Bendable Electro-Acoustic Transducer Fabricated Utilizing Frequency dispersion of Elastic Modulus

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Abstract

To realize the flexible speaker diaphragm that can be united with a flexible display without deteriorating lightweight properties and flexibility, a novel bendable electro-acoustic transducer (B.E.A.T.) has been developed employing the viscoelastic polymer as the matrix of 0–3-type piezoelectric composites.

1. Introduction

In recent years, research on flexible displays using flexible substrates such as plastic has been advanced. A flexible display has advantages in lightness, thinness, flexibility, etc. compared to a display using a conventional glass substrate, and can be rolled up and stored, resulting in the feature of not impairing portability even on a large screen.

When using such a flexible display as an image display and voice-generating equipment such as the TV receiver, a loudspeaker for generating sound is required.

In this research, for the purpose of achieving a bendable electro-acoustic transducer (B.E.A.T.) based on a 0-3 type piezoelectric composites [1-4] which can be united with a flexible display without deteriorating lightweight properties and flexibility, we focused on a viscoelastic polymer that has a large frequency dispersion in storage elasticity near room temperature and a maximum value in internal loss, and applied this to the matrix material of the piezoelectric composite.

2. Experiment

2.1 Sample preparation

First, a 40 um thick 0-3 type piezoelectric composite composed of a viscoelastic polymer and a piezoelectric ceramic was prepared by a solvent coating method on a Cu / PET film substrate. Next, a DC voltage of several kV was applied between the corona electrode provided at a distance from the upper surface of the sample and the base material to perform corona polling. Finally, the composite-based electro-acoustic transducer was completed by thermocompression bonding a Cu / PET film on the upper surface of the sample, as shown in Fig. 1.

For comparison with the viscoelastic-matrix sample, an elastic-matrix sample was also prepared using the same procedure

2.2 Characterization

The roll/unroll test was conducted using a cylinder with a curvature radius of 4 mm. The samples were rolled and unrolled repeatedly onto the cylinder for 1,000 cycles.

The rheological properties of the samples were derived using a dynamic mechanical analyzer at various frequencies from 10^{-2} to 10^{6} Hz.

3. Results and Discussion

3.1 Flexibility

Figure 2 shows the appearances of the samples subjected to the roll/unroll test: (a) viscoelastic matrix and (b) elastic matrix. No visible film failure was observed in the viscoelastic-matrix sample. In contrast, many streaks were observed in the elastic-matrix sample, which is indicative of film failure. Then, the Cu/PET film was peeled off the samples followed by direct observation of the surfaces of piezoelectric composite layers, as shown in Fig. 2. Obvious cracks were observed in the elastic-matrix sample as expected, while such cracks were not observed in the viscoelastic-matrix sample at all.

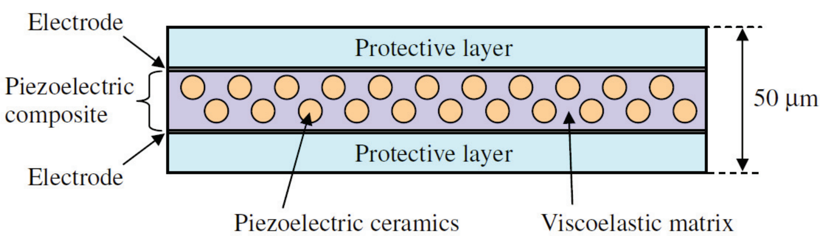

Fig. 1 Schematic of a composite-based electro-acoustic transducer prepared in this study.

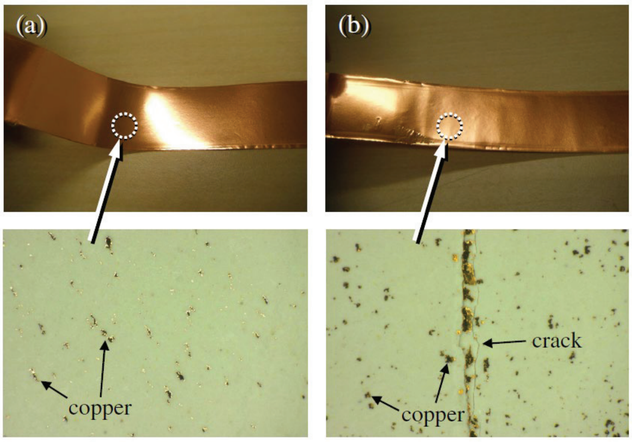

Fig. 2 Appearances of the samples subjected to the roll / unroll test: (a) viscoelastic matrix and (b) elastic matrix.

3.2 Rheological properties

Figure 3 shows the rheological properties of the samples: (a) viscoelastic matrix and (b) elastic matrix. From this figure, it can be understood that the viscoelastic-matrix sample behaves very softly against slow deformation of several Hz or less from the outside, and at the same time, it prevents cracks and peeling by dissipating strain energy as heat. On the other hand, for vibrations in the audio band (20 Hz to 20 kHz), the viscoelastic-matrix sample has a hardness that can sufficiently transmit the vibration energy of piezoelectric ceramics while maintaining a moderately large internal loss.

Figure 4 shows the acoustic properties (sound velocity and loss factor) of various speaker diaphragms including the electro-acoustic transducers prepared in this study. Compared with the cone paper, the viscoelastic-matrix sample has an equivalent or a higher sound velocity and 2–3 times larger loss factor. On the other hand, compared with the cone paper, the elastic-matrix sample has slightly lower sound velocity and equivalent loss factor.

4. Conclusions

In this study, a novel bendable electro-acoustic transducer (B.E.A.T.) has been developed employing the viscoelastic polymer as the matrix of 0–3-type piezoelectric composites. Against the comparatively slow (10 Hz or less) deformation from the outside, the viscoelastic matrix is viscous enough to prevent cracking and delamination. On the other hand, in the audible range (20 Hz to 20 kHz), the viscoelastic matrix is elastic enough to transmit piezoelectric vibration energy, maintaining a moderately large loss factor as well as a high sound velocity. BEAT is a very promising candidate for use in speaker diaphragms that can be united with a flexible display, without deteriorating lightweight properties and flexibility.

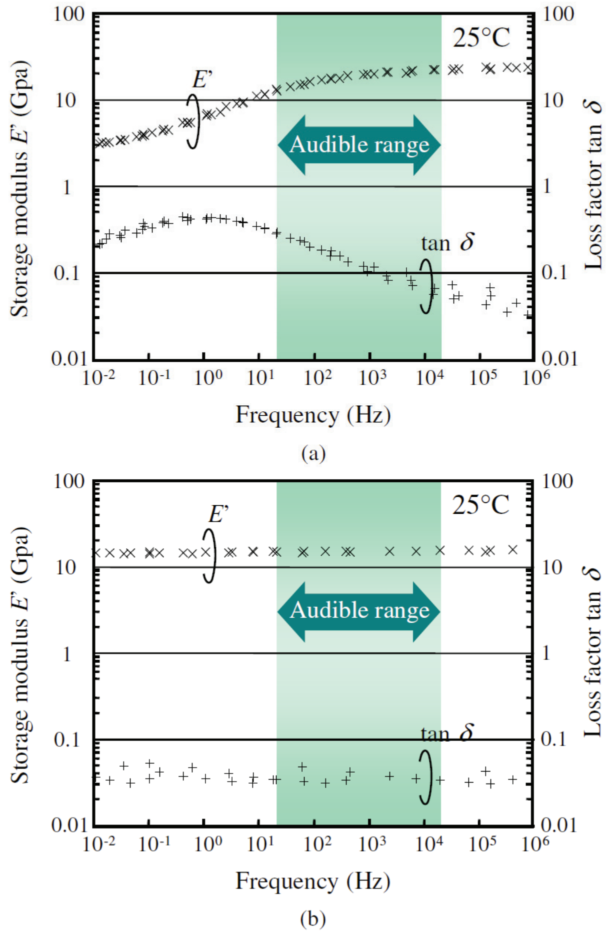

Fig. 3 Rheological properties of the samples: (a) viscoelastic matrix and (b) elastic matrix.

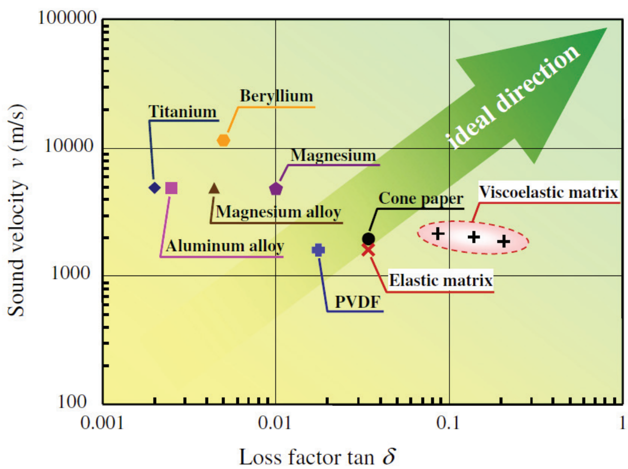

Fig. 4 Acoustic properties (sound velocity and loss factor) of various speaker diaphragms including the electro-acoustic transducers prepared in this study.

References

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