Modeling, Simulation and Optimization of Surface Acoustic Wave Driven Microfluidic Biochips

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Biochips, of the microarray type, are fast becoming the default tool for combinatorial chemical and biological analysis in environmental and medical studies. Programmable biochips are miniaturized labs that are physically and/or electronically controllable. The technology combines digital photolithography, microfluidics and chemistry. The precise positioning of the samples (e.g., DNA or proteins) on the surface of the chip in picoliter to nanoliter volumes can be done either by means of external forces (active devices) or by specific geometric patterns (passive devices). The active devices which will be considered here are nanoliter fluidic biochips where the core of the technology are nanopumps featuring surface acoustic waves generated by electric pulses of high frequency. These waves propagate like a miniaturized earthquake (nanoscale earthquake), enter the fluid filled channels on top of the chip and cause an acoustic streaming in the fluid which provides the transport of the samples. The mathematical model represents a multiphysics problem consisting of the piezoelectric equations coupled with multiscale compressible Navier-Stokes equations that have to be treated by an appropriate homogenization. We discuss the modeling approach, present algorithmic tools for the numerical simulation and address optimal design issues as well.