Microfluidic Engineering for Nanomedicine: Linking Fluid Dynamics with Next-Generation Biosensing

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Microfluidic technologies provide powerful tools to interrogate complex fluids and design next-generation diagnostic systems. In this talk, I will present recent advances in multifunctional microfluidic platforms that connect fundamental fluid dynamics with applied nanobiosensing for health diagnostics. In the first part, I will introduce 3D glass microfluidic devices fabricated via selective laser-induced etching (SLE). These systems allow high-speed, real-time visualization of viscoelastic instabilities and fluid–structure interactions in confined geometries. Beyond their fundamental significance, such instabilities offer new strategies for enhancing mixing and transport in lab-on-a-chip systems[1], with implications for drug screening, pathogen detection, and nanoparticle handling in biomedical contexts. The second part highlights biosensors integrated into microfluidic platforms, including plasmonic nanostructures and electrochemical devices. These label-free sensors enable rapid and ultrasensitive detection of clinically relevant biomarkers—such as SARS-CoV-2 antibodies and prostate cancer indicators—in small-volume samples. With assay times ranging from 7–30 minutes, these devices point toward compact, point-of-care diagnostics that bridge nanotechnology with real-world healthcare needs[2-6].

Together, these studies demonstrate how microfluidic engineering can translate physical insights into practical nanomedicine innovations, advancing both fundamental understanding and clinical applications.

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