Fabrication of Interdigital Transducers and Surface Acoustic Wave Delay Lines Using Simple Mask Printers


Department of Physics, National Tsing Hua University
Hsinchu, Taiwan

(Received November 7, 1977)

A simple, economic and efficient type of mask printer for micro-planar structure fabrications has been designed and made. Interdigital transducers and surface acoustic wave delay lines have been fabricated using this type of mask printers. Features of the delay line with two transducers each of 15 finger pairs were found excellent which include delay time 5.0 microseconds, frequency response bandwidth 4.5 MHz at center frequency 68 MHz, insertion loss 15 db and attenuation of surface acoustical wave 0.17 db/cm. The laser optical probing technique was used to measure the energy distribution profiles of surface acoustic waves.

1. INTRODUCTION

Surface acoustic waves (SAW), such as Rayleigh waves, have been commonly and widely used in various fields. Generation of surface acoustic waves is best effected by interdigital transducers. Fabrication of interdigital transducers is therefore important and fundamental. Efficient fabrication has been largely based on the recent advances in thin film planar technology and photolithographic method.

The major difficulty in fabricating interdigital transducers especially in a small laboratory would be the problem of arranging the optical mask and the substrate to contact nicely. The contact should be made uniform, smooth, neither too tight nor too loose. If the contact is not uniform or tight enough, the usual subsequent exposure of uv light would not result in well defined pattern on the photoresist on the substrate. Over tightness would damage the mask. Even after exposure of uv light the separation of the substrate and the mask should be made smooth and without side wise sliding. Slight side wise sliding would leave the mask and/or the photoresist with scratches and/or poorly defined patterns. In this paper we will report in section II a simple design of a mask printer which allows the mask and the substrate to contact nicely. In section III we will give results of some

* This work was financially sponsored by the National Science Council of the Republic of China.
† Institute of Physics, Academia Sinica, Nankang, Taipei, Republic of China.
properties and measurements on transducers and delay lines which have been fabricated using the aforementioned mask printer. Finally we conclude and summarize in section IV.

II. THE SIMPLE MASK PRINTER

Construction of the mask printer is illustrated in Fig. 1 and Fig. 2. The basic components are a bottom plate and a collar both made of brass. A thin sheet of soft rubber such as a piece cut off from a large balloon is used to float the spacer and the substrate as a whole until contact is made between the substrate and the mask. The hand-held vacuum pump (Edmund Cat. #71300), as shown in the photograph of Fig. 1, can be manually

Fig. 1. The cross section drawing of the components of the mask printer used in this work. The substrate can be raised and brought to contact with the mask by evacuating the air inside the collar.

Fig. 2. The picture of the mask printer and the hand-held vacuum pump.
operated to control very conveniently the air pressure in the collar. The controllable change in the air pressure is employed to raise up or lower down the substrate. Small holes are drilled in the central region of the bottom plate which allow ambient air to flow and therefore easy motion of the rubber sheet. The O-ring and the groove for the O-ring on the collar function to form a vacuum chamber with the mask as its top plate. If the mask is too small to seal the top, the top plate is replaced by a piece of flat glass with the mask glued underneath. The spacer is made of aluminum in reducing its wight and its height is so chosen that about 0.5 mm spacing is left between the mask and the substrate when the vacuum is released. According to the dimension and size of the substrate, the mask printer may be made large or small or even of different shape. We made two sizes of such printers of which the larger one is shown in Fig. 1. The smaller printer has been used in the fabrication of straight transducers and SAW delay lines on LiNbO₃ crystals. Using the larger mask printer we have made several curved transducers to study the steering effect, which need longer propagation distance and therefore larger substrates.

The simplicity and success in the design and making of mask printer renders the photolithograph simple and easy. Its cheapness in cost as compared to that of the commercial equipment would be one of the main advantages. Another merit of using this type of mask printer could be its educational feature in training students for thorough understanding of how mask and substrate are brought to contact. Even with our simple mask printer positioning and alignment of mask relative to the substrate can be done conveniently under an ordinary microscope.

III. TRANSDUCERS AND DELAY LINES

Using the mentioned mask printers straight interdigital transducers, SAW delay lines and curved interdigital transducers have been made on y-cut z-oriented LiNbO₃ substrates. The procedures of photolithograph are standard and are thus omitted for brevity. One end of an interdigital transducer of 15 pairs of fingers in a delay line is shown in Fig. 3 which was taken photographically under a microscope with a magnification factor of 150. The uniformness of the fingers and spacings as observed from Fig. 3 indicates that the mask printer as well as other photolithographic items and skills works quite nicely. Measurements on the delay line were made according to the arrangement of Fig. 4a. The time

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Fig. 3. One end of an interdigital transducer of 15 pairs of fingers made on a piece of LiNbO₃ crystal. The transducer is used to excite the SAW with wavelength of 50 μm.

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delay was found to be 5 microseconds which is in good agreement with the length between the centers of the two interdigital transducers. The insertion loss of the delay line at center frequency 68 MHz as read from Fig. 4b was about 15 db which is typical as compared to those reported in literature. The frequency response of the interdigital transducers is also shown in Fig. 4b. The bandwidth read from it is about 3/15 which is just as expected from the theoretical-value 1/N where N denotes the number of pairs of fingers of the interdigital transducers.

Detection of surface acoustic waves in the LiNbO₃ substrate generated by an interdigital transducer upon application of VHF modulated electrical signal will be best done by using the well known optical probing techniques. Via the diffraction of laser light by surface acoustic waves, energy distribution profiles of surface acoustic waves can be measured and the attenuation constant can be deduced. The set-up of optical probing is shown in Fig. 5. In our case with a straight transducer the attenuation constant determined was 0.17 db/cm.

![Diagram of the set-up for measuring the frequency response and the insertion loss of the interdigital transducer](image)

(b) The frequency response of the interdigital transducer used.

The transverse energy profiles were measured also at distances 1.5, 4.5, 8.5 and 12.5 mm from the input transducer with laser beamwidth of 0.5 mm. The results are shown in Fig. 6. These profiles appear rather uniform with small attenuation and demonstrate excellent quality of the SAW waveguide. The diffraction and steering effects of the SAW could be observed and a detail analysis will be given elsewhere.

**IV. CONCLUSION**

We have designed simple, economic and efficient mask printers. Based on these printers straight transducers, delay lines and curved transducers have been made and tested. The results of testing appeared very nicely. A delay time 5.0 microsecond in a delay line was obtained. The frequency response bandwidth 4.5 MHz of the delay line is just as expected theoretically. The insertion loss 15 db is comparable to typical reported values. Improvement of the insertion loss can be made by adjusting other factors in the fabricating procedures. Using optical probing techniques, attenuation of the surface acoustic waves was determined to be 0.17 db/cm. Transverse energy profiles of the SAW for the straight transducer were obtained and shown. Features of curved transducers which we made to study the steering effect using optical probing method will be reported elsewhere.
Fig. 6. The transverse energy distribution profiles of the SAW generated by the transducer with aperture size of 35 mm. The laser beam had a diameter about 0.1 mm on the substrate and moved across the substrate in a direction perpendicular to the SAW propagation direction.

The authors wish to thank Dr. T. C. Liu, Mr. C. Y. Che and Mr. C. S. Pang, Professor of the Electric Engineering Department of Chung Cheng Institute of Technology for their assistance and allowing us to use VHF signal generator and RF bridge in this experiment. They also thank the staff of the Semiconductor Laboratory of the Chiao-Tung University for their help in fabrication of masks. Thanks are further extended to Mr. J. G. Shan, M. C. Chang and M. S. Chang for their skillful assistance.