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Flow enhancement in nano-channels using surface acoustic waves

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Flow through micro-nano channels is ubiquitous in nature, such as flow inside biological nano-porins in all living beings, vascular motion in fungi, and intestinal flow due to contractions of walls. It is also present in a vast range of engineering and biomedical applications like nanorobotics, printing technology, quantum computing, optics, chemical process control, drug delivery, and cell biology. Due to the high surface-to-volume ratio, energy dissipation inside the micro/nano channel is significantly large. As a result, flow inside micro/nano channels is extremely inefficient compared to macroscale channels. Traditional approaches to enhance flow inside micro/nano channels involve making the channel wall hydrophobic [1] or changing the surface morphology [2] to reduce friction. Xie and Cao [3] showed that the flow rate inside nanochannels could be enhanced by reducing channel wall friction with the application of traveling surface waves. However, the frequency of the applied surface wave was extremely high (in THz order) in their work, which is difficult to obtain with state-of-the-art surface acoustic devices. Marbach et al. [4], using mathematical formalism, revealed that wiggling of the nanochannel wall due to thermal fluctuations could significantly enhance diffusion and, therefore, increase the flow rate. They also showed that active surface wiggling produced by external stimuli could also augment the flow rate. However, the detailed understanding of this flow enhancement is still far from satisfactory. Therefore, we perform Molecular Dynamics simulations to analyze the acoustic wave-driven flow behavior inside nanochannels at the molecular scale. Contrary to the previous work, we observe a reduction in the flow rate at low frequencies of vibration; the flow rate starts increasing beyond a certain frequency. The decline in the flow rate is attributed to the hindrance to the flow produced by the "roughness"of the surface during the propagation of the surface wave. Our results show that the magnitude of the local velocity across the channel increases significantly; however, the velocity profile remains parabolic —the profile doesn't widen and flatten with higher frequencies. This is indicative of the fact that the flow enhancement is not only due to the reduced friction at the wall but also due to increased bulk fluid motion due to the acoustic pressure produced as a result of traveling surface waves. Our study also reveals that the nanochannels with a hydrophobic surface produce better flow enhancement in response to traveling surface waves. Our work provides insights to better design strategies for surface acoustic wave-driven flow enhancement inside nanochannels.

Participation

In-Person

References

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