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## Examination of vibration sensor using lead-free piezoelectric ceramics

Yutaka Doshida[1†] and Shengkai Qin[1] ([1]Ashikaga University)

### 1. Introduction

Pb(Zr,Ti)$O_3$-based (PZT) ceramics are commonly used in variety of piezoelectric applications. However, PZT ceramics include high lead contents, piezoelectric materials containing lead have been exempted from restriction as hazardous substances, as there are no alternative materials. On the other hands, lead-free piezoelectric materials have several superior characteristics that are not found in PZT. The lead-free piezoelectric materials have been actively studied not only with environmental conservation viewpoint but also for new valuable creation. We reported (Bi,Na)$TiO_3$ based ceramics have superior high-power properties and underwater propulsion system as their application.[1-3] Bismuth layer-structured ferroelectrics (BLSFs) are candidate materials for piezoelectric and pyroelectric sensor applications that require large anisotropy, high stability, and/or high working temperatures.[4] High-temperature ultrasonic transducer was reported using $CaBi_4Ti_4O_{15}$ (CBT) based composite films.[5] CBT belongs in BLSFs, which only shows piezoelectricity in *a-b* plane in crystal structure. *c*-axis oriented CBT ceramics increased the piezoelectric properties to 3 times of randomly oriented CBT ceramics.[6] CBT is expected to fabricate *a-b* plane oriented ceramics using high-magnetic field method.[7]

In this study, we synthesized CBT and tried to fabricate and characterize vibration sensor by comparing with PZT.

### 2. Experimental Procedure

CBT powder was synthesized by a conventional solid-phase reaction. Regent-grade raw materials of $CaCO_3$, $Bi_2O_3$, and $TiO_2$ were weighed according to stoichiometric ratio. The weighed powder was mixed by ball-milling with zirconia media and water. After drying, the mixture was calcined and ground by ball-milling to prepare as CBT powder. The powder was pressed to ring then sintered. Electrodes were formed on the surfaces of the ring using the silver-printing technique. PZT ceramic ring was prepared for comparison.

Figure 1 shows the model of vibration sensor. The sensor was characterized by measuring the generated voltage under sin wave vibration along axis of the ring at 1 kHz.

### 3. Results and Discussion

The XRD profile of CBT powder is shown in **Fig. 2**. The powder represents single phase of CBT. Figure 3 shows SEM image in surface of CBT ceramics after sintering. The microstructure is observed densification and plate-like grains with grain growth along *a-b* plane. Figure 4 shows the picture of CBT ring. The ring had typical dimensions with 9.5 mm outer diameter, 4.0mm inner diameter and 2.0 mm thick.

The generated voltage of CBT ring is shown as function of time under sine wave vibration at 1 kHz in **Fig. 5**. The generated voltage of CBT was 75.9 $mV_{p\text{-}p}$ . Figure 6 shows the generated voltage of PZT ring for comparison. The generated voltage of PZT was 28.6 $mV_{p\text{-}p}$. The CBT sensor was high sensitivity than PZT sensor.

The details follow on the day.

### References

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doshida.yutaka@g.ashikaga.ac.jp

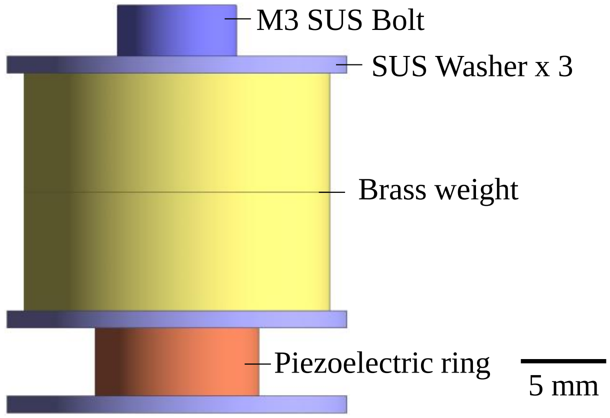

Fig. 1 Model of vibration sensor.

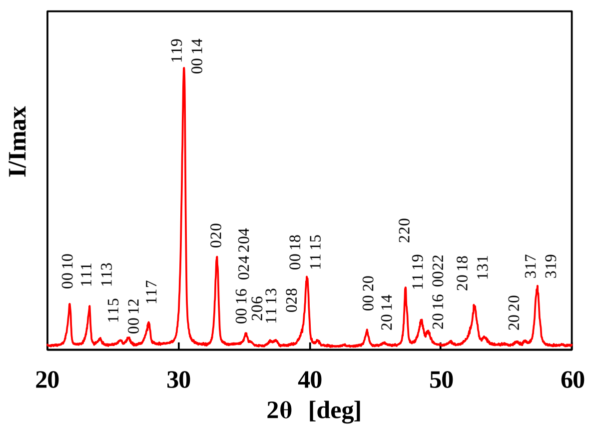

Fig. 2 XRD profiles of CBT powders.

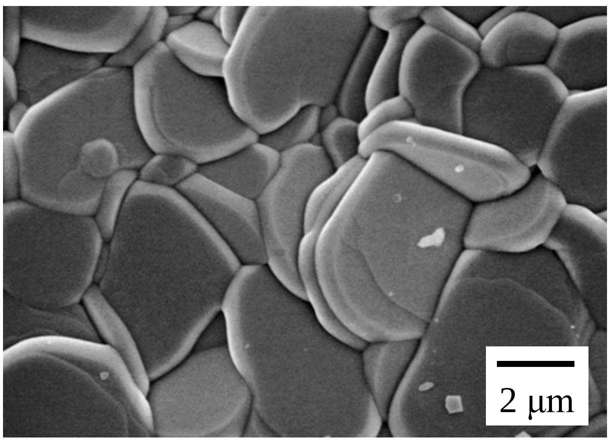

Fig. 3 SEM image of CBT ceramics.


Fig. 4 Picture of CBT ring.

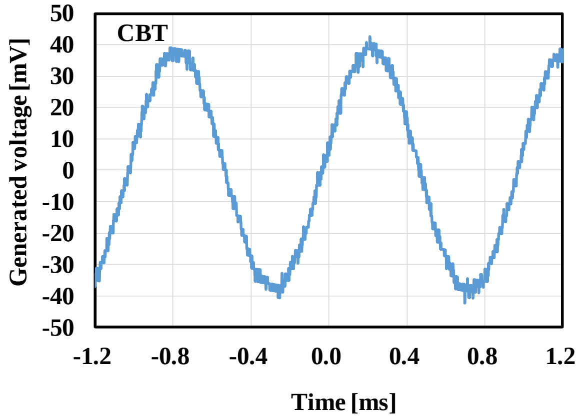

Fig. 5 Generated voltage of CBT ring.

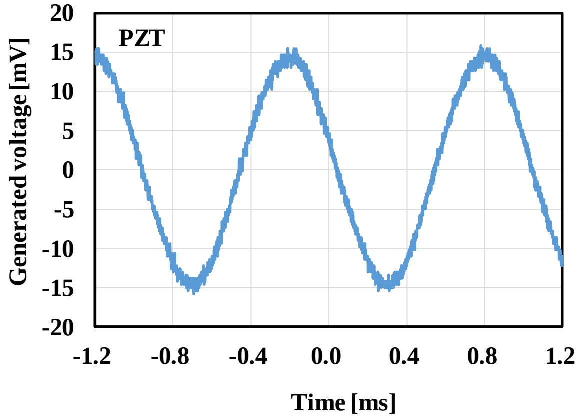

Fig. 6 Generated voltage of PZT ring.