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Flow Visualization and Mixing Enhancement in Y-Junction Microchannel with 3D Acoustic Streaming Flow Patterns Induced by Trapezoidal Triangular Structure using High-Viscous Liquids

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Abstract : The Y-shaped microchannel system is used to mix up low or high viscosities of different fluids, and the laminar flow with high-viscous water-glycerol fluids makes the mixing at the entrance Y-junction region a challenging issue. Acoustic streaming (AS) is time-average, a steady second-order flow phenomenon that could produce rolling motion in the microchannel by oscillating low-frequency range acoustic transducer by inducing acoustic wave in the flow field is the promising strategy to enhance diffusion mass transfer and mixing performance in laminar flow phenomena. In this study, the 3D trapezoidal Structure has been manufactured with advanced CNC machine cutting tools to produce the molds of trapezoidal structure with the 3D sharp edge tip angles of 30° and 0.3mm spine sharp-edge tip depth from PMMA glass (Polymethylmethacrylate) and the microchannel has been fabricated using PDMS (Polydimethylsiloxane) which could be grown-up longitudinally in Y-junction microchannel mixing region top surface to visualized 3D rolling steady acoustic streaming and mixing performance evaluation using high-viscous miscible fluids. The 3D acoustic streaming flow patterns and mixing enhancement were investigated using the micro-particle image velocimetry (μPIV) technique with different spine depth lengths, channel widths, high volume flow rates, oscillation frequencies, and amplitude. The velocity and vorticity flow fields show that a pair of 3D counter-rotating streaming vortices were created around the trapezoidal spine structure and observing high vorticity maps up to 8 times more than the case without acoustic streaming in Y-junction with the high-viscosity water-glycerol mixture fluids. The mixing experiments were performed by using fluorescent green dye solution with de-ionized water on one inlet side, de-ionized water-glycerol with different mass-weight percentage ratios on the other inlet side of the Y-channel and evaluated its performance with the degree of mixing at different amplitudes, flow rates, frequencies, and spine sharp-tip edge angles using the grayscale value of pixel intensity with MATLAB Software. The degree of mixing (M) characterized was found to significantly improved to 0.96.8% with acoustic streaming from 67.42% without acoustic streaming, in the case of 0.0986 μl/min flow rate, 12kHz frequency and 40V oscillation amplitude at y = 2.26 mm. The results suggested the creation of a new 3D steady streaming rolling motion with a high volume flow rate around the entrance junction mixing region, which promotes the mixing of two similar high-viscosity fluids inside the microchannel, which is unable to mix by the laminar flow with low viscous conditions.

Keywords : nano fabrication, 3D acoustic streaming flow visualization, micro-particle image velocimetry, mixing enhancement
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