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Fabrication of SAW device arrays on segmented piezoelectric substrates with concave structures

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1. Introduction

A surface acoustic wave (SAW) is mechanical vibration that propagates on and near the surface of an elastic material. SAW devices (**Fig.1 (a)**) are a type of piezoelectric microdevices that consist of piezoelectric substrates and interdigital transducers (IDTs). In SAW devices, the IDTs work as the micro-transducer between the electrical signals (input and output signals) and the SAW (mechanical vibration wave).

The center frequency of SAW excited by the IDTs (f) [Hz] (design value) is one of important features of SAW devices, and is obtained using the equation (1).

$$f = \frac{v}{p} \tag{1}$$

Therefore, the center frequency (f) [Hz] of SAW device can be designed and controlled by the propagation velocity (v) [m/s] of the SAW for the substrate or the pitch length between adjacent electrodes (p) [m] in the IDTs.

SAW devices are also expected to be used in physical and chemical sensors in the future. The shift of the center frequencies and/or the phase shift of SAW devices can be used in the sensing applications. When we can develop SAW device array integrated on the same substrate for gas sensing, it may be convenient to detect a wider range of multiple gas species in parallelly. However, SAW excited by each IDTs of SAW device may affect the adjacent IDTs of other SAW devices worked simultaneously on the same substrate.

Therefore, the final goal of this research is to develop an array of SAW devices with reduced mutual interference in the sensing. In this study, we attempted to investigate the effect of the mechanical structures on the propagation characteristics of SAWs on segmanted surface of the substrate.

2. Microfabrication of SAW Devices

In this study, we have fabricated SAW device arrays on quartz substrates which are segmented with concave step structures. **Fig.1(b)** shows the cross-sectional view of the adjacent two SAW devices including concave step structure. The concave structures are fabricated by etching of the ST-cut quartz substrate (ST-X) among the IDT fabrication areas of multiple SAW devices.

Fig.2 shows the procedure for the microfabrication of SAW device arrays. First, Ti as electrode material was deposited on the frontside of ST-X substrate by DC sputtering (Fig.2-(a)). Next, Al is deposited on the backside of the same ST-X substrate by DC sputtering (Fig.2-(a)). After that, photoresist were spin-coated on the deposited Ti thin film and UV light was exposured to fabricate a photoresist etching mask (Fig.2-(b)). In addition, Ti thin film (Fig.2-(c)) and the ST-X substrate were sequentially dry-etched to form the concave step structures on the frontside of ST-X substrate (Fig.2-(d)). Next, photoresist is spin-coated on the frontside of substrate again and UV light was exposured again (Fig.2-(e)). Finally, IDTs of Ti thin film (IDTs (Ti)) was fabricated by dry etching of Ti thin film again. The residual resist was removed (Fig.2-(f)).

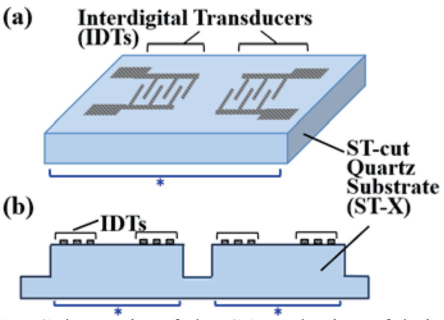

Fig. 1 Schematic of the SAW devices fabricated in this study. (a) a unit structure of the SAW device. (b) cross-sectional view of adjacent two SAW devices segmented by concave structure.

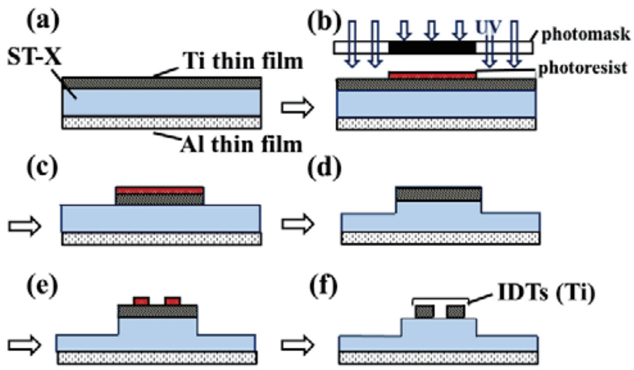

Fig. 2 Microfabrication process of SAW devices with concave step structures fabricated on ST-X substrates.

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3. Estimations of fabricated SAW device array

Fig. 3 shows the micrographs of the IDTs (Ti) fabricated in this study. Micropatterns of Ti thin film for the IDTs have been successfully fabricated on the frontside of ST-X substrate. **Fig. 4** shows the appearance of the SAW device arrays fabricated on ST-X substrate (substrate: 3-inch wafer of ST-X). SAW devices with IDTs (Ti) have been arrayed on the surface (frontside) of ST-X substrate segmented with concave structures.

In this study, we have measured the frequency response of SAW between the two IDTs (input / output) fabricated on the same ST-X substrate to investigate the effect of concave structures on the propagation characteristics of SAW. In particular, we selected two sets of paired IDTs, which were located within the same segmented area (case-(i)) and which were separated with concave structure (case-(ii)) on the same ST-X substrate. In these experiments to investigate the frequency response, SAW was excited by IDT(L) in Fig.4, and the frequency response (transmission response (S_{21})) obtained at IDT(L1) (case-(i)) and IDT(L2) (case-(ii)) as the output IDT which were measured in each case. Figs.5 show the measurement results of the transmission responses (S_{21}) for each case. In this experiment, the sheets of electromagnetic wave absorption material were also used as the other way to reduce the mutual interference between the adjacent IDTs.

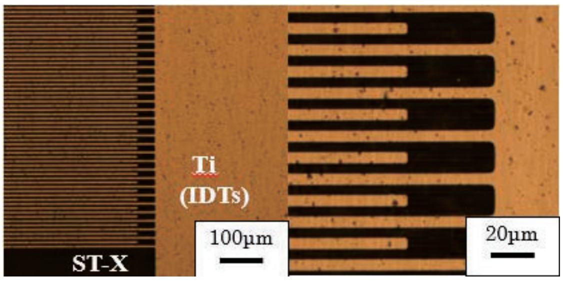

Fig. 3 Micrographs of IDTs of Ti thin film in SAW devices fabricated on ST-X substrate.

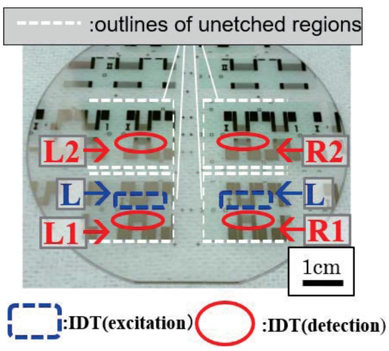

Fig. 4 Appearance of SAW device array fabricated in this study.

As a result, the reduction in transmission responses was small when the pair of IDTs were mechanically separated with concave structures (depth: 300~500nm) though the attachment of sheets of electromagnetic wave absorption material on the concaves indicated more significant reducing effect on the transmission characteristics. It is likely that the reducing effect on the transmission characteristics with concave structures is not enough due to the insufficient depth of the concave structures in this study.

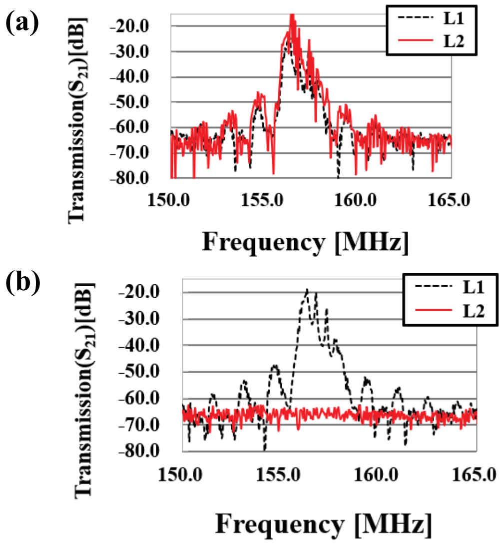

Fig. 5 Frequency responses S_{21} (transmission) between two IDTs selected as described in Fig.4. L1: between two IDTs (L and L1) located in the same segment on the ST-X substrate, L2: between two IDTs(L and L2) separated with concave structure on the ST-X substrate (without (a) / with (b) the sheet of electro-magnetic wave absorption material).

5. Conclusion

In this study, we have investigated the effect of concave structures fabricated on the surface of device substrates on the propagation characteristics of excited SAW. When the depth of the concaves structures was 300~500nm, the reduction of the propagation characteristics is small. It is likely that the reducing effect is also small for the insufficient depth. In the future, we plan to compare the results with those obtained when the ST-X substrate is segmented by more deep concave structures and/or rectangular grooves.

References

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