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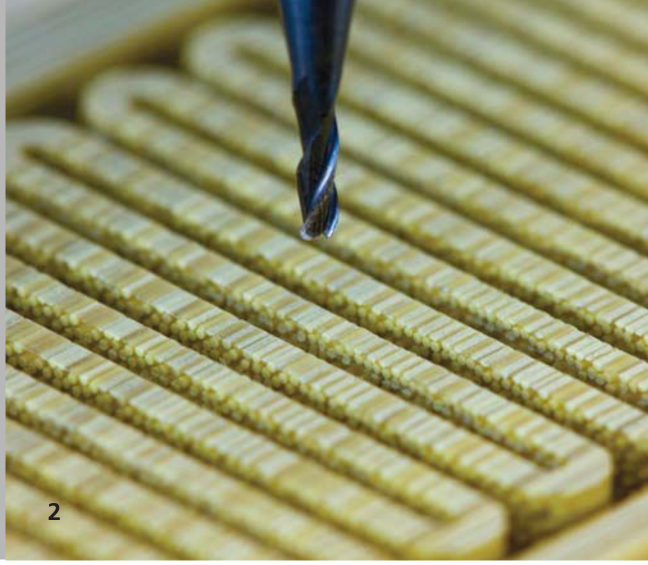

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TAILORED COMPOSITE TRANSDUCERS BASED ON PIEZOCERAMIC FIBERS AND PEARLS

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Piezoelectric transducers based on piezoceramic polymer composites are predominantly used as sensors, actuators, ultrasonic transducers or energy harvesters applied in adaptronics, medical technology and non-destructive testing. In respect of high-performance and cost-effective production, piezoceramic components as well as thereof derived piezoelectric composites have to be tailored to application needs. While piezocomposites with aligned fiber arrangement are advantageous for actuators and ultrasonic transducers, sensors and energy harvesters also accept random arrangement of piezoceramic components within the polymer matrix.

At Fraunhofer IKTS, a fiber spinning plant is available, which allows for quasi-continuous fabrication of dense piezoceramic fibers. The basic principle of the technology relies on a phase inversion process by which a solvent-based slurry consisting of binder solution, piezoceramic powder and additives is spun through a spinneret into an aqueous precipitation bath. By substituting the organic solvent inside the ceramic slurry with water as a dissolvent, the binder coagulates and a rigid green fiber is formed. Diameter of the piezoceramic fibers can be adjusted by setting of spinneret diameter D, extrusion velocity v_E and running speed v_R during the fiber spinning process. Piezoceramic fibers with diameters d = 100–800 µm have been fabricated so far.

For fabrication of spherical piezoceramic components, the solvent-based slurry is dropped into the precipitation bath. Fall length l and spinneret diameter D define geometry and diameter of the resulting components. By optimizing the fall length, spherical pearls can be produced. Stretched or flattened objects occur when a too low or too high fall length is used. The dropping rate can be controlled by the pressure p. Piezoceramic pearls with diameters d = 0.8–1.6 mm can be fabricated using spinneret diameters of D = 0.2–0.8 mm. Both technologies allow for an efficient production of dense piezoceramic components in a broad geometrical variety.

For transducer manufacturing, piezoceramic components are embedded into a polymer matrix combining functionality of the piezoceramic with mechanical stability of the matrix material. Piezocomposite transducers can be used in a wide range of application fields. For vibration and noise damping as well as for structural control, piezoceramic fibers are aligned in parallel and infiltrated with an epoxy polymer. After exposing the fiber surface by grinding or dicing, interdigital electrodes for poling and electrical operation are deposited. As a result, a patch transducer particularly suitable for sensor and actuator function as well as for energy harvesting purposes is developed.

For fabrication of ultrasonic transducers for non-destructive testing, medical and sonar applications, piezoceramic fibers are also aligned in parallel but in a three-dimensional arrangement. After the infiltration with a polymer and subsequent curing, the piezofiber polymer block can be easily shaped into any form by dicing, CNC machining and grinding. By varying the fiber arrangement (defined/random), thickness and shape of the so-called 1–3 composite, ultrasonic transducers can be tailored for different tasks (high frequency/low frequency, focused/non-focused, segmented/single element).

Piezocomposites based on piezoceramic pearls seem to be suitable for sensor or energy harvesting applications. In this approach, a monolayer of piezoceramic pearls is integrated into a polymer matrix. Surface of the spheres is exposed by grinding or polishing. Then, planar electrodes can be applied. The technique is very suitable for cost-effective fabrication of large-area transducers with lower power density demands.

1 *Fabrication of piezoceramic fibers by fiber spinning process.*

2 *CNC machining of piezofiber composite.*

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