Acoustic Manipulation Capabilities Of A Multifrequency AlN Based PMUT

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Abstract

Contactless manipulation of microscopic objects through acoustic waves has proven an attractive solution for several applications over the past decades. This modality is particularly interesting for the manipulation of bio-particles (BPs) due to its relatively low intensities, capability to manipulate particles across a length scale spanning several orders of magnitude, and ease of integration into microfluidic systems. Acoustic manipulation has e.g. been used successfully for cell separation, cytometry, cell enrichment and washing, and positioning and arraying of BPs.

This work investigates the acoustic manipulation capabilities of a single piezoelectric ultrasound transducer (PMUT) operated in different vibration modes. Acoustic radiation forces are computed in a frequency domain study in COMSOL Multiphysics®. First, the resonance frequencies of the first 4 vibration modes of the PMUT are determined via a frequency sweep. Optimal top electrode designs are chosen based on a previous study to efficiently excite each mode. Second, acoustic radiation forces on a spherical cell in water are computed at multiple positions above the PMUT for each mode excited at resonance frequency. This second order effect is computed from first order fields by applying perturbation theory under the assumption of an inviscid fluid.

The simulations couple the solid mechanics, electrostatics and pressure acoustics interfaces via the piezoelectric effect and an acoustic-solid boundary. An axisymmetric model is built for modes (0,1) and (0,2) due to the axial symmetry of the modes and the involved physics. A 3D model is built for modes (1,1) and (2,1) which includes symmetry planes such that only one quarter and one eighth of the device needs to be simulated, respectively. A water domain surrounded by a perfectly matched layer is added on top of the PMUT to approximate a large water tank in which a cell is suspended.

This work aims to provide insight into the force landscapes that can be realized with a single PMUT by excitation of higher vibration modes.

Figures used in the abstract

Figure 1 : Simulated deformation of a PMUT for mode (1,1) at resonance with the sphere representing a cell.