MANUFACTURING OF 1-3 PZT-POLYMER COMPOSITES BY INJECTION MOLDING

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Robust manufacturing processes have been developed for 1-3 PZT-polymer composites (Figure 1). PZT ceramic preforms containing hundreds of uniform rods aligned in a precise array are produced by injection molding, a process well suited for large scale production of complex shapes. Following binder burnout, the injection-molded preforms are sintered and poled and then filled with a polymer matrix. Composites have been produced with both rigid and flexible polymer matrices, giving a wide range of performance capabilities.

The baseline fabrication process produces 50 mm x 50 mm PZT preforms containing 361 rods (Figure 2). Each rod is 1.1 mm diameter and 8 mm long, representing a 15% volume fraction of PZT. The sintered and poled preforms are aligned in an array to make composites of arbitrarily large size (Figure 3). Piezoelectrically soft PZT-5H ceramic, which has been used exclusively to date, exhibits d_{33} values of 700 ± 50 pC/N. The dielectric constant is approximately 3200 and the density is 7.50 g/cm³.

The composites are subsequently electroded, cabled, and encapsulated with polyurethane for underwater service (Figure 4). Current efforts are focussing on 250 mm square, 6 mm thick panels as part of a large area demonstration array. Several 100 mm square transducers have also been fabricated and tested. These have exhibited excellent receiving and transmitting performance (Figure 5). Receiving voltage sensitivities are -187 dB, re: 1 V/µPa, at 10 kHz and are exceptionally uniform from 1 to 100 kHz. Transmit voltage response is 122 dB, re: 1 µPa/V-m, at 10 kHz. Peak response is 175 dB near the 250 kHz thickness mode resonance. Transmit response is linear for drive voltages up to 1300 V rms.

The research is being extended to produce ultra-fine scale 1-3 PZT composites. Uniform arrays of 120 µm diameter fibers 1000 µm long have been demonstrated, and composites (Figure 6) have been fabricated and characterized. PZT preforms with 70 µm fibers have recently been produced. Work is continuing to push the limitations of the technology with a goal of achieving 25 µm diameter fibers.

This work is supported by the Office of Naval Research.
Figure 1. 1-3 composite with PZT rods aligned parallel in a square array.

Figure 2. Sintered PZT ceramic preform containing 361 rods. The rods are 1.1 mm diameter and 8 mm long. The base measures 50 mm square.
Figure 3. Array of 25 ceramic preforms to be incorporated into a 250 mm square 1-3 composite. This assembly contains more than 9000 PZT rods.

Figure 4. 100 mm transducers with cable attached and encapsulated in polyurethane.
Figure 5. Receiving voltage sensitivity (dB re: 1 V/μPa), and Transmit voltage response (dB re: 1 μPa/V-m), of two different 100 mm transducers with 6.4 mm thick 1-3 PZT-polymer composite.

Figure 6. Ultra-fine scale 1-3 PZT preform. Individual rods are 120 μm diameter and 1000 μm long. Human hair size reference is 60 μm diameter.