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Research papers

Nonlinearity analysis of piezoelectric micromachined ultrasonic transducers based on couple stress theory

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Abstract This paper studies the static deformation behavior of a piezoelectric micromachined ultrasonic transducer (PMUT) actuated by a strong external electric field. The transducer membrane consists of a piezoelectric layer, a passive layer and two electrode layers. The nonlinearities of the piezoelectric layer caused by electrostriction under a strong electric field are analyzed. Because the thickness of the transducer membrane is on the microscale, the size dependence of the deformation behavior is evaluated using the couple stress theory. The results show that the optimal ratio of the top electrode diameter and the membrane diameter is around 0.674. It is also found that this optimal value does not depend on any other parameters if the thicknesses of the two electrodes are negligible compared with those of the piezoelectric and passive layers. In addition, the nonlinearities of the piezoelectric layer will become stronger along with the increase of the electric field, which means that softening of the membrane stiffness occurs when a strong external electric field is applied. Meanwhile, the optimal thickness ratio for the passive layer and the piezoelectric layer is not equal to 1.0 which is usually adopted by previous researchers. Because there exists size dependence of membrane deformation, the optimal value of this thickness ratio needs to be greater than 1.0 on the microscale.

Keywords: piezoelectric micromachined ultrasonic transducer (pMUT) couple stress theory static deformation Nonlinearity analysis

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