# High Performance Piezoelectric Transformers by PIM Using Nano-sized Powders

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**Abstract**

*Processing and properties of high power piezoelectric transformer (PT) fabricated by PIM with nano-sized piezoelectric powders are demonstrated. The high power characteristics of a PMed dome-shaped PT were examined by the lighting test for a 55watt PL lamp. The 55watt PL lamp was successfully driven by the PIMed PT with sustaining efficiency higher than 98%. The transformer with ring/dot area ratio of 2.1 exhibited the maximum properties in terms of output power, efficiency and temperature stability.*

**Keywords : Piezoelectric transformer, Powder Injection molding, FEM**

## 1. Introduction

Electronic ballasts for fluorescent lamps have good features compared with the conventional magnetic ballast, and are widely used in recent years [1]. New type of slim lamps has been developed to reduce materials cost while to obtain an incensement in luminous efficiency [1]. Therefore, there exists a need for low profile electronic ballasts. Application of slim lamps, however, requires small sized electronic ballasts to fulfill the miniaturization design philosophy.

A piezoelectric transformer (PT) is a very attractive device since it has many advantages such as low profile, high efficiency, no windings and no electromagnetic noise. If the PT would be applied to the electronic ballast, a new lighter feature, which has a thin profile and high performance, would be essential.

The objectives of the present study are to demonstrate a newly processed dome-shaped piezoelectric transformer suitable for 55watt PL lamp. For this purpose, the microstructure of dome-shaped piezoelectric device fabricated by powder injection molding (PIM) method was compared with those of disc type device fabricated by dry press processing. Then, sintered microstructures and its voltage step-up ratio was investigated. In addition, power efficiency of 55W PL lamp driven by the dome-shaped piezoelectric transformer were evaluated as a function of input/output electrodes area ratio.

## 2. Experimental and Results

**Specimen preperration:** $0.03Pb(Sb_{0.5}Nb_{0.5})O_3$-$0.03Pb(Mn_{1/3}Nb_{2/3})O_3$-$0.465PbTiO_3$-$0.475PbZrO_3$ composition, which is generally used for high power ultrasonic devices, was used to fabricate piezoelectric devices. In this experiment, two types of piezoelectric samples were fabricated; One is a disc shape sample fabricated by conventional die press forming process and the other is a dome-shaped samples fabricated by PIM. To evaluate electromechanical properties, the polished specimens were electroded with silver paste, fired at 650℃ for 30 min and then poled in a stirred silicone oil bath at 150℃, by applying a dc electrical field of 2.5㎸/㎜ for 40 min.

**Step- up ratio and high power characteristics:** Samples with different ring /dot electrode area ratio (sample 1: 1.6, sample 2: 2.1, and sample 3: 2.5) were used to measure the step-up ratio of the dome-shaped piezoelectric transformers. ±10 $V_{p-p}$ square wave, generated by high speed bipolar amplifier (nF, HSA4052) connected with a function generator (nF, WF 1943A), was applied on the ring electrodes. For high power characterization, slim sized 55 watt PL lamps were used to measure the output power and efficiency.

**Microstructure:** When specimens were sintered at 1300℃ for 2 hrs, the average grain size of the PIM specimens appeared to be ~2μm, which was slightly larger than that (~1.5μm) by the conventional die pressing method. However, both specimens do not show noticeable pores, as shown in Fig. 1. In general, the full density could not be obtained by a conventional die pressing method when 75 Vol. % of binders were incorporated. On the contrary, the specimen processed by PIM shows a fully densified microstructure.

**Step-up ratio and feasibility study for high power piezoelectric transformer:** For measuring the step-up ratios, the samples with different ring/dot electrode area were fabricated. The electrode pattern of PIMed sample was

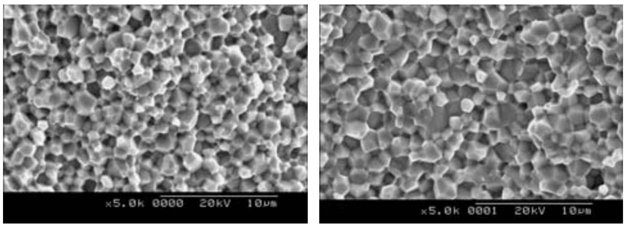
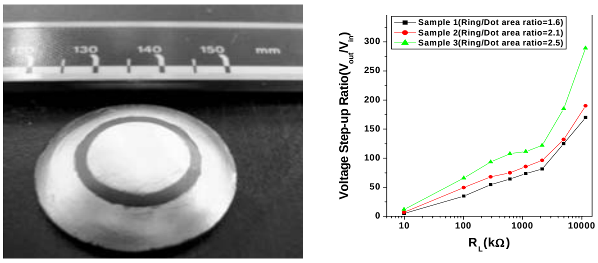


**Fig. 1. SEM micrographs of PSN-PMN-PZT sintered at 1300°C for 2hr; (a) disk-typed sample produced by die-pressing method, (b) dome-shaped sample produced by PIM.**

shown in Fig. 2(a). The step-up ratios as a function of load resistance are presented in Fig. 2(b). These results suggest that the voltage step-up ratio of dome shape transformer for a given load resistance ($R_L$) increases with decreasing dot areas. During the measuring the step-up ratios, ±10 $V_{p\text{-}p}$ square wave was applied at 1st resonance frequency (~98kHz) and the step-up ratios were calculated. As a result, the maximum step-up ratio is 290, which is 14 times higher than that of Rosen type device [2].




(a) (b)

**Fig. 2. (a) Real picture of dome shaped piezoelectric transformer (b) Step-up ratio of dome shaped piezo-electric transformer.**

General feature for the 55W lamp lit by the dome-shaped piezoelectric transformer was demonstrated in Fig. 3. A 55W PL lamp was successfully driven using the dome-shaped piezoelectric transformer fabricated by PIM method. 55W PL lamp driving characteristics of each piezoelectric transformer are summarized in table I. From the results, the transformer with ring/dot electrode area ratio of 2.1(sample 2) exhibited the best properties in terms of output power, efficiency and low temperature raise, 54.9W, 98% and 6.6K, respectively.

From the discussions above, the high power characteristics of dome-shaped transformer is related to a geometrical effects and proves that this transformer is adequate to apply to high power devices.

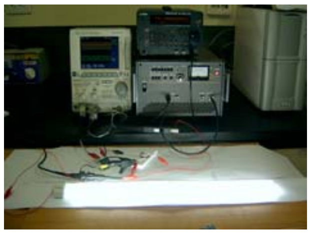


**Fig. 3. Light experiment of 55W PL lamp.**

**Table 1. Driving characteristics of 55W PL lamp by dome-shaped piezoelectric transformer**

| Sample No. | Ring/Dot area ratio | $V_{in}$ [$V_{rms}$] | $I_{in}$ [$mA_{rms}$] | $P_{in}$ [W] | $V_{out}$ [$V_{rms}$] | $I_{out}$ [$mA_{rms}$] | $P_{out}$ [W] | Efficiency(%) |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.6 | 175.1 | 302.8 | 53 | 212.5 | 234.4 | 49.8 | 94 |
| 2 | 2.1 | 180.3 | 311.1 | 56 | 240 | 228.8 | 54.9 | 98 |
| 3 | 2.6 | 185.1 | 313.3 | 58 | 268.5 | 205.2 | 55.1 | 95 |

## 3. Summary

The microstructure of piezoelectric materials fabricated by PIM was compared with that of disc type material fabricated by dry press processing. The average grain size of the PIMed specimen and the conventional die press processed specimen was similar and the dense and poreless morphologies were observed in both two different samples.

The possibilities for high power piezoelectric transformer were also examined using dome- shaped piezoelectric transformer. The voltage step-up ratio and lighting experiment were performed by using the samples with different ring/dot electrode area ratio. The observed maximum step-up ratio was 290 and the voltage step-up ratio of dome shaped transformer for a given load resistance ($R_L$) increases with decreasing dot areas. From the lighting experiments, the dome-shaped piezoelectric transformer with ring/dot electrode area ratio of 2.1(sample 2) exhibited the best properties in terms of output power, efficiency and low temperature raise, 54.9W, 98% and 6.6K, respectively.

## 4. References

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