Ultrasonically induced electrical potentials in round poly-L-lactic film

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1. Introduction

Osteosynthesis materials are often used for fixed treatment of bone fracture. Main osteosynthesis materials are metal and bioabsorbable polymers. The poly-L-lactic (PLLA) is one of the most famous bioabsorbable materials. PLLA is also known to have piezoelectricity. Ikeda reported that the piezoelectricity of a drawn PLLA rod could increase new bone formation in 1996[1)]. On the other hand, low intensity pulsed ultrasound (LIPUS) is used for bone healing therapy. The mechanism of LIPUS bone healing is still unknown, however, we think the weak piezoelectricity of bone may be one of the key factors. Low intensity ultrasound irradiation decreases 30 – 40% of healing period of bone fracture.[2)].

In this study, we experimentally investigate the piezoelectricity of PLLA. The piezoelectricity of PLLA is still unclear in the MHz range (LIPUS frequency range). If the piezoelectricity of PLLA is larger than bone, the combination of PLLA and LIPUS may improve the bone healing process.

2. Sensitivity of a PLLA ultrasonic receiver

Tajitsu reported the piezoelectric constants of PLLA in the low frequency range.[3)]

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$$[d] = \begin{bmatrix} 0 & 0 & 0 & d_{14} & 0 & 0 \\ 0 & 0 & 0 & 0 & -d_{14} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \cdots (1)$$

We have fabricated an ultrasonic receiver using a PLLA film (round shape, diameter:10mm, thickness:50μm, Murata Manufacturing Co., Ltd). The structure of the handmade PLLA transducer is same as the PVDF transducer and is shown in **Fig. 1**. For comparison, we also fabricated PVDF transducer using PVDF film with similar thickness.

In this experiment, the receiver sensitivity of the PLLA transducer was obtained by using comparative calibration method[4)].

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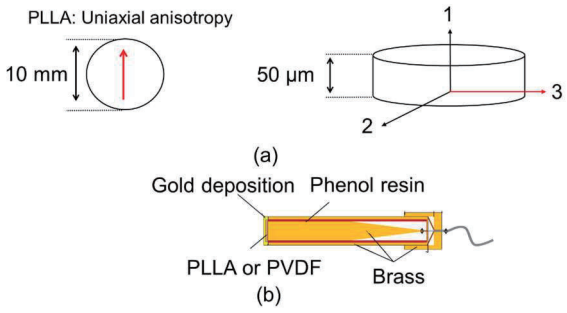

Fig. 1 (a) PLLA sample (b) structure of transducer.

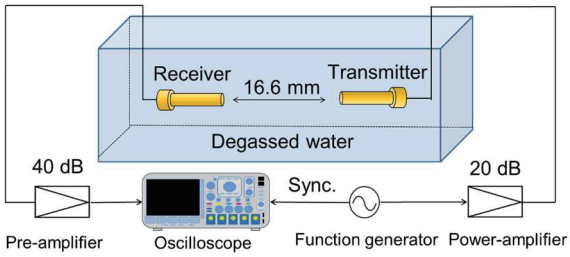

Fig. 2 Experimental sysytem.

3. Experimental system

The experimental system is shown in **Fig. 2**. A transmitter (PVDF) and receiver (PVDF or PLLA) were set coaxially in degassed water with distance of 16.6 cm (far field region). A function generator (33600A: Agilent Technologies) generated a sinusoidal burst wave (i.e, 7 Vp-p, burst cycle: 10, frequency: 1 – 9MHz, 250 kHz step). The electrical signal was amplified to 70 Vp-p by an amplifier (BA4850: NF) and was applied to the transmitter. The ultrasound waves were measured by the PLLA receiver or the calibrated PVDF receiver. The received signals were then amplified 40 dB by a pre-amplifier (BX-31A: NF) and observed by an oscilloscope (DPO7104C: Tektronix).

4. Results and Discussion

The observed waveforms by the PLLA receiver are shown in **Fig. 3**. The amplitudes were about quite small compared to the wave observed by the PVDF receiver. However, the induced electrical potentials of PLLA were clearly observed even at high frequency such as 9 MHz.

The sensitivity of PLLA and PVDF receiver are shown in **Fig. 4**. The sensitivity of the PLLA receiver was about 1/1000 of the PVDF receiver. This is because the piezoelectric constant (d_{33}) of PVDF is about 30 pC/N, while the PLLA piezoelectric constant (d_{14}) is about 10 pC/N [5]. Furthermore, since longitudinal waves have a large influence on the sensitivity of transducers, the sensitivity of PLLA is much smaller than that of PVDF. In addition, the piezoelectric constant of the human tibia (d_{14}) is about 7 pC/N. Therefore, the receiver sensitivity of bone would be smaller than that of PLLA. In fact, Okino et al. fabricated a transducer using an anterior part of a bovine femur, which is similar to the human bone structure, and measured its receiver sensitivity. The receiver sensitivity of bone was about 1/10 that of the PLLA transducer[6]. The above results suggest that the ultrasonically induced electric potential in PLLA may be higher than that in bone.

5. Conclusion

The small piezoelectricity of the PLLA film was experimentally investigated. For this purpose, a PLLA ultrasonic receiver was fabricated. The sensitivity of the PLLA receiver was higher than the bone transducer reported in our former study[6]. The results indicate that ultrasonically induced potentials may increase by the use of PLLA at a osteosynthesis material. The combination treatment of PLLA and LIPUS would be effective for better bone healing. In the next step, we should study on the piezoelectricity of bulk PLLA materials, which are sometimes used for osteosynthesis.

6. References

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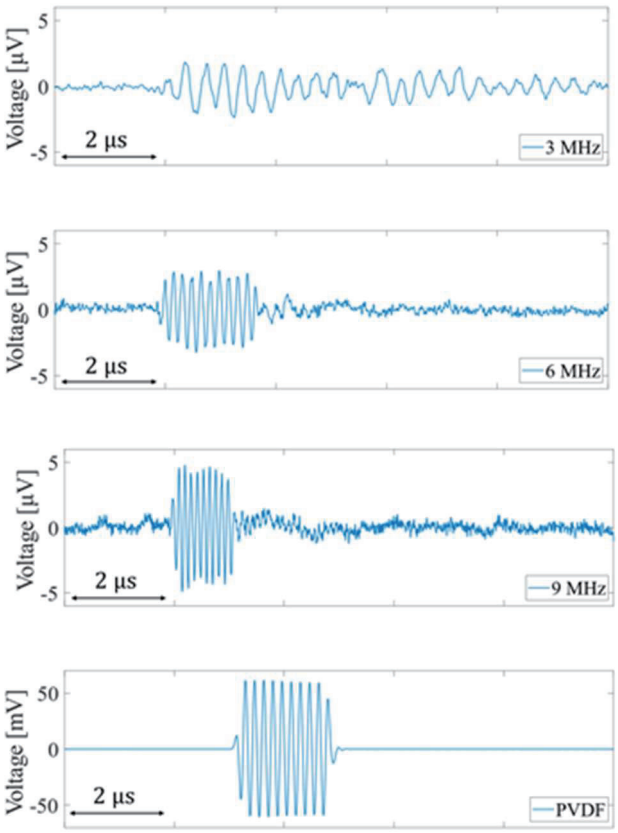

Fig. 3 Observed waveforms by PLLA (3, 6, 9 MHz) and PVDF (6 MHz) receivers.

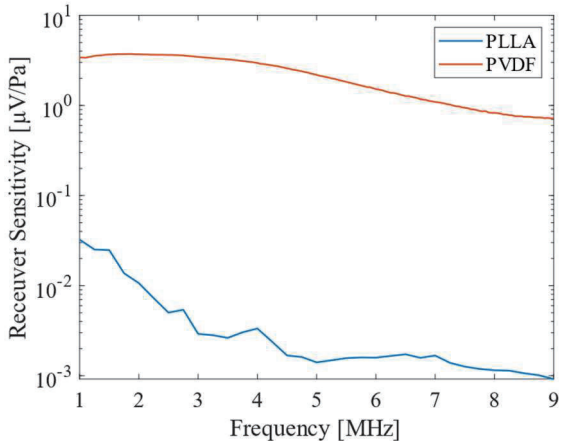

Fig. 4 Sensitivities of PLLA and PVDF receivers.