Tailoring Pillar Diameter and Pitch of 1-3 Piezocomposites for 40 MHz Ultrasonic Transducers Fabricated by the Soft Mold Process

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Background, Motivation and Objective

For high resolution in medical or material imaging, high frequency ultrasonic transducers based on fine scale 1-3 piezocomposites are needed. 1-3 piezocomposites are advantageous when compared to single-phase materials because of their better electromechanical coupling, higher sensitivity and larger bandwidth. Due to their lower acoustic impedance, they are better acoustically matched to water and biological tissue. Furthermore, acoustically separated pillars within the polymer matrix allow for phased array transducers when applying patterned electrodes. Due to the regular arrangement of the piezoceramic pillars, spurious modes can occur, which must not interfere with the operation mode. In order to shift spurious modes up to uncritical frequency ranges, the lateral dimensions of the composite layout, such as pillar size and spacing, must be reduced. This requirement puts high challenges on the fabrication of respective 1-3 piezocomposites.

Statement of Contribution/Methods

Within this contribution, we report on the latest developments of the fabrication of fine scale 1-3 piezocomposites via soft mold process. In contrast to the established dice-and-fill method, the soft mold process allows for fine-scale piezoceramic structures with higher variability of pillar design and distribution as well as smaller structural size. Basis of the procedure are silicon master molds fabricated by structuring techniques known from microsystems technology, like deep reactive ion etching (DRIE) or LIGA process. From these, reusable soft plastic templates are taken. Therein a ceramic slurry based on lead zirconate titanate (PZT) is casted and demolded after drying. After debindering, sintering and filling with an epoxy polymer resulting 1-3 piezocomposites are lapped to the desired thickness, electroded and poled.

Results/Discussion

By reducing the lateral composite dimensions, 1-3 piezocomposites for ultrasonic transducers with operating frequencies of up to 40 MHz could be developed and characterized successfully. For this, different designs of circular piezoceramic pillars in hexagonal arrangement with varying pillar diameter and spacing have been prepared in order to shift spurious modes to frequencies approximately twice as the desired working frequency. The influence of the composite layout on the location of the resonance modes was investigated both by finite element analysis (FEA) and by measuring the electrical impedance spectra of physical ultrasonic transducers. With a reduction of the pillar diameter and pitch to 15 µm and 19 µm respectively, first spurious mode could be shifted to frequencies ~ 80 MHz.