Manufacturing Technologies for Ultrasonic Transducers in a Broad Frequency Range

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Piezoelectric ultrasonic transducers are widely used in many fields, such as medical ultrasonic, non-destructive testing and structural health monitoring in aerospace engineering, mechanical and civil engineering. The limits of piezoelectric bulk ceramics in high electromechanical coupling, broad bandwidth, good acoustic impedance matching and high resolution of acoustically separated elements lead to an emerging attention on piezoelectric 1-3 composites with improved electrical, electromechanical and mechanical properties. With regard to high performance and cost-effective manufacturing, piezoceramic components and composites thereof have to be tailored to application requirements. At Fraunhofer IKTS, several fabrication technologies are available each enabling a specific range of structure dimensions and therefore being suitable for a specific frequency range of ultrasonic transducers.

The polysulphone spinning process has been developed and is applied for shaping green ceramic fibers of lead zirconate titanate (PZT) [1]. So far, fibers with diameters of 100-800 µm as well as spherical pearls with diameters of 0.8-1.6 mm have been fabricated. For transducer manufacturing, the sintered piezoceramic fibers are aligned and embedded into a polymer matrix, and after curing shaped by dicing, CNC machining, and grinding. 3D designs are feasible within the framework of CNC processing possibilities. Because of the very high aspect ratio of the fibers, ultrasonic transducers in the frequency range of 40 kHz up to 10 MHz are possible.

Structured PZT thick films can be prepared by screen printing with thicknesses between 20 µm and 150 µm on different substrates like Al_2O_3, LTCC, silicon, and selected steel grades. The process is industrially established and allows for excellent accuracy and reproducibility. Miniaturization as well as batch production is feasible. However, 3D designs are limited to printing on tubular substrates, which enables transducers acting in radial direction. Depending on the coupling to the substrate material, ultrasonic transducers with frequencies between 5 and 30 MHz can be produced.

For high resolution imaging high frequency ultrasonic transducers are needed which can be operated well above 15 MHz. The soft mold process offers the opportunity to fabricate fine scale 1-3 piezocomposites with free design of the piezoceramic part. The basis of this approach are master molds, which are structured by microsystems technologies. That allows a high variety of rod size, shape, spacing, and arrangement. The combination of silicon industry based microstructuring and ceramic molding is possible through soft plastic templates taken from the master mold, which are reusable. A ceramic slurry based on PZT is filled into the soft molds under vacuum and therein dried. After demolding array structures are debindered, sintered and filled with an epoxy polymer. Ceramic body and excessive epoxy are removed by grinding and the resulting 1-3 piezocomposite lapped to the desired thickness, electroded and poled. Perspectively, the soft mold process may close the technology gap to high frequency ultrasound transducers based on thin film processes.

[1] K. Hohlfeld, S. Gebhardt, A. Schönecker, A. Michaelis, Advances in Applied Ceramics, 114, 4 (2015), 231-236