An Innovative Rapid Thermal Cycling Device for Polymerase Chain Reaction

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Polymerase chain reaction (PCR) is the most commonly used molecular biology technique to amplify nucleic acid (DNA and RNA) in vitro. This technique is highly temperature sensitive and thermal management has an important role in PCR operation in reaching the required temperature set points at each step of the process (denaturing, annealing and elongation). In this work, an innovative microfluidic PCR thermal cycling device is designed to increase the heating/cooling thermal cycling speed while maintaining a uniform temperature distribution throughout the substrate containing the aqueous nucleic acid sample. The device design is incorporating the jet impingement and micro-channel thermal management technologies utilizing a properly arranged configuration filled with a porous medium. Porous Inserts are attractive choices in heat transfer augmentation. They provide a very large surface area for a given volume which is a key parameter in heat transfer processes. Various effective parameters that are relevant in optimizing this flexible thermal cycler are investigated such as thermal cycler configuration, thickness of inlet and exit fluid channels, fluid flow rate and velocity, the porous matrix material and properties, and utilization of thermal grease. An optimized case is established based on the effects of the cited parameters on the temperature ramp, temperature distribution and the required power for circulating the fluid in the thermal cycler. The results indicate that the heating/cooling temperature ramp (temperature change per heating/cooling cycling time) of the proposed device is considerably higher (150.82□C/s) than those in literature. In addition, the proposed PCR offers a very uniform temperature in the substrate while utilizing a low power.