Gen III Piezoelectric PMN-PZT Single Crystal Sensors and Actuators for Structural Health Monitoring Application

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1. Introduction

Crystallographically engineered Relaxor-PT single crystals, specifically PMN-PT (Generation I) and PIN-PMN-PT/PMN-PZT (Generation II), offer much higher piezoelectric and electromechanical coupling coefficients (d_{33} > 1,500 pC/N, k_{33} > 0.9), when compared to polycrystalline PZT ceramics.[1-3)] Recently Ceracomp Co., Ltd. (www.ceracomp.com) has developed the solid-state single crystal growth (SSCG) technique and successfully fabricated Gen III PMN-PZT single crystals modified with acceptors or donors [Fig. 1].[4-6)] The piezoelectric constants (d_{33}) of (001) Gen III PMN-PZT single crystals were measured to be higher than 4,000 pC/N and thus about two times higher than those of PMN-PT/PZN-PT (Gen I) and PIN-PMN-PT/PMN-PZT (Gen II) single crystals. The Gen III PMN-PZT single crystals have been firstly applied to single crystal-epoxy composites, ultrasonic transducers, piezoelectric sensors, and piezoelectric actuators [Fig. 2]. In this paper, we introduce the recent development of high performance piezoelectric sensors and actuators by using the Gen III PMN-PZT single crystals for SHM (structural health monitoring) applications.

Fig. 1. PMN-PT/PMN-PZT single crystals produced by SSCG technique

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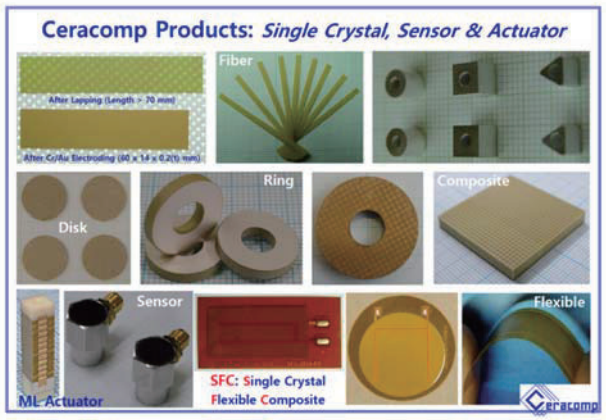

Fig. 2. Gen III PMN-PZT single crystals, single crystal-epoxy composites, SFC (Single crystal Flexible Composite), sensors and actuators

2. Development of Gen III PMN-PZT Single Crystal Actuators and Sensors

2-1. "Ultrahigh Strain" Single Crystal Actuators and Sensors for SHM

Figure 3 shows a photo and strain characteristics of the two multilayer actuators: polycrystalline PZT *vs.* single crystal. The strain of the single crystal actuator was about four times higher and the strain hysteresis was about one-third when comparing those of polycrystalline PZT ceramic actuators.

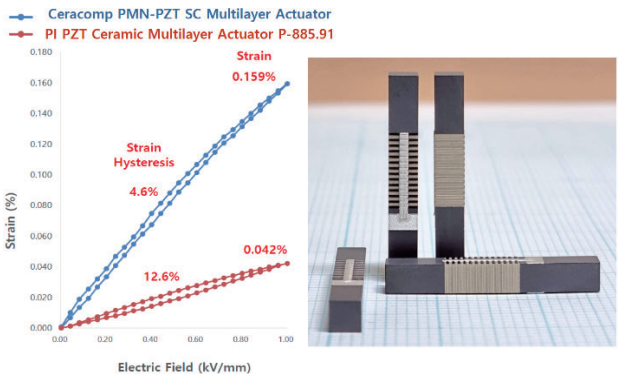

Fig. 3. Strain and strain hysteresis of two multilayer actuators: Polycrystalline PZT ceramics *vs.* single crystals

2-2. SFC (Single Crystal Flexible Composite) Sensors and Actuators for SHM

Figure 4 is a photo of the 2-2 piezoelectric single crystal-polymer composites (SFC [Single Crystal Flexible Composite]) covered with two PI films. When the thickness of the 2-2 composite was processed to be 200 μm or less, a flexible composite could be produced. Figure 5 shows strain characteristics of three 2-2 composite actuators: polycrystalline PZT ceramics, Gen I and Gen III single crystals. The strains of single crystal composite actuators were much higher and their strain hysteresis were much lower when comparing those of polycrystalline PZT ceramic actuators. This SFC can be used as piezoelectric sensors, piezoelectric actuators, ultrasonic transducers, and energy harvesting components.

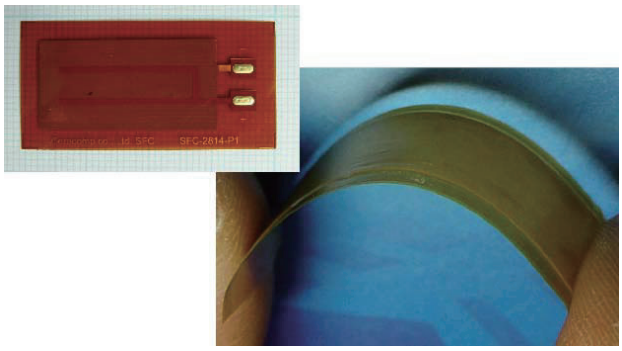

Fig. 4. "Flexible" SFC (Single Crystal Fiber Composite) for SHM

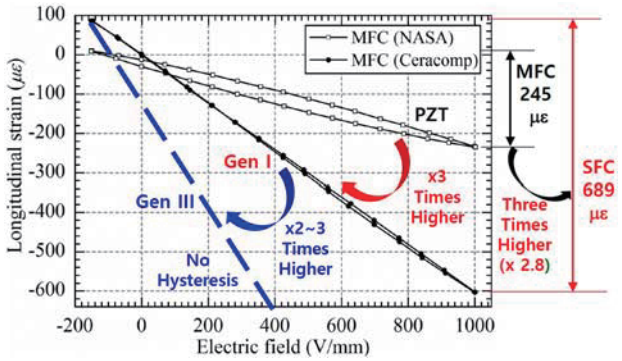

Fig. 5. Strains and strain hystereses of three composite actuators: Polycrystalline PZT ceramics, Gen I and Gen III single crystals

2-3. "Transparent" Single Crystals and Single Crystal-Epoxy Composites for SHM

Third-generation piezoelectric single crystals are known to exhibit transparent properties depending on the type of additive. Figure 6 shows the transparent "1-3" single crystal-polymer composite manufactured using transparent PMN-PZT single crystals that exhibit high piezoelectric properties and transparent properties at the same time.

Transparent & High d_{33} (> 3,000 pC/N)
SSCG PMN-PZT Single Crystal-Epoxy Composite
<Double Side Polished; 300μm Thick; No Electrode; No Poling>

Fig. 6. Transparent 1-3 Single Crystal-Polymer Composite

3. Conclusions

The development of these third-generation piezoelectric single crystals is expected to significantly improve the performance of existing piezoelectric application parts as well as develop new functional application parts, and will greatly expand the scope of application of piezoelectric single crystals in the civil and defense industries.

References

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