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Investigation on detections of laser induced thermal and stress wave using PVDF film transducers.

PVDF 膜トランスデューサを使うレーザによる熱波や応力波の計測研究

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1. Introduction

Since a polyvinylidene fluoride film (PVDF film) has both piezoelectric and pyroelectric characters, it can be widely used in various practical sensings. We have also studie to new aspect on sensing by the PVDF film transducer. As we know, when lights of various lasers are irradiated on endothermic surface absorbing material, photothermal effects may be observed. When weak and middle class energy lasers such as He-Ne laser, Ar ion laser and laser diode are used to irradiate on the material, heat source on surface of it may be formed and then thermal wave is formed by it. We call it "Laser induced thermal wave (LITW)". It has been used as a probe for material characterization, irregularity of materia., On the other hand, when high intensity lasers such as Q-switched double frequency Nd:YAG pulse laser, Excime laser and CO_2 laser are irradiated to surfaces of endothermic surface absorbing materials, laser ablation phenomena on the surfaces may be caused positive going configuration wave (compression wave) called laser induced stress wave (LISW) is generated. It is said that these waves can be used to carry out DNA transfection and drug delivery into a cell membrane in a biomedical field.[1)] In order to confirm whether or not above investigations will be succeed, a sensor with wide frequency range, high sensing ability, and easy performance must be developed. For finding out the sensor material satisfied above requirement we discussed to pick up potentiality of the PVDF film. However, it is difficult to perform with direct way of conventional methodology which has been already done because plant corresponds upon complex system and obeys always to rule of life arrow (time irreversibility) relating with an energy dispersive process.[2)] We consider that the PVDF film transducer for sensing has capability for various applications in bionics. In this paper we describe experimental results of photothermal effect in the living leaf of plant "scheffelera arboricola (Kapok)" and also of dynamics of photomechanical wave (stress wave) induced by Q-switched Nd:YAG laser.

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2. Sensing methods by PVDF film transducers

We have used commercial PVDF seats produced by production a manufacturer (Measurement specialiteis Co.Ltd, USA) since we cannot make them by ourselves. The representative film thicknesses were 28, 52, and 110μm, respecitivly. **Figure 1** shows schematically detection of photothermal signal at a living leaf of plant. The leaf measured was put in space between two PVDF film transducers. In this configuration we can measure simultaneously amplitude and phase of the photothermal signal. The sensing system was in a similar to that in Ref. (3). On the other hand, detection of stress wave as shown in **Fig. 2** was done by the PVDF film transducer. The PVDF film transducer was contacted, by mediating an adhesive, with a natural rubber for the LISW generation.

3. Experimental results

Figures 3(a) and (b) show the experimental result on amplitude and phase of photothermal signal in the living leaf. Irradiated wavelength was 633nm. Parameters in this figure were various sensing time which were forenoon, noon,and afternoon. The dependence of amplitude on light modulation frequency was proportional to f^{-04} in ranging from 10 to 1000 Hz. On the other hand the phase was increased gradually from about -40 degreee to -10 degree with the f. Change of subjects, the LISW for DNA transfection and drug delivery were generated by laboratory-scaled Q-switched ns-pulse Nd:YAG laser (200 [mJ/puse]). The PVDF film transducer plays important role in detection of the LISW since it is not only wide band frequency response and rapid pulse reaction but also acoustic impedance approaches to that of an organism. **Figure 4** shows temporal profiles of the thermoelastic wave and the positive-going stress wave in the case of confined ablation when irradiated energies were about 5 and about 843 [mJ/cm^2], respectively. It was found that the thermoelastic wave was a bipolar signal having both positive and negative components and the stress wave, on the other hand, was unipolar signal of positive-going component alone. From above

experimental results, the PVDF film transducer can be used effectively, in spite of simple configuration, as a sensor for multi-purpose sensing.

4. Conclusion

We presented experimental results on photothermal effect in the living leaf of plant "Kapok". and on dynamics of the LISW induced by Q-switched Nd:YAG pulse laser using PVDF film tarnsducer.

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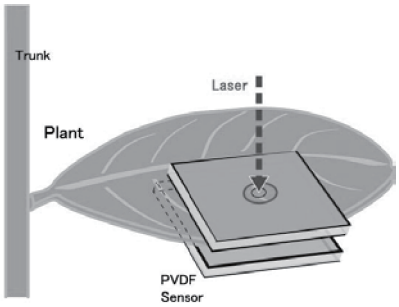

Fig.1 For detection of photothermal signal in a living leaf. Two transducers were contacted directly with the leaf. Pyro-electric effect in the PVDF film was used.

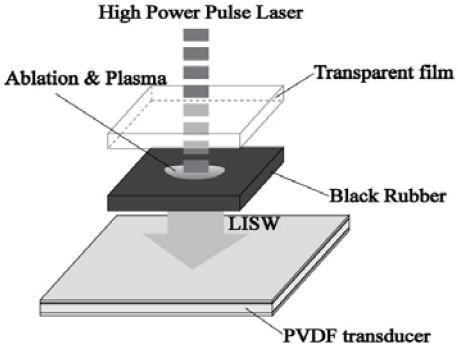

Fig.2 For detection of the LISW. Piezoelectric effect in the PVDF film was used.

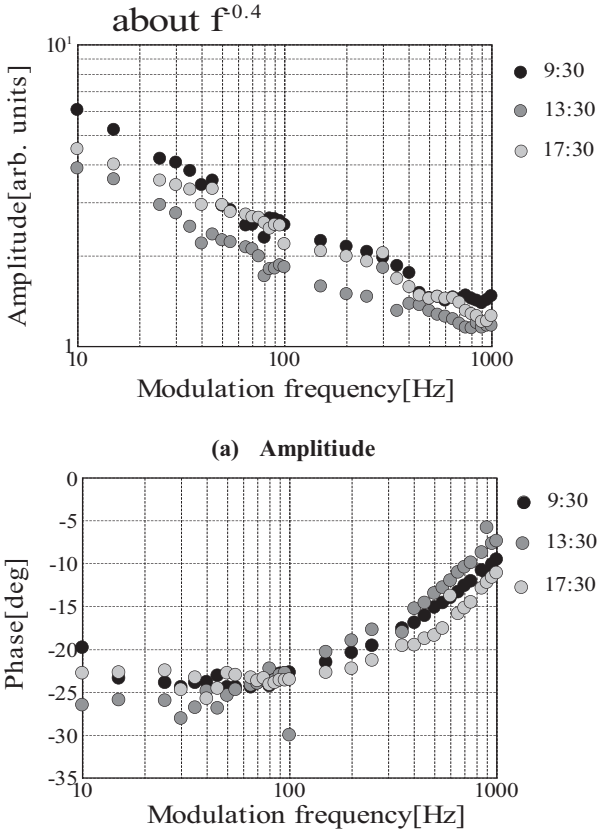

Fig.3 Modulation frequency dependence on amplitude and phase of photothermal signal in a living leaf (633nm)

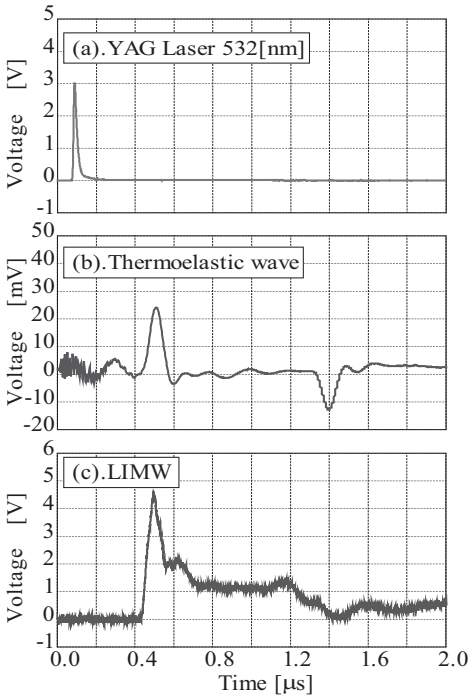

Fig.4 Temporal profiles of thermoelastic and stress waves: (a)laser irradiation profile, (b)profile of thermoelastic wave,and (c)that of LISW