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Preliminary measurement of high-power properties for crystal-oriented $(Sr,Ca)_2NaNb_5O_{15}$ piezoelectric ceramics in a longitudinal mode

結晶配向$(Sr,Ca)_2NaNb_5O_{15}$ の 33 縦振動モードにおけるハイパワー特性の測定検討

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1. Introduction

The piezoelectric actuators are almost always fabricated using $Pb(Zr,Ti)O_3$-based (PZT) ceramics, however PZT ceramics easily experience a large strain and produce a notable degree of nonlinearity under practical use condition as the high-power properties. It is induced the heat generation with decreasing quality factor and to deteriorate the performance of PZT ceramics. Therefore, the lead-free piezoelectric ceramics have been actively studied not only from the viewpoint of environmental conservation but also for the possibility of outstanding high-power characteristics. It was reported $(Sr,Ca)_2NaNb_5O_{15}$ (SCNN) ceramic disk has good high-power properties as the piezoelectric ratelal effect, moreover c-axis crystal-oriented SCNN ceramic plate has the effective piezoelectric constant as large as that of hard PZT ceramics and superior high-power characteristics.[1-4] We recently reported SCNN rectanglar column has also good high-power properties in a longitudinal vibration mode (33-vibration mode). [5]

In this study, we investigated the high-power properties of crystal-oriented SCNN ceramics in a longitudinal mode by comparing with randomly oriented SCNN ceramics and hard-PZT ceramics. Where, the crystal-oriented SCNN ceramics were fabricated by the slip casting under rotating magnetic field.

2. Experimental Procedure

SCNN powder were synthesized by a conventional solid-phase reaction.[1] The powder was dispersed homogeneously in isopropyl alcohol with dispersant. As slip casting, the obtained slurry was placed in a casting mold which was rotated on the axis perpendicular to the magnetic field of 10 T. The green compact is shown as schematic in Fig. 1(a). After sintering, X-ray diffraction (XRD) analysis was examined as shown in Fig. 1(b). SCNN ceramics were cut into rectangular columns with dimensions of W 2.0 x D 2.0 x L 5.0 mm. The terminal electrodes were formed and the poling was performed. Then contact electrodes were formed. Figure 1(c) shows the schematic of the SCNN rectangular column mounted on the sample fixture for evaluation of high-power properties. As comparison, SCNN ceramics without magnetic field were fabricated and hard-PZT was used C-213 manufactured by Fuji ceramics.

The high-power properties were measured as a resonator in the 33-mode by continuous driving it with constant current driving method and the electrical transient responses of burst voltage.

3. Results and Discussion

The XRD profiles of SCNN ceramics with and without magnetic field are shown in Fig. 2. Those ceramics show single phase of SCNN. SCNN without magnetic field shows randomly oriented SCNN ceramics. On the other hand, SCNN with magnetic field shows *a*-*b* plane crystal-oriented SCNN ceramics. The *c*-axis of SCNN is orientated parallel to the rotation axis and the longitudinal of rectangular column.[2] The piezoelectric constant d_{33} increased from 60 pC/N of randomly oriented SCNN ceramics to 160 pC/N of crystal-oriented SCNN ceramics.

Figure 3 shows the vibration velocity dependence of sample temperature for SCNN and hard-PZT ceramics. SCNN ceramics could drive 2 times higher vibration velocity than that of hard-PZT ceramics. The quality factor of hard-PZT decreased with the vibration velocity significantly, however those of SCNN ceramics decreased slightly as shown in Fig. 4. The crystal-oriented SCNN ceramics had lower decrease rate of quality factor than that of the randomly oriented SCNN ceramics.

Figure 5 shows equivalent stiffness as function of the vibration velocity. Hard-PZT ceramics

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represent the mechanical nonlinearity of soft spring effect which the equivalent stiffness decreased with vibration velocity. The equivalent stiffness of SCNN ceramics was constant, there was no mechanical nonlinearity. As the result, the crystal-oriented SCNN ceramics had good high-power properties and improvement of piezoelectric properties in a longitudinal mode.

The details follow on the day.

References

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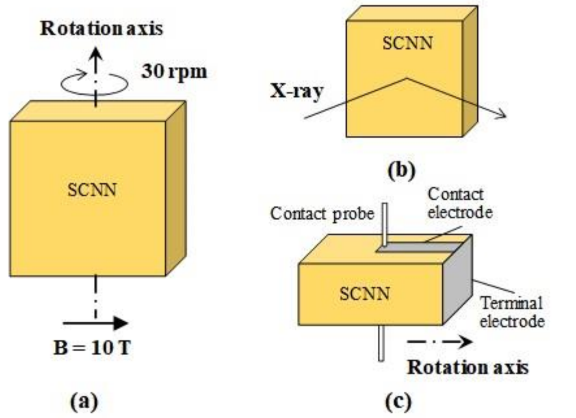

Fig. 1 Sample configurations for (a)slip casting under rotating magnetic field, (b)XRD measurement after sintering, (c) measuring high-power properties mounted on fixture.

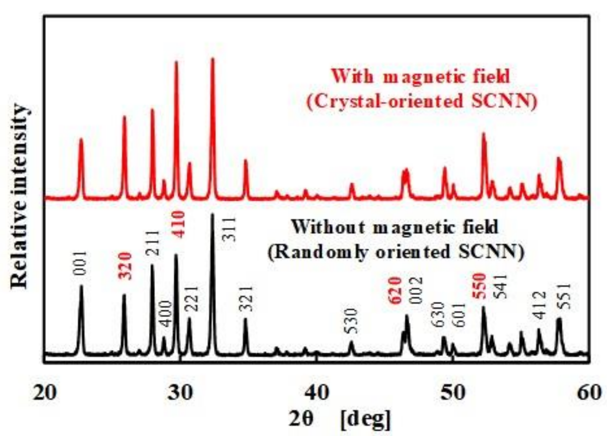

Fig. 2 XRD profiles of SCNN ceramics fabricated with and without magnetic field.

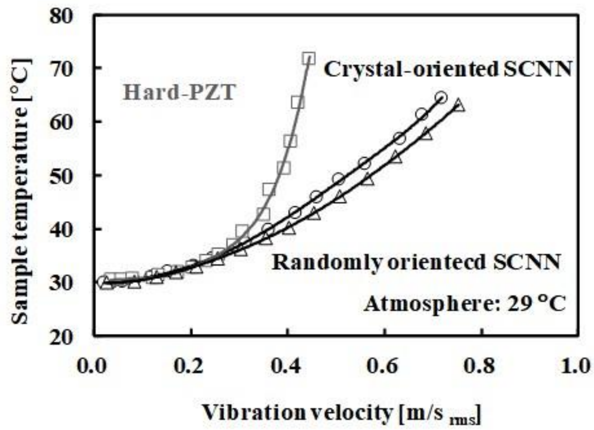

Fig. 3 Vibration velocity dependence of sample temperature for oriented SCNN, SCNN, and hard-PZT.

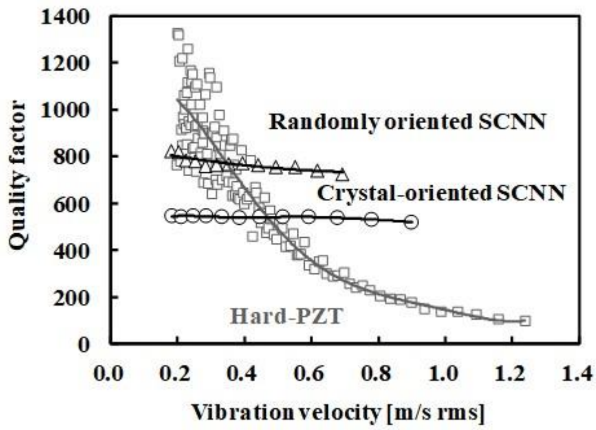

Fig. 4 Vibration velocity dependence of quality factor for oriented SCNN, SCNN, and hard-PZT.

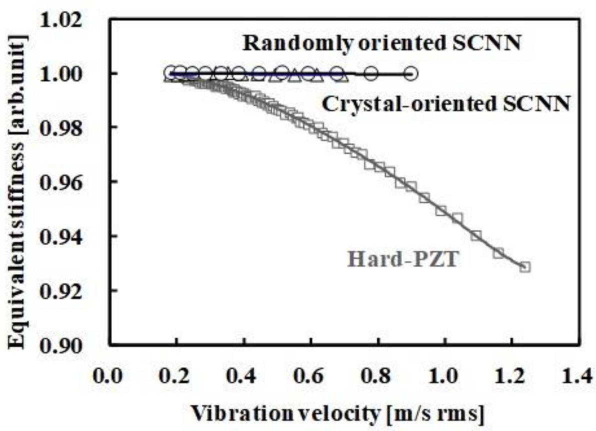

Fig. 5 Vibration velocity dependence of equivalent stiffness for oriented SCNN, SCNN, and hard-PZT.