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Fabrication and Application of a CNT/PDMS Coated Optoacoustic Film Transducer

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1. Introduction

Due to optoacoustic effect, a composite of light-absorbing and elastomeric materials generates ultrasound waves when it is illuminated by a pulse laser. Recently, the optoacoustic transducers with the effect and their applications have been intensively investigated[1-3]. In order to make the transducers, the light-absorbing and elastomeric materials should be coated on a transparent substrate. As the substrate, a stiff solid material such as glass has been generally used so far. We reported that an optoacoustic plane transducer made of carbon nanotubes (CNTs) and poly-dimethyl siloxane (PDMS), which were coated on a 5 mm-thick poly(methyl methacrylate) (PMMA) substrate, generates the blast wave type shockwaves effectively[4]. In this study, we have fabricated an optoacoustic film transducer by coating the CNTs and PDMS on a surface of polyethylene terephthalate (PET) sheet with 0.1 mm thickness. The acoustic waves radiated from the film transducer were measured and analyzed. In addition, an application of the film transducer in making a line-focusing optoacoustic source was shown.

2. Transducer Fabrication

Multiwalled-CNTs and PDMS were coated on a surface of the PET sheet with 50 x 50 cm^2 area by a vacuum filtration and transition method and a spin-coating method, respectively, as the previous report[4]. As shown in Fig. 1, the diameter and thickness of the CNTs/PDMS composite layer were about 38 mm and 20 μm, respectively. The total thickness of the film transducer is about 120 μm and it is flexible.

3. Experimetal Setup

Figure 2 shows a schematic diagram of the experimental setup. As the optical source, a Q-switched Nd:YAG laser of 532 nm wavelength and about 8 ns pulse width, with 11~499 mJ/pulse energy and maximum 10 Hz PRF was used. The transducer was set in 24.5 °C water and the laser beam illuminates it with vertical angle approximately. The produced acoustic waves were measured using a needle hydrophone (Φ = 0.2 mm, Precision Acoustics) with an 8 dB preamplifier and a digital oscilloscope (LT354, LeCroy).

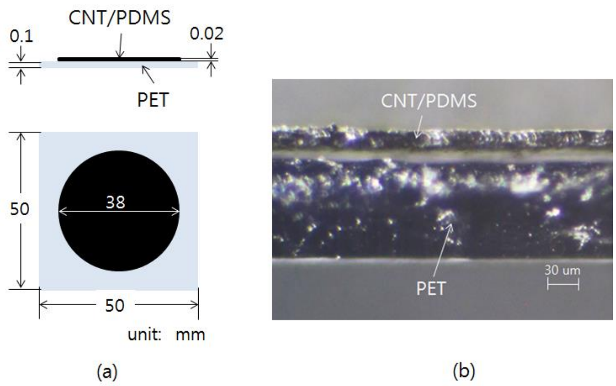

Fig. 1. Structure of the film (a) and microscope photograph showing thickness of each layer (b).

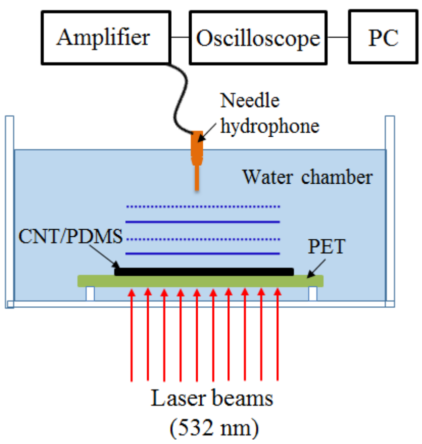

Fig. 2. Schematics of experimental setup

4. Results and Discussions

In Fig. 3(a), typical waveform of the wave generated from the optoacoustic film transducer is shown with the waveform fitted by modification of Friedlander equation[5]. The waveform was measured at 1.0 cm position from the transducer surface. In the modification, the pressure was assumed to be increased linearly until it reaches to peak pressure. The peak pressure was varied with the laser energy. It was 1.7 MPa and -6 dB pulse width of the sharp positive(+) phase was about 27 ns when the laser energy is 150 mJ/pulse. Because

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of the reflection from bottom of the transducer, there is a peak in the negative(-) phase. In the amplitude spectra of Fig. 3(c), the periodical patterns are shown due to the two shockwaves of the direct propagation and the bottom reflection as Fig. 3(b). The measured and the fitted ones are in good agreement in waveform. It reveals that the CNT/PDMS layer produces a blast wave type shockwave. The transducer could endure the laser energy higher than 300 mJ/pulse, and the positive(+) peak pressures changed linearly as shown in Fig. 4. The maximum 5.4 MPa was obtained when the laser energy is 330 mJ/pulse.

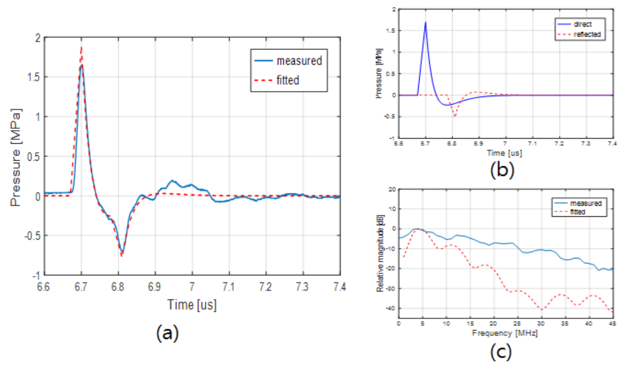

Fig. 3. Measured and fitted waveforms, two shockwave components of the fitted waveform (b) and frequency spectra (c).

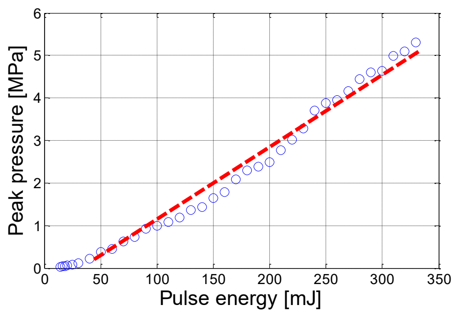

Fig. 4. Variation of the positive(+) and negative(-) peak pressures with laser energy.

Because the fabricated film transducer is flexible, it is easy to make different shape of acoustic shockwave sources. As an example, a cylindrical focusing source with the radius of curvature r=14 mm and aperture D=26 mm were made using the film transducers. A holder made by a 3D printer kept the cylindrical shape. Figure 5 shows the measured and simulated acoustic fields. In the simulation by PZFlex(Weidlinger Associates Inc.), it is assumed that the radiation surface consists of simple sources which generate the measured shockwave shown in Fig. 3(a). The simulated acoustic field shows that the beam is strongly focused within 0.18 mm of full width half maximum(FWHM) at focus. However, due to the hydrophone size and the step size(0.1 mm) of motor, the measured field was not so clear as simulation one and the beam was confined within 0.2 mm at focus. However, the waveform at focus was quite similar with the measured one in Fig. 3(a), and the peak pressure was 15.7 MPa for the laser energy 330 mJ/pulse.

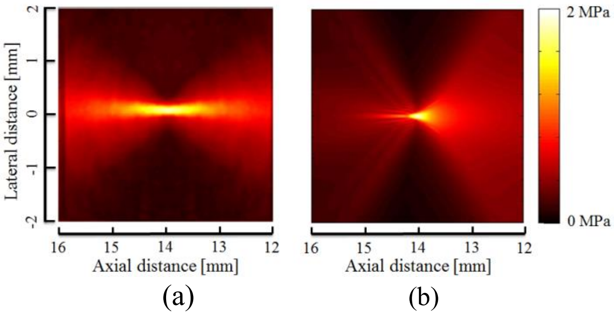

Fig. 5. Measured (a) and simulated (b) acoustic fields by the shockwave source with cylindrical radiation surface.

5. Summary

In this study, we have fabricated an optoacoustic film transducer by coating CNTs and PDMS on a thin PET sheet. The transducer generated shockwaves which have high peak pressures and very short pulse widths. It is noted that the waves have the waveform of a blast wave. The transducer is useful to make shockwave sources with different shape of radiation surface. As an example, it was shown that a line-focusing source, which is made by the film transducer, gives strong focusing effect with high pressure.

References

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