High Temperature Poling and Aging Behavior in PIN-PMN-PT Single Crystals

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Relaxor ferroelectric single crystals are attractive for applications in actuators, transducers, and sound projectors due to their large electromechanical response. In near-morphotropic compositions, the Navy is interested in high-coupling modes that are stable under typical naval operating conditions of uniaxial compression up to 60 MPa, electric drive fields exceeding 0.5 MV/m, and temperatures ranging from ~ 5 to 60 ^{o}C. With the development of increasingly stable material systems and compositions, conventional room temperature poling may soon no longer be sufficient to completely pole these high stability relaxors due to increasing coercive fields. Based upon a preliminary investigation conducted at NUWCDIVNPT in 2014, an increase in poling temperature of PIN-PMN-PT was found to increase flexural strength. It was determined that this increase in strength was related to the resultant fine domain structure and is a consequence of the increased thermal energy present during the poling process. To better understand the relationship between the engineered domain structure and material performance, the influence of high temperature poling and aging on relaxor PIN-PMN-PT single crystal is investigated. It is found that the domain size and domain wall density is dependent on the poling temperature with the finest domain structure resulting from poling in the tetragonal phase. On average, a higher poling temperature corresponds to a reduction in domain size, leading to increased electromechanical performance and mechanical strength. Room temperature poled PIN-PMN-PT is found to exhibit a piezoelectric coefficient, d_{33} of 1422 pC/N with an average flexural strength of 31.0 MPa while poling at 120 ^{o}C, above the rhombohedral-to-tetragonal transition, leads to a d_{33} of 1645 pC/N with an average flexural strength of 51.2 MPa. This finding highlights the fact that poling conditions become increasingly important in order to fully utilize stable, high-coupling modes. In addition, short-term aging is found to occur within a limited time span of a few days following poling and acts to relax the domain structure, resulting in slightly diminished electromechanical performance while simultaneously increasing material resistance to crack propagation under tensile loads.