NexTech Materials Ltd. Piezoelectric Overview

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Piezoelectric ceramics are used in a variety of commercial and military applications due to their electromechanical nature. Piezoelectric ceramics display both a direct effect (generating effect), in which an electrical charge is generated by a mechanical stress, and the converse effect (motor effect), in which an electrical field produces a mechanical displacement. The first-order, linear piezoelectric relationships can be described as (Figure 1):

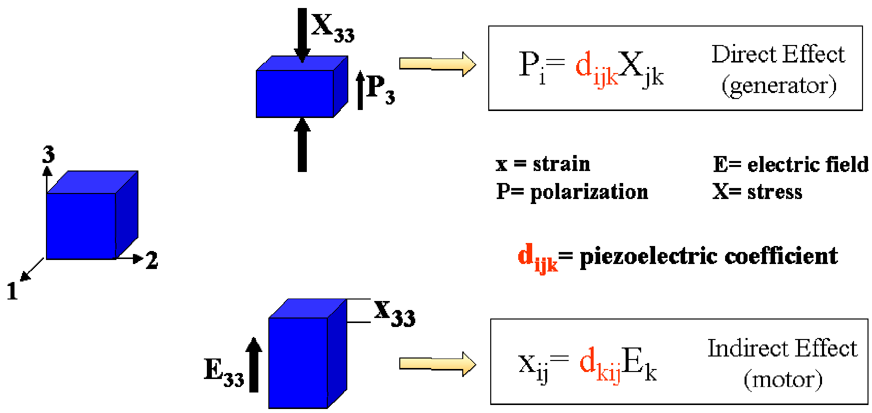

Figure 1: General description of piezoelectricity

where D_i is the dielectric displacement, S_{jk} is the applied mechanical stress, s_{ij} is the induced strain, E_k is the applied electrical field, and d_{ikl} is the piezoelectric coefficient. The piezoelectric coefficient is the figure of merit for both the direct and converse effect. The piezoelectric coefficient expresses both the ratio of strain developed due to an applied field and the ratio of dielectric charge per area developed due to an applied mechanical stress.

Piezoelectric ceramics are being applied to a variety of transducers and sensors, which include hydrophones, sonar, accelerometers, power supplies, ultrasonic motors, transformers, micropositioners, filters, robotic muscles, and medical ultrasound. Various solid-state or polymeric materials with piezoelectric, electrostrictive, piezomagnetic, magnetostrictive, photostrictive, thermoelastic, or shape-memory characteristics may equally be applied to various electromechanical sensor and transducer applications. Currently, piezoelectric ceramics are the mostly widely used since they comparatively show the highest generative forces, accurate displacements, and best high frequency capabilities.

NexTech has taken a lead in the development of lead-based piezoelectric ceramics having a general composition $Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$ (lead magnesium niobate-lead titanate- PMN-PT), with precise control on material yield, morphology, composition and purity of the material. The proprietary method of materials manufacturing, processing and net-shaping of the green as well as sintered ceramic components evolved by NexTech scientists has proven to be superior to any other method reported hitherto. NexTech is developing textured polycrystalline piezoelectric ceramics via Templated Grain Growth (TGG). In the TGG process, a number of large anisotropic template particles are oriented in a fine particle matrix in the green state, and grow during heat treatment, consuming the surrounding matrix grains and creating a crystallographically oriented ceramic (Figure 2).

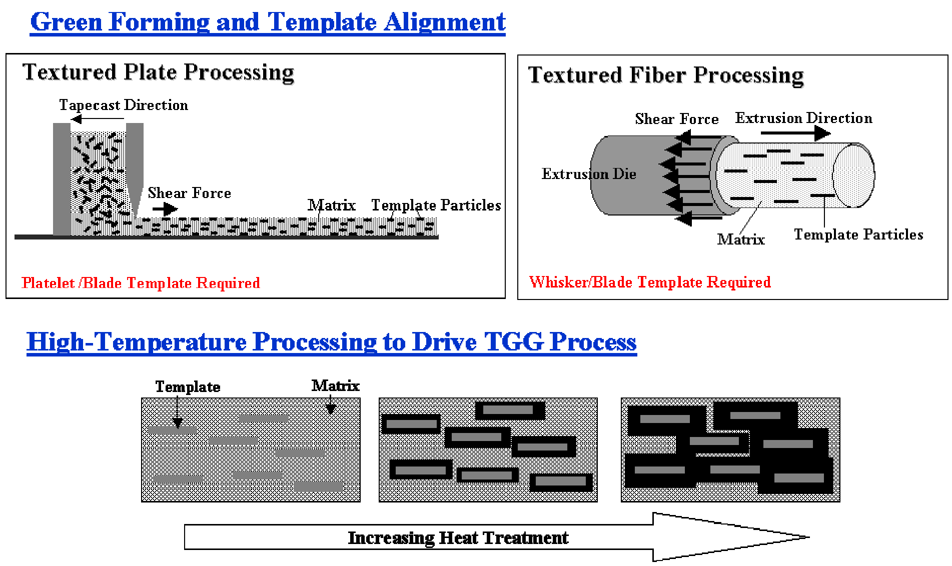

Figure 2: Schematic of the Templated Grain Growth (TGG) process

NexTech routinely manufactures high quality lead-free template compositions (pure as well as substituted titanates and zirconates to assist in grain growth of the PMN-PT matrix). NexTech template synthesis processes can consistently produce highly anisometric particles with various perovskite compositions for use in TGG (Figure 3).

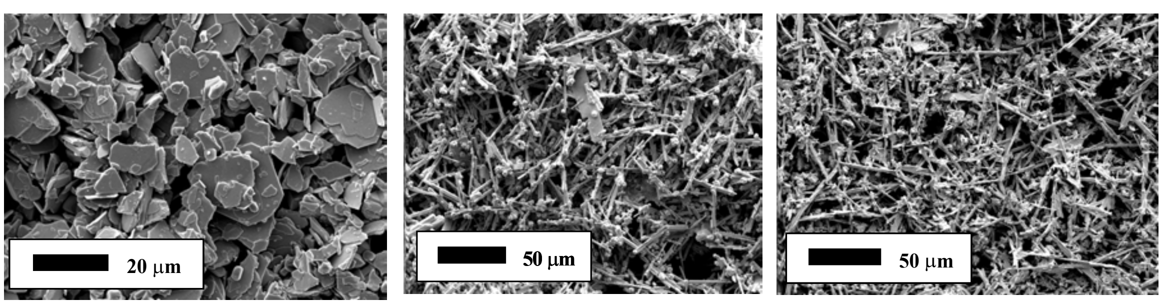

Figure 3: SEM micrographs of highly anisometric perovskite particles

NexTech has developed a TGG process to produce highly <001>-textured rhombohedral PMN-PT ceramic compositions in order to take advantage of the electromechanical properties identified for the single crystals in this orientation (Figure 4).

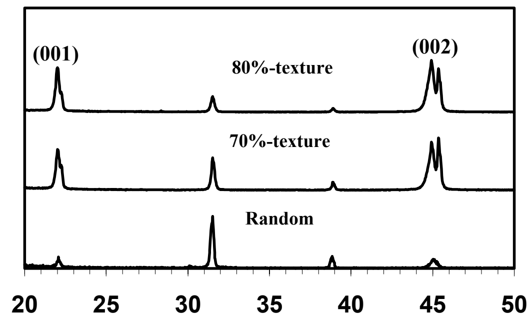

Figure 4: XRD patterns of textured PMN-32.5PT ceramics.

The textured PMN-PT samples showed a two-fold improvement in the strain-field response resulting in low field d_{33} coefficients as high as 1200 pC/N (Figure 5). The piezoelectric response showed low strain-field hysteresis indicating a low degree of loss due to domain movement or heat. The work at NexTech proved that the crystallographic engineering utilized for single crystal morphotropic phase boundary systems (rhombohedral-tetragonal MPBs) can also be applied to <001>-textured ceramics of the same compositions.

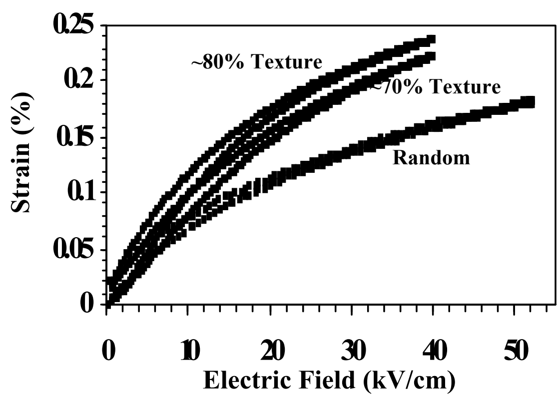

Figure 5: Unipolar strain-electric field measurement for random and textured PMN-32.5PT ceramics.