הטכניון מכון טכנולוגי לישראל TECHNION Israel Institute of Technology

Faculty of Mechanical Engineering הפקולטה להנדסת מכונות

MECHANICAL ENGINEERING GRADUATE STUDENT SEMINAR SERIES

Sunday, Dec 07, 2025, at 12:30, D. Dan and Betty Kahn Building, Room 217

Glimpse into the Multiphysics of Microfluidics: Diffusioosmotic Flow Drives Fluid-Structure Instability

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Adviser: Assistant Prof. Evgeniy Boyko

Fluid-structure interactions involving electrokinetic phenomena are increasingly relevant in microfluidics, biomedical systems, and soft robotics. One notable electrokinetic phenomenon is diffusioosmotic flow—the spontaneous movement of fluid along a stationary surface driven by a solute concentration gradient. In electrolyte solutions, diffusioosmotic flow arises from two effects: chemiosmosis, driven by osmotic pressure gradients within the electric double layer, and electroosmosis, which can be induced by a spontaneously generated electric field due to unequal ion diffusivities.

In this theoretical study, we analyze the fluid-structure interaction between diffusioosmotic flow of an electrolyte solution and a deformable microfluidic channel. We provide insight into the physical behavior of the system by developing a simplified one-dimensional model, in which a viscous film is confined between a rigid bottom surface and an elastic top substrate, modeled as a rigid plate connected to a linear spring. Considering a slender configuration and applying the lubrication approximation, we derive a set of two-way coupled governing equations describing the evolution of the fluidic film thickness and the solute concentration. Diffusioosmotic flow, driven by solute concentration differences at the edges, generates fluidic pressure acting on the plate, leading to fluid-structure interaction. Our theoretical predictions show that above a certain concentration gradient threshold, negative pressures induced by diffusioosmotic flow give rise to fluid-structure instability, causing the elastic top substrate to collapse onto the bottom surface. We employ theoretical analysis to elucidate the underlying physical mechanisms for the onset of fluid-structure instability and identify three distinct dynamic behaviors: (i) a stable steady state, (ii) a bottleneck, and (iii) an immediate collapse. We validate our theoretical results with finite-element simulations and find excellent agreement. The understanding of this instability is important for the design of electrokinetic systems containing soft elements.

The findings of this study are summarized in a recent publication by Nataly Maroundik, Dotan Ilssar, and Evgeniy Boyko, titled "Diffusioosmotic flow in a soft microfluidic configuration induces fluid-structure instability," published in *Physical Review Fluids*.

Note: the seminar will be given in English

Seminars Coordinator: Prof. Steven Frankel