Proceedings of Symposium on Ultrasonic Electronics, Vol. 32 (2011) pp. 235-236
8-10 November, 2011

A study on Power Accumulator of Surface Acoustic Wave and its Application to Plastics Welding

弾性表面波のパワー合成とプラスチック溶着への応用

Kengo Naruse[1†] and Yuji Watanabe[2] ([1]Seidensha Electronics Co., Ltd.; [2]Takushoku Univ., Faculty of Engineering)
成瀬 健悟 [1†], 渡辺 裕二 [2] ([1] 精電舎電子工業(株), [2] 拓殖大 工学部)

1. Introduction

We are carrying out ultrasonic plastic welding by using a surface acoustic wave (SAW) device by means of $LiNbO_3$ substrate. [1)-4)] The advantage of usage of a SAW device for welding is as follows : It is known that usage of higher frequencies makes joining time shorter, because ultrasonic absorption coefficient of polymer is proportional to the square of frequency. Furthermore, damages of joined parts can be avoided and positioning accuracy becomes higher, because displacement of vibration of joining tool can be small at higher frequencies. Therefore, it is thought that it is suitable for precise welding. On the other hand, it is very difficult to get wider area of joining part by using conventionally used longitudinal-mode transducer system at higher frequencies. By using the SAW joining system, however, we can get a wider work area on the SAW device.

On the other hand, $LiNbO_3$ substrate cracks easily by static load in the SAW joining. Therefore, we tried using PZT substrate in this study, because PZT substrate is very harder than $LiNbO_3$ substrate. However, unfortunately, PZT substrate cannot excite high enough amplitude of SAW, because the electro-mechanical coupling efficiency of PZT is very low. In order to overcome these problems, we try power accumulation of SAW. Since PZT substrate is assumed to be isotropy for SAW, we can superpose some SAW which are propagating in various directions.

In this study, we describe the design method of the SAW power accumulator, and a result of a trial of plastic joining by means of the accumulator.

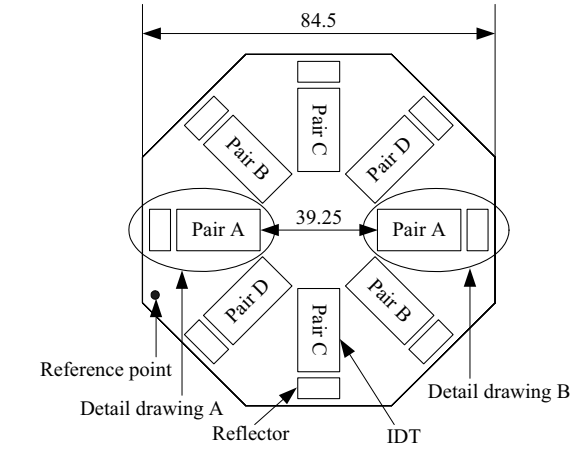
2. Construction of SAW power accumulator

Figure1 illustrates the SAW device that used in this study. The substrate of the SAW device is PZT (Model : C-213 FUJI CERAMICS). The form of substrate is regular octagon. The size of substrate is a width of 84.5 mm and a thickness of 10 mm. Using the substrate, we designed a 2.0 MHz SAW resonator.[5),6)] Since, the acoustic velocity of the SAW of the substrate is 1988 m/s, one wavelength is 1.0 mm. Therefore, the width of every electrode finger and the gap width between electrode fingers were both designed as 0.25 mm. Moreover, we arranged inter-digital transducer (IDT) and reflector on the substrate as shown in Figure 1 (a) and (b). We used aluminum for the vapor-deposition of the electrode of the PZT substrate.

*E-mail address : k_naruse@sedeco.co.jp

3. Electrical characteristic of SAW power accumulator

Figure 2 shows frequency characteristic of



Width of inter-digital electrode : 0.25mm
Aperture length : 10mm
IDT : 17pairs×8 Reflector : 5pairs×8
Substrate : PZT(Model : C-213 FUJI CERAMICS)

Fig. 1 Construction of SAW power accumulator (Unit : mm).
(a) Construction of electrode fingers
(b) Detail drawing A and B of electrode fingers

the SAW power accumulator. We can see that SAW power accumulator has some natural frequencies. We considered that it is difference of natural frequencies of each pair of IDT. In addition, the phase angle of frequency characteristic not reached zero degree. We consider that it is caused by the fact that the damped-capacitance of the PZT substrate is too large. In order to find a mechanical resonant frequency, we tried atomization of a drop of ethanol on the accumulator. As the result, we obtained 2.18 MHz as the natural frequency of the SAW accumulator.

Next, we checked electric current flowed into each pair of IDT when the SAW accumulator is driven at 2.18 MHz. In this measurement, we measured input current of each pair of IDT under the each pair of IDT is driven in parallel. Figure 3 shows the result. The values of current were 2.60 $A_{p\text{-}p}$ for Pair A, 3.08 $A_{p\text{-}p}$ for Pair B, 3.12 $A_{p\text{-}p}$ for Pair C and 2.48 $A_{p\text{-}p}$ for Pair D under the supplied voltage of 200$V_{p\text{-}p}$. As shown in Fig.3, the values of current for each pair of IDT are almost same. Therefore, we can confirm that the each pair of IDT apportioned an acoustic load.

Figure 4 shows a result of joining of polyethylene films by means of the SAW power accumulator. The static load was about 10kgf and the joining time was 10 s. The joint strength was too low to measure.

4. Conclusions

The power accumulation of SAW by means of PZT substrate with four pairs of IDT was described. We can conclude that the idea and method are correct. Moreover, we confirmed that the accumulator can be used to plastic joining.

However, the resonant characteristics and vibration amplitude of SAW are still poor. So that we are considering positioning and dimension of IDTs in order to improve the characteristics of the accumulator.

References

1. K. Naruse, K. Mori and Y. Watanabe : Jpn. J. Appl. Phys. **47** (2008) pp.4305-4308.
2. K. Naruse, K. Mori and Y. Watanabe : Proc. Symp. Ultarason. Electro. **29** (2008) pp.473-474.
3. K. Naruse, K. Mori and Y. Watanabe : Proc. Symp. Ultarason. Electro. **28** (2007) pp.345-346.
4. K. Naruse and Y. Watanabe : Proc. Symp. Ultarason. Electro. **26** (2005) pp.109-110.
5. T. Kojima : Doctoral Dissertation, Tohoku Univ. 1988[in Japanese]
6. Y. Watanabe, Y. Tsuda and E. Mori : 13th International Congress on Acoustics **3** (1989) pp.451-454

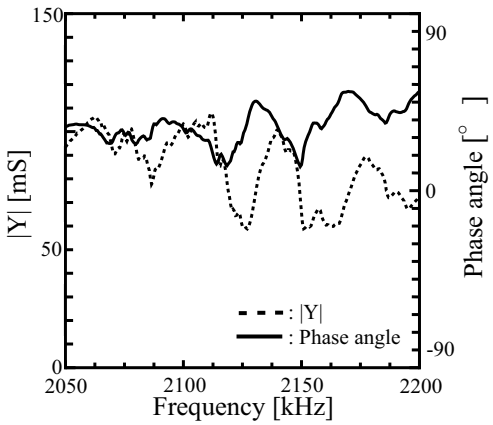


Fig. 2 Frequency characteristic of SAW power accumulator.

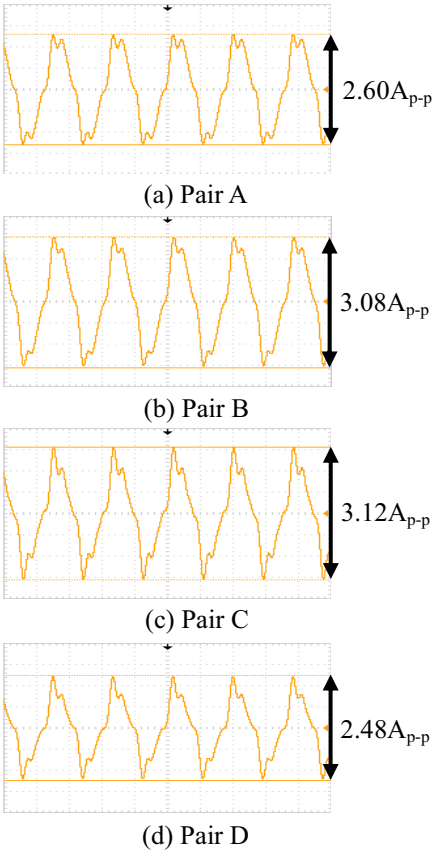


Fig. 3 Electric current waveform of each pair of IDT (Supplied voltage : 200$V_{p\text{-}p}$)

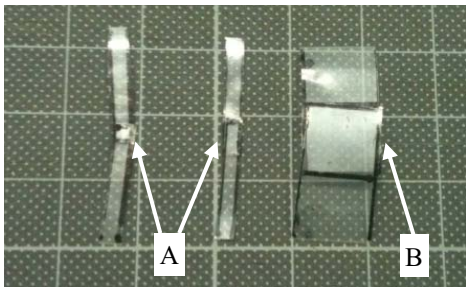


Fig. 4 Optical observation of joined samples.
Specimens : PE film(Thickness 0.3mm)
Area of joind part A : 2×2 mm^2
Area of joind part B: 10×10 mm^2