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Design, Simulation, and Experimental Study of a Droplet-Based PCR by EWOD

Kessararat Ugsornrat*, Nitin V. Afzulpurkar,
Anurat Wisitsoraat[1] and Adisorn Tuantranont[1]

School of Engineering and Technology, Asian Institute of Technology,
Klong Luang, Pathumthani 12120, Thailand
[1]Nanoelectronics and MEMS Laboratory, National Electronics and Computer Technology Center,
Klong Luang, Pathumtani 12120, Thailand

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In this paper, a droplet-based polymerase chain reaction (PCR) with electrowetting on a dielectric (EWOD) is developed to focus on minimizing reagent consumption without the use of a mechanical mechanism to move the sample in the system. The droplet-based PCR system consists of a parallel-plate EWOD microchannel and serpentine-shape microheaters integrated underneath to maintain temperature for denaturation, annealing, and extension. Silicone oil is introduced at the bottom of the microchannel to reduce the temperature impact from control electrodes, prevent evaporation, and increase the contact angle reduction of droplets. The EWOD actuation is used to control the droplet in a PCR system. The EWOD configuration and serpentine-shape microheaters are designed on the basis of theoretical calculation and finite element (FEM) simulation. The simulation results indicate that the applied voltage of control electrodes does not affect the temperature of the microchannel. In addition, the optimized applied voltages of three microheaters for the temperature of PCR are 1.08, 0.57, and 0.91 V. The contact angle characterization shows a significant increase in contact angle reduction by silicone oil application. Moreover, the use of silicone oil allows a higher applied voltage for transporting a droplet without evaporation. The thermal characterization of the PCR microchannel shows that the temperature of microheaters is in good agreement with the simulation. Moreover, the PCR experiment in the droplet-based PCR chip confirms a successful DNA amplification.

*Corresponding author: e-mail: Kessararat.Ugsornrat@ait.ac.th