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Investigation of High-Power Properties of Lead-Free Piezoelectric Ceramics
非鉛圧電体のハイパワー特性の調査

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1. Introduction

The piezoelectric actuators are almost always fabricated using Pb(Zr,Ti)O_3-based (PZT) ceramics. Under practical use condition, however PZT ceramics easily experience a large strain and produce a notable degree of nonlinearity called the high-power properties occur as follows. The heat generation increases, the quality factor and certain performance characteristics of resonators deteriorate from the level they display under a small signal condition.

Resently, lead-free piezoelectric ceramics have been actively studied not only from the viewpoint of environmental conservation but also for the possibility of superior high-power characteristics. In particular, (Bi,Na,Ba)(Ti,Mn)O_3 (BNBTM) ceramics and $(Sr,Ca)_2NaNb_5O_{15}$ (SCNN) ceramics represent higher output power dinsity than that PZT ceramics as shown in **Fig. 1**, estimated from the high-power properties.[1,2] They also exhibited the jump phenomena with soft-spring-effect similar to PZT ceramics as shown in **Fig. 2** and hard-spring effect as unique elasticproperties among the piezoelectric ceramics, respectively. And then, the output power density characteristics of the motors using SCNN ceramics were high in comparison with those of the commercialized motors of PZT ceramics, reflecting the high-power properties of SCNN ceramics.[3]

In this study, we evaluated the high-power properties of BNBTM ceramics and SCNN ceramics by comparison with them of hard PZT ceramics, using an electrical transient response of burst voltage with changing the sample temperature.[4,5] And then, the high-power properties of those were investigated with the distinction between mechanical nonlineality and temperature dependence of properties by comparison with the previous results using contiuas driving method.

2. Experimental Procedure

BNBTM powder and SCNN powder were synthesized by a conventional solid-phase reaction as $(Bi_{1/2}Na_{1/2})_{0.85}Ba_{0.15}Ti_{0.98}Mn_{0.02}O_3$ and $Sr_{1.9}Ca_{0.1}NaNb_5O_{15}$ + $MnCO_3$ (0.5 wt %). The disks were sintered at temperatures of 1050 and 1200 ºC and had a sample diameter of 8 mm and a thickness of 0.5 mm. Poling was performed by applying an electric field of 5 kV/mm for 15 min at 150 ºC. For comparison, we prepared the hard PZT disk of Pb(Zr,Ti)O_3–Pb(Ni,Nb)O_3–Pb(Zn,Nb)O_3.

The high-power properties were measured as a resonator in the first radial vibration mode using an electrical transient response of burst voltage after the sample temperature was changed by continuous driving it.[4,5]

3. Results and Discussion

The resonance frequency of PZT disk decreased with an increase of vibration velocity and temperature rise as shown in **Fig. 3**. The quality factor of PZT disk drastically decreased with increasing vibration velocity and decreased with temperature rise as shown in **Fig. 4**. On the other hand, the resonance frequency of BNBTM disk slightly decreased with an increase of vibration velocity and decreased with temperature rise as shown in **Fig. 5**. The quality factor of BNBTM disk slightly decreased with increasing vibration velocity and decreased with temperature rise as shown in **Fig. 6**. It appeared that the mechanical nonlinearity of BNBTM ceramics is lower than that of PZT ceramics. Therefore, the jump phenomena of BNBTM were mainly caused by the temperature dependence of properties.

We are evaluating the high-power properties of SCNN disks and will report the results.

References

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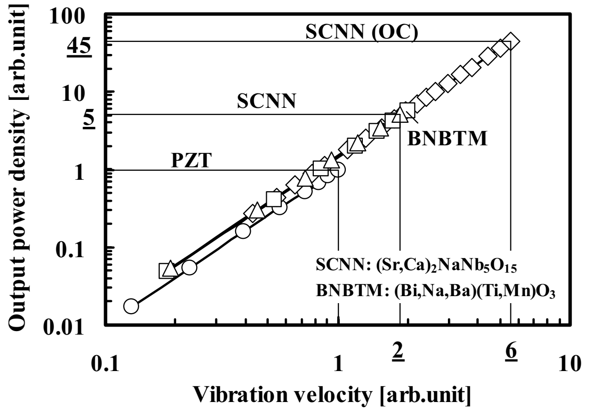

Fig. 1 Vibration velocity dependence of output power density for PZT and lead-free piezoelectric ceramics.

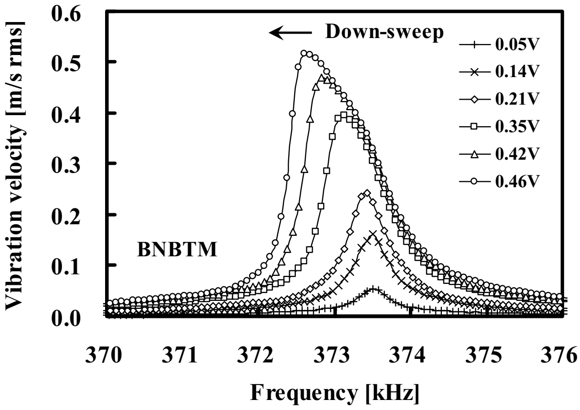

Fig. 2 Jump phenomena under constant-voltage driving for BNBTM disk.

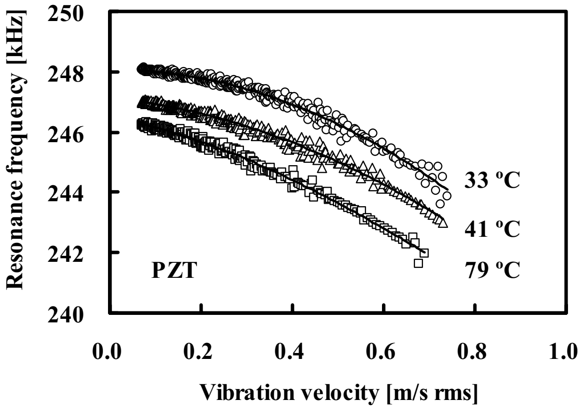

Fig. 3 Vibration velocity dependence of resonance frequency of PZT disk.

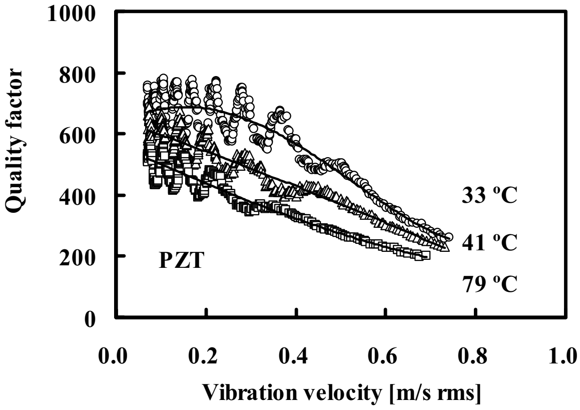

Fig. 4 Vibration velocity dependence of quality factor of PZT disk.

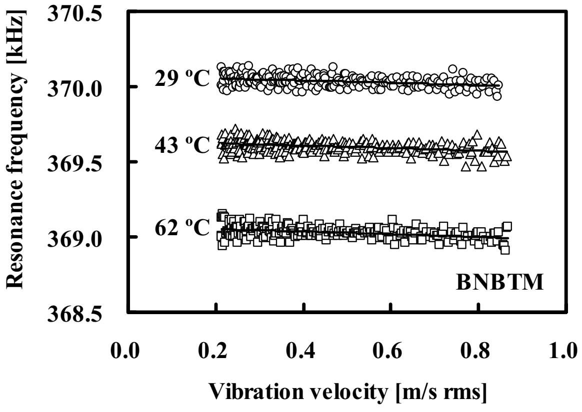

Fig. 5 Vibration velocity dependence of resonance frequency of BNBTM disk.

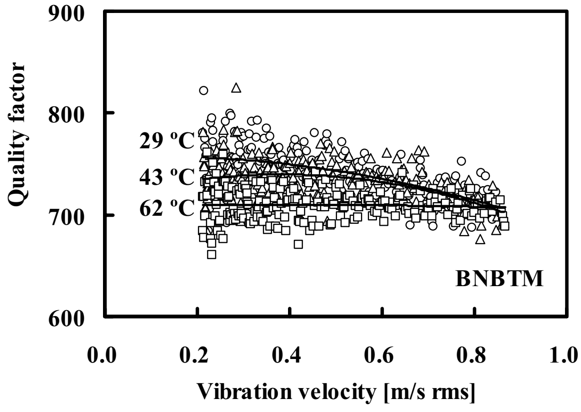

Fig. 6 Vibration velocity dependence of quality factor of BNBTM disk.