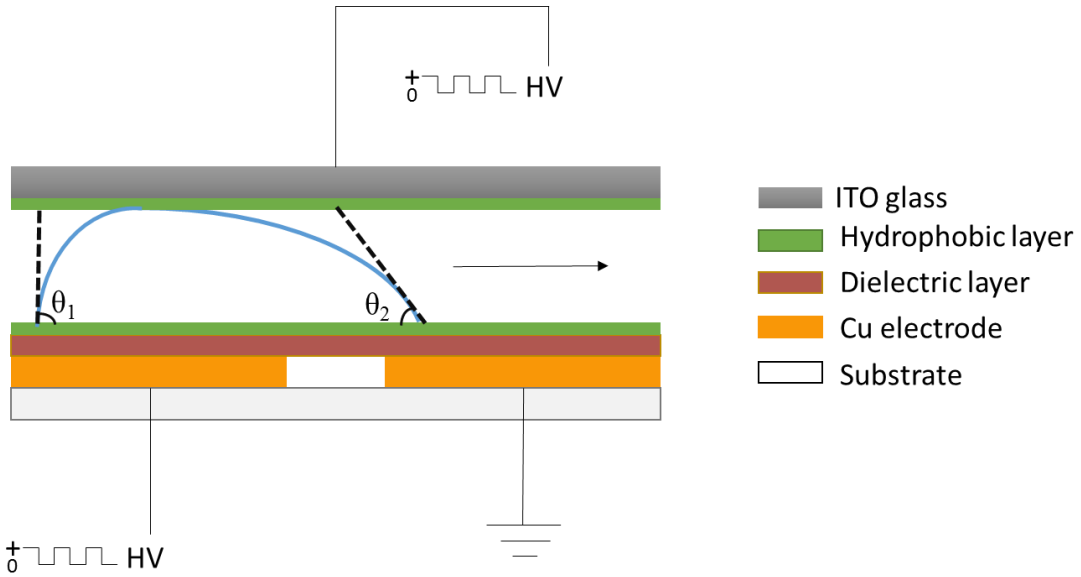

Figure 2. The architecture of a pixel in a digital microfluidic droplets chip

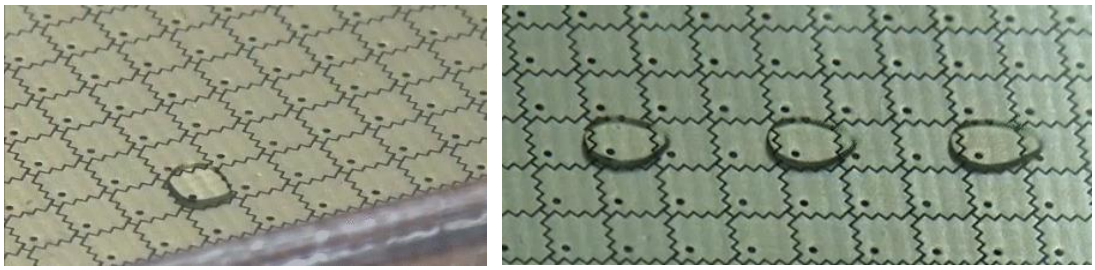

Figure 3. One droplet (left) and multiple droplets (right) in movement