Performance Comparison of Piezoceramic and Piezocrystal for Low-frequency Power Ultrasonics Application in Surgical Needles

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For nearly 60 years, the materials of choice for the active elements in most piezoelectric power ultrasonics devices have been hard piezoceramics. Recently, however, relaxor-PT single crystals have been identified by material researchers as potential replacements for piezoceramic in low-power devices because of their extremely high piezoelectric and electromechanical coupling coefficients. The objective of the work described here was to investigate whether the major improvement in material properties available at low power levels can be realized in practical transducers requiring higher power ultrasonics.

This paper first outlines recent relevant developments in single crystal materials for power ultrasonics then describes work in which a needle actuation transducer was developed by utilizing the d_{31} piezoelectric mode. Prototyping was performed with both piezoceramic and piezocrystal incorporated within the same overall design, the former based on PZT4 and the latter on Generation I PMN-PT and Generation III Mn:PIN-PMN-PT. Small and large signal characterizations was performed on the three prototype transducers and specific properties including electrical impedance, tool resonance, effective electromechanical coupling coefficients, quality factor and output displacement were determined.

The transducers based on single crystals had electrical impedance approximately one-third that of the equivalent PZT-based transducer. Additionally, the displacement of the front surfaces of the PMN-PT and Mn:PIN-PMN-PT transducers were 5.7μm and 6.9 μm respectively when operating in the fundamental longitudinal mode with 70 Vpp excitation. These figures exceeded the value for the PZT4 transducer by a factor more than two.