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Dynamic Behavior of Nanosecond Nd:YAG Laser Induced Impulse acoustic Wave

ナノ秒 Nd:YAG レーザ誘起インパルス音響波の動的振舞

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1. Introduction

The effect of an acoustic signature with shock wave on tissue or cell is one of great interes in topical applications such as drug deliverly [1] and gene transfer [2]. The shock wave with compressive stress can be generated in an endothermic optical absorber by using a laser pulse with high fluence. As we know, the laser-target interaction using a laser pulse was summarized by Los Alamos National Laboratory [3].

Black natural rubber (NR) sheet coverd with transparent material such as poly(ethylene terephthalate) sheet has been generally used as laser target for gene transfer [2,4]. Therefore, investigation of an impulsive acoustic wave induced by a laser pulse irradiation onto NR surface is essential to comprehend interaction between acoustic signature and cell. This paper presents dynamic behavior of nanosecond laser-inducded impulsive acoustic wave through NR sheet with several thicknesses.

2. Experimental procedure

The black NR sheets (1x1 cm^2, Sound Lab. Co. Ltd) with the thickness of 0.53, 1.1, 2.1, and 3.2 mm were used in this experiment. A constructed structure for measurement is shown in Fig. 1. An NR sheet was placed on a piezoelectric sensor using a 110-μm-thick poly(vinylidene difluoride) (PVDF) film with silver electrode (Tokyo Sensor) and the PVDF sensor was fixed on a 5-mm-thick bio phantom. In this structure, the gel was used for matching the acoustic impedance, namely, for reducing the reflection of acoustic wave at the interface.

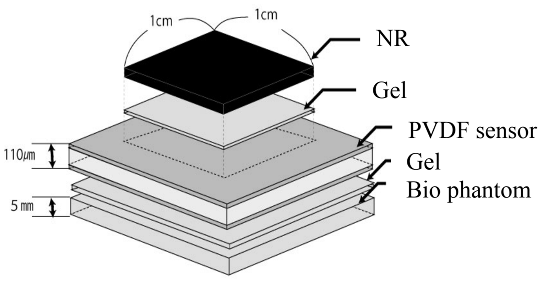

Fig.1 A constructed structure for measurement

Q-switched Nd:YAG (Spectra Physics, LAB-130) with second harmonic generation at a wavelength of 532 nm was used as a laser source, in which the maximum laser energy was 0.2 J/pulse. A single pulse with 10-ns-duration was focused on the NR surface through ND filter and lens. A focused beam size on the surface was approximately 2.3 mm in diameter and the laser fluence was changed by using ND filter with different transmittance. The acoustic signatures were observed as voltage signal from piezoelectric sensor by using 1.5 GHz digital oscilloscope (LeCloy, LC684DXL). An illustration of typical measurement system has been introduced in our previous work [5]. Table 1 shows the laser intensity, fluence, and transmittance of ND filter used in this experiment.

Table 1 Laser intensity, fluence, and transmittance of ND filter

Intensity [MW/cm^2]	9.6	48	96	144	240	480
Fluence [J/cm^2]	0.096	0.48	0.96	1.4	2.4	4.8
Transmittance of ND filter	2%	10%	20%	30%	50%	100%

3. Results and discussion

Figures 2 and 3 show typical acoustic signatures observed as voltage signal from the piezoelectric sensor at various fluence and the peak voltage variations as function of fluence in the case using 0.53-mm-thick NR sheet, respectively. The absolute voltage values of 1st positive peak were larger than those of 2nd negative peak in the high fluence region, because ablation pressure increased in accordance with fluence. We found from measurement of full-width at half-maximum (FWHM) value and rise time of the 1st positive peak in the case using 0.53-mm-thick NR sheet that the

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FWHM values tended to saturation under larger fluence than 1 J/cm^2, whereas the rise time was independent on fluence and its value roughly ranged from 30 to 40 ns.

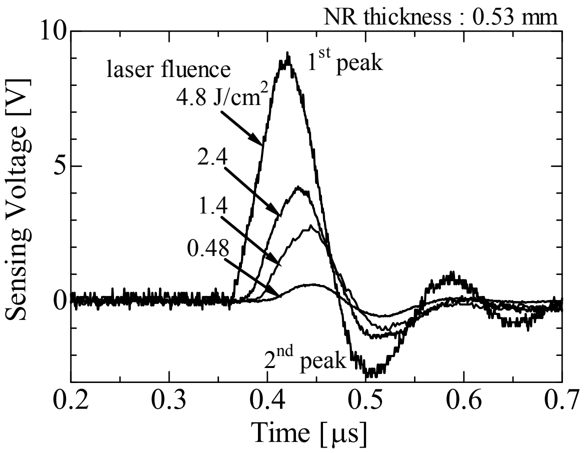

Fig.2 Typical acoustic signatures in the case using 0.53-mm-thick NR sheet at various fluence.

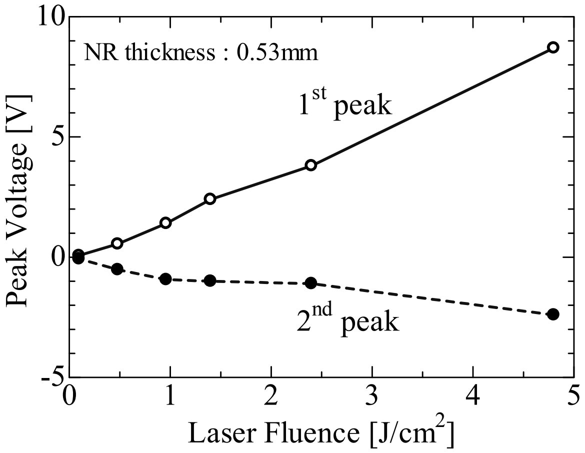

Fig.3 Peak voltage variations as function of laser fluence using 0.53-mm-thick NR sheet.

Figure 4 shows the acoustic signatures of different thicknesses of NR sheet at a fluence of 4.8 J/cm^2. It was found from this result that the 1st positive peak width became spread and the positive peak voltage exponentially decreased in increasing NR thickness. The reduction coefficient α of the 1st positive peak was approximately 0.85 mm^{-1} when the peak voltage values as function of NR thickness (d) were fitted by using an exponential function described as $\exp(-\alpha d)$.

Figure 5 shows the NR thickness vs. time of 1st peak voltage in the case at a fluence of 4.8 J/cm^2. By least square fitting of the obtained results, an estimated velocity of the impulsive acoustic wave was approximately 1590 m/s. This value was slightly larger than a sound velocity of bulk NR.

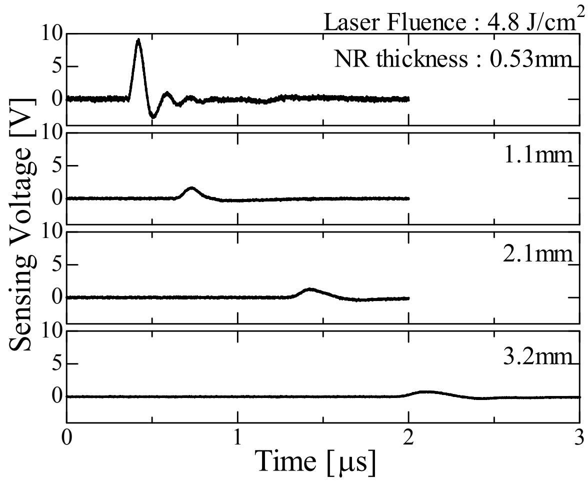

Fig.4 Acoustic signatures with different thickness of NR sheet at a laser fluence of 4.8 J/cm^2.

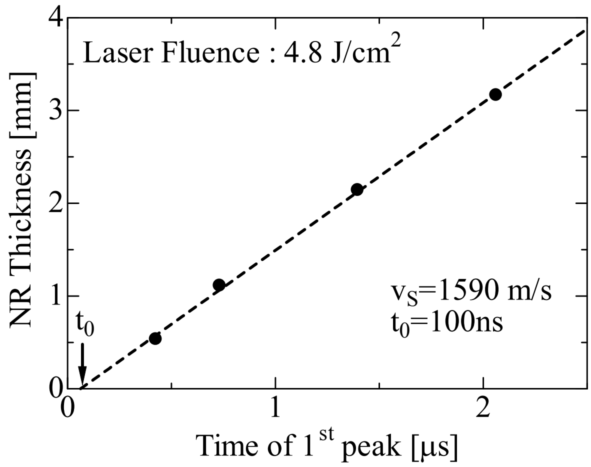

Fig.5 NR thickness vs. time at 1st peak voltage in the case at a laser fluence of 4.8 J/cm^2.

4. Conclusion

We investigated the dynamic behavior of impulsive acoustic wave induced in the NR sheet with the thickness from 0.5 to 3 mm by a 10-ns laser pulse with several fluences up to 4.8 J/cm^2.

Acknowledgment

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References

1. S. Lee et al., IEEE J. Sel. Top. Quantum Electron. **5** (1999) 997.
2. M. Terakawa et al., Opt. Lett., **29** (2004) 1227.
3. C. R. Phipps et al., J. Appl. Phys., **64** (1988) 1083.
4. M. Ogura et al., Lasers in Surgery and Medicine, **34** (2004) 242.
5. Y. Tokunaga et al., Proc. of Sympo. on Ultrason. Electron., **31** (2010) 255.