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An Improved Micro-Fabrication Technique for Aluminum Electrodes of Surface Acoustic Wave Transducers

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Introduction UHF circuit application of surface-acoustic-wave (SAW) devices requires interdigital-transducers (IDT) having about 1 μm electrode width. An aluminum electrode causes much less mass-loading effect than any other electrode material and so is most suitable to the SAW-IDT. A spacer-inserted lift-off method is known to be a useful accurate pattern-definition technique; especially for such a tenacious metal film as gold[1). Whereas aluminum is also tenacious, this technique cannot be applied to it, because employment of the spacer and the etchant used by the author in Ref.1 damage the aluminum electrode. Using a sputtered ZnO thin film as a spacer has solved this problem and made the aluminum-pattern-definition more accurate and more reproducible.

Experiment Figures 1(a) to (d) explain the main process of the present lift-off method. A resist film was photo-etched on the ZnO thin film r.f.-sputter-deposited on the ST-cut quartz substrate [Fig.1(a)]. The ZnO film was over-etched in 1 % H_3PO_4 solution so that the etched film side-wall was cut inward by some distance D from the edge of the resist film [Fig.1(b)]. An aluminum film was vacuum-vapor-deposited thereon [Fig.1(c)]. Removal of resist films lifted off only aluminum films on the resist, while the aluminum on the substrate remained. ZnO residues were removed in the 5 % H_3PO_4 with the desired aluminum electrodes undamaged [Fig.1(d)]. Figure 2 is a photograph of the photo-etched resist film and the under-cut ZnO film, corresponding to Fig.1(b), thickness of each film being 0.5 μm and 0.45 μm, respectively. The under-cut distance D was about 0.6 μm. Figure 3 is a photograph of the finished aluminum interdigital electrode. It should be noted that immersion in ZnO remover, i.e. 5 % H_3PO_4 solution did not damage the aluminum electrode. This technique is based on the fact that the H_3PO_4 solution etching rate on the sputtered ZnO film is much larger than that on the aluminum film. The reason for this is considered to be as follows: The ZnO film sputter-deposited at rather low substrate temperature has a polycrystalline structure whose grain size is less than several hundred Å, due to deficient crystal growth. Hence, existance of a vast grain boundary region raises the etching rate of the film as a whole.

One of the most important problems of the present technique is the precise control of under-cut distance D. Figure 4 shows the measured result of the etching-time dependence of D with a 0.45 μm thick ZnO film and 1 % H_3PO_4 etchant. Figure 5 shows the relation between ZnO film thickness and the optimum etchant-concentration for obtaining D equal to the film thickness at 5-second etching-time. Another problem is the reduction of the surface roughness on the ZnO film. The roughness, i.e. the grain size can be controlled by the substrate temperature during sputtering. As is shown in Fig.6, it can be limited to under several hundred Å at from R.T. to 120° C, while it exceeds several thousand Å at temperature over 150° C. The latter condition does not fit the present purpose. In conclusion, the aluminum electrode width of 0.7 to 0.8 μm can be obtained by this method. This electrode width corresponds to about 1 GHz fundamental frequency.

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Reference 1) Y. Mimura: 5th Symposium on Semiconducter, IC, Tokyo (Nov. 1973) 53, (in Japanese)

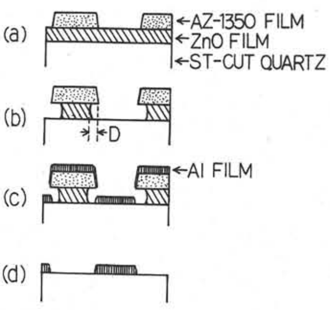

Fig.1 The main process of the improved lift-off method.

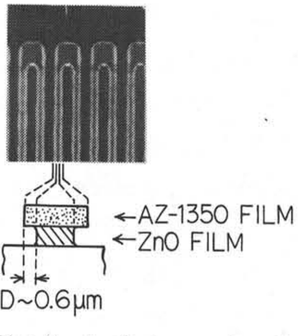

Fig.2 A photograph of the photo-etched resist film and the under-cut ZnO film.

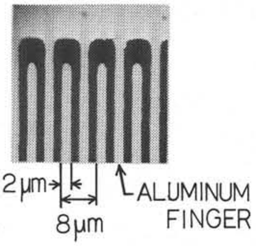

Fig.3 A photograph of the finished aluminum interdigital electrode.

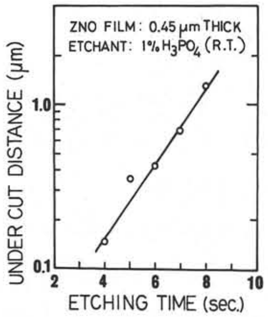

Fig.4 Experimental results of the etching-time dependence of D.

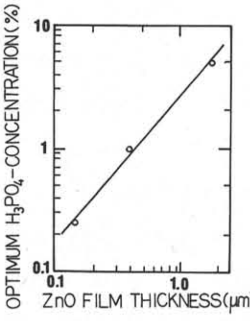

Fig.5 The relation between ZnO film thickness and the optimum H_3PO_4 etchant-concentration.

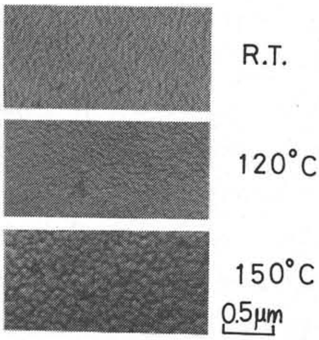

Fig.6 Electro-microscope photographs of ZnO thin film surfaces r.f.-sputtered at various substrate temperatures. (x20,000)