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Rosen type 변압기 응용을 위한 PNN-PMN-PZT 세라믹스의 전기적 특성

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Electrical Properties of PNN-PMN-PZT ceramics for Rosen Type Transformer Applications

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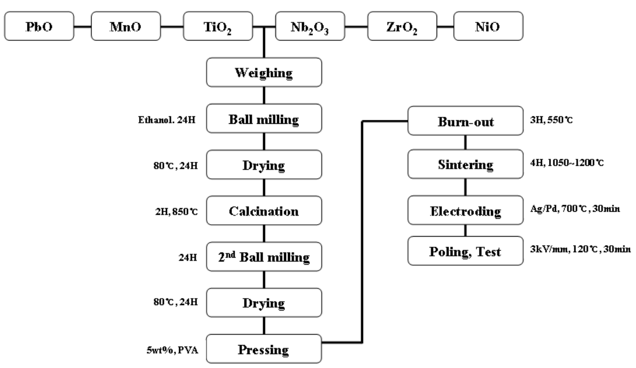
Abstract - Recently, piezoelectric transformer is applied to wide fields. Multi layer piezoelectric transformer has the advantage of high step up ratio, electromechanical coupling coefficient(Kp) and mechanical quality factor(Qm), but is indicated of peeling-phenomenon of electrode, rising sintering temperature made price of costly electrode. So in this study, it discuss on method for fabrication of rosen type piezoelectric transformers. For the fabrication as rosen type piezoelectric transformers, synthesized the powder using $0.01Pb(Ni_{1/3}Nb_{2/3})O_3$ - $0.08Pb(Mn_{1/3}Nb_{2/3})O_3$ - $0.91Pb(Zr_{0.505}Ti_{0.495})O_3$ (abbreviated as PNN-PMN-PZT) ceramics. The density, microstructure, dielectric and piezoelectric properties as a function of sintering temperature were investigated. The results indicated that the optimized properties of ceramics were obtained at sintering temperature of 1200℃, showed the value of d_{33}=273pC/N, K_p=0.60 Q_m=1585, ε_r=1454, density=7.917g/cm^3 and tanδ=0.0064.

1. Introduction

In recent years, piezoelectric transformers are mainly applied to the light liquid crystal display (LCD) backlight inverters for notebooks, DC-DC converters, PDA, etc. because piezoelectric transformers have favorable characteristics, such as miniaturized, low-profile, high efficiency and superior power density compared to conventional electromagnetic transformers [1-5]. In this work, we studied the influences of the sintering temperature on the microstructure, piezoelectric and dielectric properties of PNN-PMN-PZT ceramics for Rosen type piezoelectric transformers applications. On the other hand, the piezoelectric transformers with various sintering temperatures were fabricated and the characteristics, such as step-up ratio were measured. The aim of this work is to show that the Rosen type piezoelectric transformers with high Q_m, high K_p, high d_{33}, low tan δ and high step-up ratio can be successfully fabricated.

2. Results and discussion

2.1 Experimental

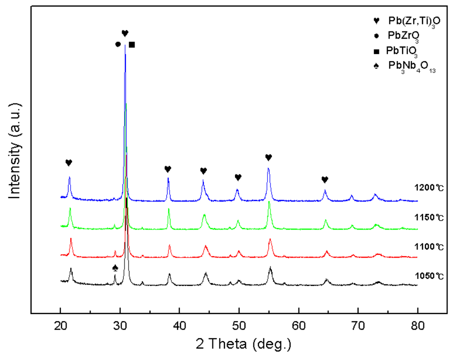


<Fig. 1> Experimental procedure

Industrial grade raw powders of PbO(99%), ZrO_2(99%), TiO_2(98%), NiO(99%), Nb_2O_5(99.5%), MnO_2(99%) were used as the raw materials to prepare the powders and ceramics with the composition of $0.01Pb(Ni_{1/3}Nb_{2/3})O_3$ - $0.08Pb(Mn_{1/3}Nb_{2/3})O_3$ - $0.91Pb(Zr_{0.505}Ti_{0.495})O_3$ (respectively abbreviated as PNN-PMN-PZT) and these specimens added 0.5wt% PbO by conventional method. The sintered ceramics were examined by X-ray diffractometry (XRD, Philips PW3830) to determine the phase structure. The bulk densities of the sintered specimens were measured by using the Archimedes method. The microstructures of fracture of as sintered ceramics were measured by using a scanning electron microscope (SEM, Hitachi S-5200). Dielectric properties were obtained by measuring the capacitance and dielectric loss at 1 kHz at room temperature by using an impedance analyzer (HP4194A). The piezoelectric constant (d_{33}) was measured using a quasi-static piezoelectric d_{33} meter (Model ZJ-3d). The electro-mechanical coupling factor (K_p) and mechanical quality factor (Q_m) were determined using an impedance analyzer (HP4194A).

2.2 Phases analysis

Fig. 2 Shows XRD patterns, $PbTiO_3$ and $PbZrO_3$ can be detected from the powder sintered at 1050℃, 1100℃ and 1150℃. Meanwhile, a little amount of $Pb_3Nb_4O_{13}$ pyrochlore phase can also be detected. However, the $PbTiO_3$ and $PbZrO_3$ disappear gradually with increasing the sintering temperature and the PZT solid solution begins to form at the same time. Pyrochlore phase cannot be detected at 1200℃. The results indicate that increasing sintering temperature is effective in the formation of the PZT solid solution and can inhibit the formation of pyrochlore phase.



<Fig. 2> XRD patterns of powders sintered at different temperature

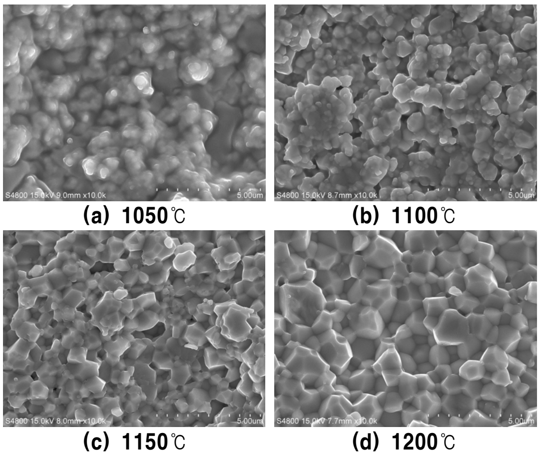
2.2 Physical, piezoelectric, dielectric properties and microstructure

Table. 1 shows the electro-mechanical coupling factor (K_p), mechanical quality factor (Q_m), piezoelectric constant (d_{33}), dielectric loss, bulk density, dielectric constant (ε_r) of ceramics with the different sintering temperatures. The maximum value of 0.60, 1585, 273pC/N, 0.0064, 7.917g/cm^3, 1454 can be obtained from the ceramics sintered at 1200℃.

Fig. 3 shows the SEM micrographs of the fractured surfaces of the piezoelectric ceramic disks calcined at 850℃ as a function of the sintering temperature. It is clear that a uniform microstructure with fewer pores is obtained from the ceramics sintered at 1200℃. The PNN-PMN-PZT ceramics sintered at 1200℃ have the homogeneous microstructure and well-grown grains.

<Table 1> Dielectric and piezoelectric properties of PNN-PMN-PZT ceramics sintered at different temperature

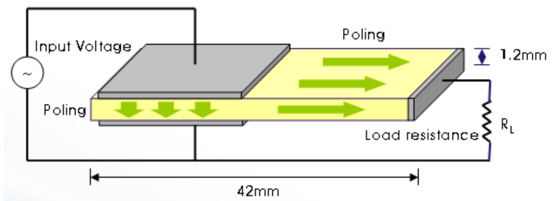
	K_p	Q_m	d_{33}	tan δ	density	ε_r
1050 ℃	0.22	198	90	0.0065	7.499	899
1100 ℃	0.28	275	160	0.0062	7.677	937
1150 ℃	0.52	1609	227	0.0062	7.726	1127
1200 ℃	0.60	1585	273	0.0064	7.917	1454



<Fig. 3> SEM photographs of powders sintered at different temperature

2.3 Application of Rosen type piezoelectric transformer and properties

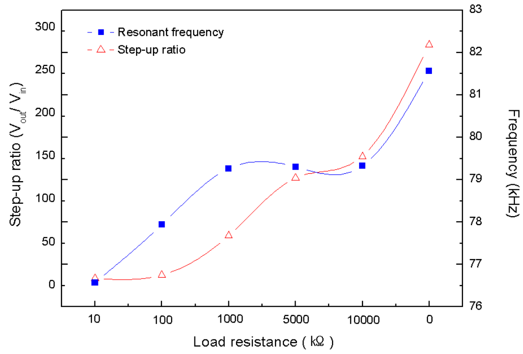
The Rosen type Piezoelectric transformer were sintered at temperature of 1200℃. The sintered material was fabricated as Rosen type transformer with the size of 12mm × 42mm × 1.2mm, pasted with Ag/Pd, and finally heat treated at 700℃ for 10 min. The poling treatment was followed in the 120℃ silicon oil bath at length direction 2kV/mm and thick direction 3kV/mm.



<Fig. 4> Rosen type piezoelectric transformer

Fig. 5 shows the voltage step-up ratios as a function of frequency at different load resistances. The step-up ratio increased up to 280 with increase of the frequency at non-load resistance. The step-up ratio increased with the increases of the load resistance. And also, the driving frequency showing the maximum step-up ratio increased with the increases of the load resistance. This phenomenon can be illustrated by the increase of elastic vibration of piezoelectric transformer due to the increase of load resistance. The maximum voltage step-up ratios of piezoelectric transformer at the operating frequency from 76.573 to 79.323 kHz were 8, 12, 58, 125 and 150, respectively, at the load resistances of 10kΩ, 100kΩ, 1MΩ, 5MΩ and 10MΩ.

Table. 2 shows resonant frequency and step-up ratio according to load resistance.



<Fig. 5> Voltage step-up ratio with the variations of load resistance and driving frequency

<Table 2> Resonant frequency and step-up ratio according to load resistance

Load resistance (kΩ)	Resonant frequency (Hz)	Step-up ratio
0	81.563	280
10 kΩ	76.573	8
100 kΩ	77.943	12
1 MΩ	79.263	58
5 MΩ	79.303	125
10 MΩ	79.323	150

3. Conclusions

The dielectric and piezoelectric properties of $0.01Pb(Ni_{1/3}Nb_{2/3})O_3$-$0.08Pb(Mn_{1/3}Nb_{2/3})O_3$-$0.91Pb(Zr_{0.505}Ti_{0.495})O_3$ (PNN-PMN-PZT) ceramics with different sintering temperatures are investigated for the application of Rosen type piezoelectric transformers. Meanwhile, the characteristics of piezoelectric transformers with the various sintering temperature are studied at a load resistance ranging from 10kΩ to 10 MΩ. The results obtained from the experiments are summarized as follows:

- The composition calcinated at 850℃ and sintered at 1200℃ shows a uniform microstructure with fewer pores, and the optimal electrical properties are also obtained. This composition values of d_{33}=273pC/N, K_p=0.60 Q_m=1585, ε_r=1454, density = 7.917g/cm^3 and tanδ=0.0064.

- The piezoelectric transformers with the composition of PNN-PMN-PZT calcined at 850℃ and sintered at 1200℃ are fabricated and measured at different resistance loads. The maximum values are step-up ratio of 280 at no load resistance. The step-up ratio increased with the increases of the load resistance.

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