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Geometric Effects of a Micromachined ZnO-Based Microspeaker

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This paper reports the performance improvement of micromachined piezoelectric microspeakers that are audible in open air according to the geometrical parameters. The sound pressure level (SPL) of the microspeaker fabricated with a piezoelectric ZnO film is even more enhanced due to the carefully designed process conditions and electrode shapes. The SPL of the fabricated microspeakers, which have a square electrode, shows more than 50 dB from 400 Hz to 20 kHz; the highest SPL is about 94 dB at 9.5 kHz with 5 V_{pp} sinusoidal input biases and 3 mm distances from the fabricated microspeakers to the reference microphone.

Keywords: microspeaker, MEMS, piezoelectric, ZnO

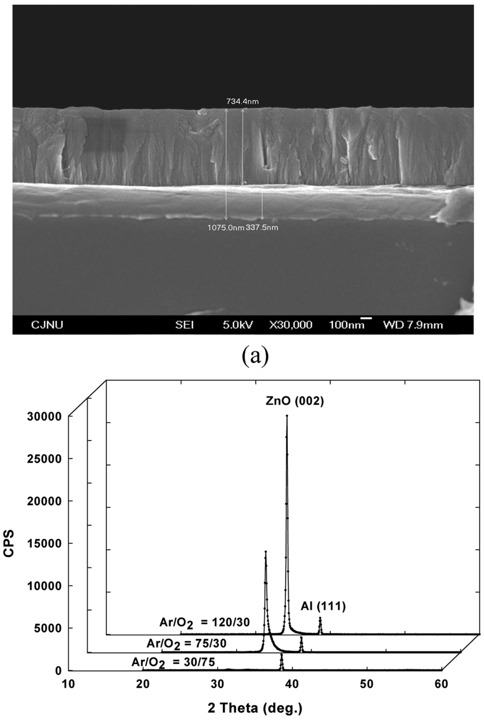
1. INTRODUCTION

Microelectromechanical system (MEMS) technology makes it possible to realize miniature microphones and microspeakers on a silicon wafer; this has the advantages of potentially low cost due to the batch process, possibility of integrating the acoustic transducer and the related read-out circuit on a single chip, and size reduction.[1-3] Furthermore, piezoelectric MEMS transducers are simple to fabricate and responsive over a wide dynamic range.[4,5]

In this paper, we present a miniaturized microspeaker for which ZnO piezoelectric thin film is used as an actuating layer. The effects due to the geometric variations are also studied in order to discover the appropriate design that can work in an open air environment.

2. MIRCOSPEAKER DESIGN AND FABRICATION

The ZnO piezoelectric layer was deposited by an RF magnetron sputtering system. Figure 1(a) shows a cross-sectional scanning electron microscopy (SEM) photograph of the deposited ZnO film. The deposited film is perpendicular to the bottom Al layer and has a fine grain structure. Figure 1(b) is one of the X-ray diffraction (XRD) patterns as a function of Ar/O_2 gas ratio (not showing temperature, chamber pressure effects on XRD data). As the Ar/O_2 gas ratio is increased, the intensity of the ZnO (002) XRD peak is significantly increased and shows the highest XRD peak when Ar/O_2 gas ratio is 120:30. The deposition conditions were set as follows: substrate temperature at 150°C, radio frequency (RF) power 1,500 W, chamber pressure 23 mTorr, and Ar/O_2 gas ratio 120:30. The characteristics of ZnO thin film have



(a)

(b)

Fig. 1. Structural analysis results: (a) SEM photo, (b) XRD data as a parameter of Ar/O2 gas ratio.

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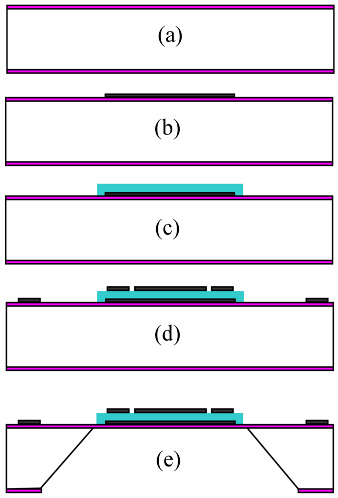

Fig. 2. Fabrication processes of micromachined piezoelectric microspeakers.

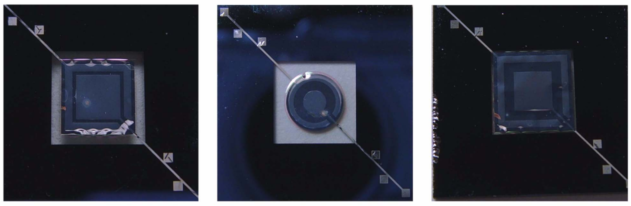
(a) (b) (c)

Fig. 3. Fabricated piezoelectric microspeakers with ZnO film: (a) square electrode (S1), (b) circular electrode, and (c) square electrode (S2).

been applied to the fabrication of piezoelectric microspeakers in this research.

Figure 2 shows the fabrication process-steps of the microspeaker. As can be seen in this figure, only four masks are used to fabricate a micromachined piezoelectric microspeaker. The fabrication process started with the isolation of the silicon wafer. Then, the deposited bottom Al was patterned to form electrodes (b) and followed by the ZnO piezoelectric film deposition and patterning (c). After defining the top electrodes onto the top surface of ZnO film (d), the silicon body residing below the actuating area was removed by anisotropic etching (e).

The fabricated microspeakers are shown in Fig. 3. The tested microspeakers have two geometrical shapes: one has a square electrode at the center of a diaphragm and a segmented electrode at the peripheral of the centered electrode; the other is circular with the same configuration. The fabricated microspeakers were tested in order to compare the performance difference as a function of electrode shape and the dimensional effect on the SPL of the microspeakers.

3. EXPERIMENTAL RESULTS AND DISCUSSION

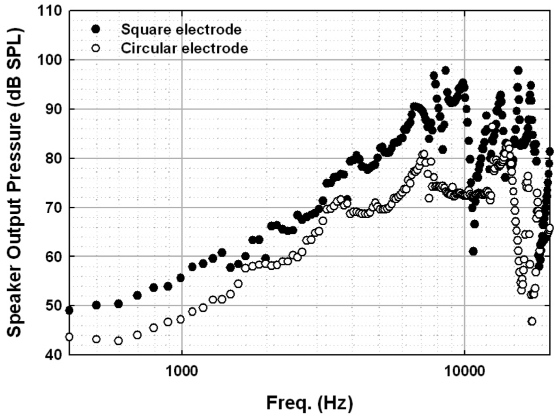

Fig. 4. Microspeaker output pressure as a function of frequency with different geometrical shapes and 5 Vpp input voltages.

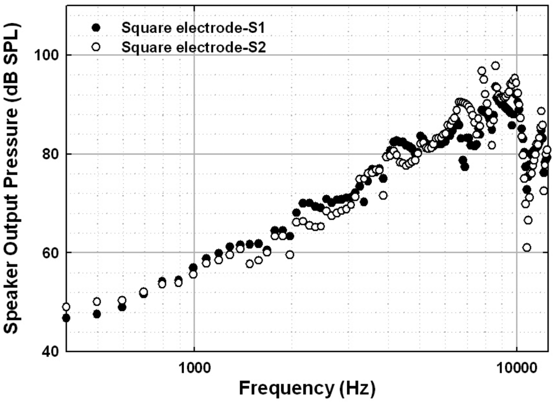

Fig. 5. Microspeaker output pressure as a function of frequency with different geometrical dimensions and 5 Vpp input voltages.

Figures 4 and 5 show the SPL comparison of fabricated microspeaker according to the electrode shape and the size of square electrodes, respectively. For comparison, microspeakers having a different electrode shape were prepared with a similar size. The SPL of the microspeaker that has a square electrode shows a relatively 10 dB higher value throughout the input frequency range and reveals 94 dB at 9.5 kHz with 5 V_{pp} sinusoidal input biases and 3 mm distances from the fabricated microspeakers to the reference microphone, as shown in Fig. 4.

In the case of the square-electrode microspeaker, the bottom electrode width of *S*2 is 4750 mm while that of *S*1 is 4000 mm. Even though there is improvement of microspeaker performance as the electrode shapes are changed from circular to square, the dimensions of the electrode, in the case of the square electrode type, seems not to be a critical factor in the performance of microspeakers, as can be seen in Fig. 5.

4. SUMMARY

In this study, a MEMS-based, piezoelectric microspeaker was presented including the geometrical effects. The SPL of the fabricated microspeakers, which have a square electrode, was measured at more than 50 dB from 400 Hz to 20 kHz; the highest SPL was about 94 dB at 9.5 kHz with 5 V_{pp} sinusoidal input biases and 3 mm distances from the fabricated microspeakers to the reference microphone. By using a square electrode, the microspeaker performance was expected to improve; however, the dimensions of electrode seem not to be a critical factor in performance of microspeaker.

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