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Flow Characterization for Multi-Phase Lab-in-a-Tube Devices via Low-Cost Optical Methods

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Tube-based microfluidic platforms have been promoted as inexpensive and reconfigurable alternatives to microfabricated devices, partly because they offer ready access for in-situ optical characterization. Both single- and multi-phase flow regimes can be achieved within the tube-based flow reactors. The recirculation pattern formed within each moving liquid slug intensifies microscale mixing of the reagents and reduces the characteristic diffusion length scale. The enhanced mass transfer rates make gas-liquid segmented flow an ideal strategy for kinetic studies of fast reactions, whereas poor mixing in single-phase flow may result in mass transfer-limited reaction regimes and possibly inaccurate kinetic measurements. However, process control suffers due to the compressibility of the gas phase, leading to inaccuracies in calculating residence time and flow velocity based on the manipulated volumetric flow rates. We designed and developed a low-cost velocity meter using off-the-shelf optical sensors for precise process control of gas-liquid segmented flow in lab-in-a-tube microfluidic platforms. Each optical sensor provides a voltage signal corresponding to the absorbance of the medium within the tube. The changing phase at each sensor appears as a regular pattern of the measured voltage, which may be processed to time the passing of the interfaces and further obtain the velocity and slug length. We utilized optical strategies for measurement and control of the velocity and slug length of gas-liquid segmented flow within a wide range of tube diameters. We believe the developed low-cost technique can be readily integrated with various tube-based microfluidic platforms for applications in materials science and Biological Sciences.