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Synthesis and characterization of BNBT15-BNM lead-free piezoelectric ceramics

BNBT15-BNM 非鉛圧電セラミックスの合成と特性評価

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1. Introduction

The piezoelectric actuators are almost always fabricated with $Pb(Zr,Ti)O_3$-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 induces 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. $(Bi_{0.5}Na_{0.5})_{0.85}Ba_{0.15}Ti_{0.98}Mn_{0.02}O_3$ (BNBTM) ceramic disk showed good high-power properties as the piezoelectric ratelal effect in the previous studies.[1-4] The piezoelecic constant of crystal-oriented $(Bi_{0.5}Na_{0.5})_{0.85}Ba_{0.15}TiO_3$ (BNBT15) increased 1.4 times higher than that of randomly oriented BNBT15 by the magnetic field orientation method.[5,6] It is expected that crystal oriented BNBTM ceramics increase piezoelectric characteristics with superior high-power properties. For this purpose, it needs the Mn diffusion powder containing BNBT15 prepared for the orientation green compact by the magnetic field orientation method. Because BNBT15 is a perovskite structure and is much lower cristal anisotoropy than other structures such as tungsten-bronze and bismuth layered structures.

In this study, we tried to synthesize and characterize BNBT15-$(Bi_{0.5}Na_{0.5})MnO_3$ (BNM) ceramics, where BNM was added as the preparation composition of Bi_2O_3, Na_2CO_3, and $MnCO_3$.

2. Experimental Procedure

BNBT15 powder was synthesized by a conventional solid-phase reaction. Regent-grade raw materials of Bi_2O_3, Na_2CO_3, $BaCO_3$, and TiO_2 were weighed according to stoichiometric ratio. The weighed powder was mixed by ball-milling with zirconia media and organic solvent. After drying, the mixture was calcined and ground by ball-milling to prepare for BNBT15 powder. BNBT15 powder was mixed with BNM (0 to 1.25 wt%) the preparation composition of which consisted BNBT15, Bi_2O_3, Na_2CO_3, and $MnCO_3$. The mixtures were calcined at lower temperature than that of BNBT15 and were ground by ball-milling as BNBT15-BNM powders.

BNBT15-BNM powder was pressed into a disk which was sintered at temperatures from 1000 to 1200 °C. The disk had typical dimensions of 8 mm diameter and 0.5 mm thick. The electrodes were formed on the surfaces of the disk using the silver printing technique. Poling was performed by applying an electric field of 5 kV/mm at 150 °C.

The characteristics were evaluated crystal phase, microstructure, dielectric and piezoelectric properties. Furthermore, the high-power properties will be measured as a resonator in the radial mode.

3. Results and Discussion

The XRD profiles of BNBT15-BNM powders are shown in Fig. 2. Those powders represent same profile as phase of BNBT15. Figure 2 shows XRD profiles of BNBT15-BNM ceramics. The peaks of BNBT15-BNM ceramics belonged in BNBT15 and moved to high angle with increasing BNM slightly. It is considered that BNBT15-BNM ceramics are the solid solutions with single phase based on BNBT15. The microstructures of BNBT15-BNM ceramics are shown in Fig. 3. BNBT15-BNM ceramics have more grain growth than BNBT15 ceramics without BNM.

Figure 4 shows typical polarization-electric field curves of BNBT15-BNM. The coercive electric field of BNBT15-BNM increased with BNM. Figure 5 shows typical frequency dependence of admittance for BNBT15-BNM in the radial mode. The electromechanical coupling coefficient was 10.5%, quality factor was 1200.

As the result, it was confirmed that BNBT15-BNM ceramics become hard type piezoelectric ceramics as same as BNBTM.

The details follow on the day.

References

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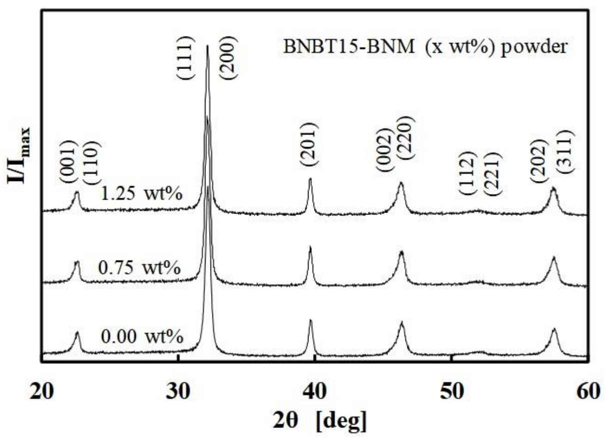

Fig. 1 XRD profiles of BNBT15-BNM powders.

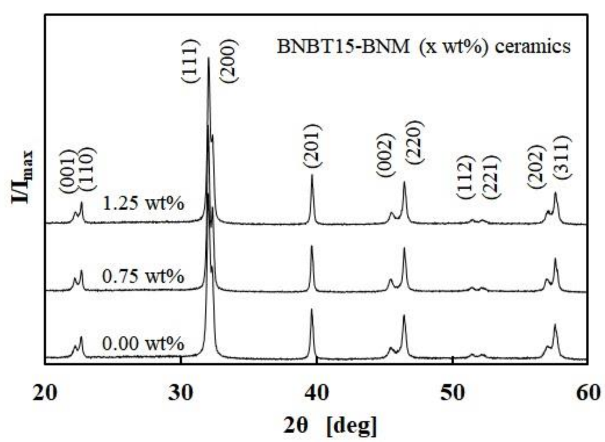

Fig. 2 XRD profiles of BNBT15-BNM ceramics after grinding disk.

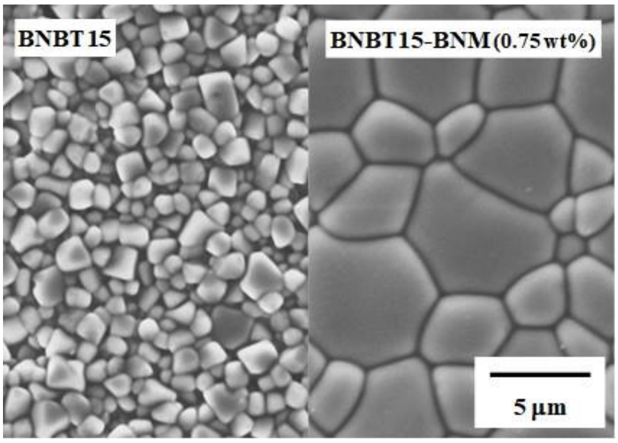

Fig. 3 Microstructures of surfaces of BNBT15-BNM disks.

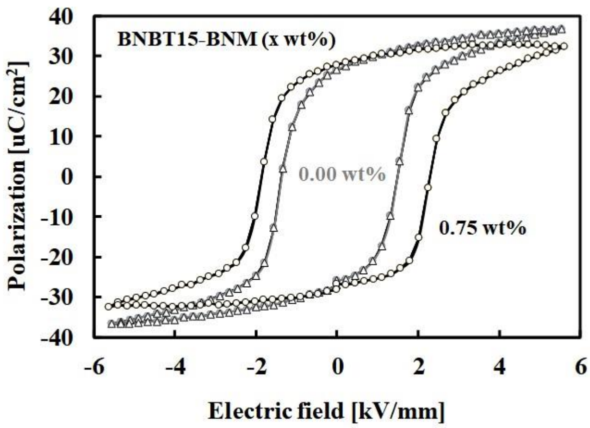

Fig. 4 Typical P-E curves of BNBT15-BNM disks.

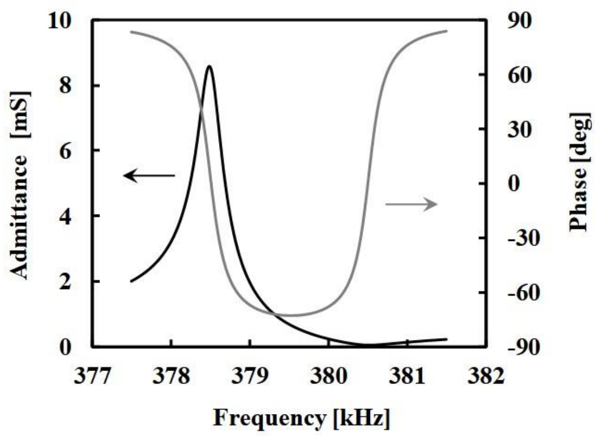

Fig. 5 Typical frequency dependence of admittance of BNBT15-BNM(0.75wt%).