Layered Manufacturing for Prototyping of Novel Transducers

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Abstract

In the last two decades, Layered Manufacturing (LM) processes have clearly demonstrated great capability of rapid prototyping and low volume manufacturing of advanced engineering components including various metals and ceramics. In LM, components are built in a layer-by-layer fashion via a computer-controlled system directly from a CAD file. This leads to significant cut in lead-time and expenses when a new component is being developed. Tremendous design flexibility of LM methods provides a great tool for fabrication of complex parts with microengineered porosity, functionally graded structures, and multimaterials constructions. Applications of LM include fast metal tooling, advanced structural and biomaterial components, advanced piezoelectric sensors and actuators, and aerospace components, etc.

Fused Deposition of Ceramics (FDC), and other LM techniques such as Sanders Prototyping and DirectWrite processes have been employed to fabricate a variety of electroceramic components. Several novel piezoelectric actuators and sensors, piezocomposites with various connectivity patterns, and integrated ceramic components have been prototyped and characterized. Piezoelectric and electrostrictive (e.g., PZT and PMN-PT) actuators in the form of tubes, domes, telescoping, spirals and ovals were fabricated and their field-induced displacements analyzed. Spiral actuators have shown giant displacements up to several millimeters and moderate blocking force (~1N), rendering them suitable candidates for high displacement applications. In oval actuators, the effects of curvature (minor axis) on the induced strain at high and low fields, resonance frequency, and blocking force were investigated. Using a newly developed multi-materials deposition facility, bender and spiral actuators with piezoelectric /electrostrictive compositions of PMN-PT (65/35 and 90/10, respectively) have been prototyped. The fabrication process and field-induced strain characteristics of these actuators (both monomorph and bimorph structures) are presented.

The net-shape capabilities of Layered Manufacturing and the cost efficient growth technique of templated grain growth (TGG) have been integrated to fabricate textured and single crystal PMN-PT components. Single crystal of $SrTiO_3$ (111), (110) and fine anisometric templates of $SrTiO_3$ and $BaTiO_3$ were surface-mounted or embedded in the prototyped PMN-PT components to produce large single crystals or grain-oriented components, respectively. The anisometric templates (needle-like and platelets) were prepared using molten salt synthesis in one- or two-step processes. In addition, bismuth titanate, magnesium niobate, and PMN seeds (synthesized from needle-like magnesium niobate) were also synthesized. Grain oriented components were made using LM feedstock containing small amounts (5-10 vol.%) of the anisometric seeds. The processing and properties of single crystal and grain oriented PMN, PMN-PT, and lead metaniobate components are presented.