MINIATURIZATION OF SURFACE ACOUSTIC WAVE LINEAR MOTOR

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Abstract: This paper describes the way of a miniaturization of a surface acoustic wave (SAW) linear motor and the first success of driving the miniaturized SAW linear motor. A problem which occurs with the miniaturization of the motor is also mentioned. The motor was operated at 50 MHz. The miniaturized motor could work at 0.7 m/s.

INTRODUCTION

We have already demonstrated an extremely high performance surface acoustic wave (SAW) linear motor operating at 10 MHz [1][2]. The SAW motor has a lot of merits such as high output force of 3.5 N [1], high speed more than 1 m/s [2], fine resolution positioning of 10 nm order [1][2], long stroke of centimeter, high energy density, easy holding and suitability for miniaturization.

For miniaturization of transducer, we should use high frequency. This paper describes the way of miniaturization and trial fabrication of a miniaturized SAW linear motor whose operating frequency is 50 MHz. The motor successfully worked. This is the first trial and the first success of higher frequency operation of the SAW motor.

PRINCIPLE

When the Rayleigh wave propagates on elastic material surface, particles on the surface move along an elliptical locus as shown in Fig. 1. A slider arranged on the elastic substrate is driven by frictional force. The slider is pre-loaded so that friction force is enough to drive.

A piezoelectric material of 128° Y-cut LiNbO₃

Fig. 1 Surface particles movement.

Fig. 2 Rayleigh wave generation.

Fig. 3 The projections on the silicon slider surface.
was used for the SAW motor. When high frequency voltage is input to an interdigital transducer (IDT) on the piezoelectric substrate, the Rayleigh wave is generated and propagates, as shown in Fig. 2.

The slider made of silicon has many projections on its surface in order to control contact conditions. Figure 3 is a photograph of the slider surface. The diameter of the projections is 10 to 50 µm.

**PREVIOUS MOTOR**

We have also updated 10 MHz SAW motor performance. The size of the transducer was 15 x 60 x 1 mm³. The operating frequency was 9.6 MHz. The dimension of the silicon slider was 4 x 4 x 0.3 mm³. Figure 4 shows experimental setup of the Previous linear motor. The slider was pre-loaded by leaf spring and the pre-load was about 30 N.

When the driving voltage was 170 V₀ₚ, the 10 MHz motor worked at more than 1.1 m/s. The maximum output force was 3.5. The response was more than 130 kHz.

We also succeeded in the step driving. 80 V₀ₚ cycle of the operating frequency was driven to the IDT. The slider motion was observed by using the laser Doppler displacement meter. 40 nm steps can be seen in Fig. 6.

**MINIATURIZATION**

Limits of the stator transducer dimensions such as the width and the thickness described in Fig. 7 are proportional to wavelength of the SAW. Therefore, the transducer can be miniaturized by using higher operating frequency. If we use 5 times higher
frequency, the limits of the width and the thickness are a fifth. In the case of 50 MHz operation frequency, the limits of the width and the thickness of the stator transducer are 3 mm and 0.2 mm approximately.

A problem may occur with miniaturizing the SAW motor. When tangential vibrating velocity is 1 m/s, vibration amplitude is about 20 nm at 10 MHz operating frequency. By using 5 times higher frequency, the amplitude becomes a fifth, 4 nm. However, surface-roughness of the stator transducer is (Ra =) 5 nm and is same as the vibration amplitude. It is wondered that the miniaturized SAW motor can actually work.

MINIATURIZED SAW MOTOR

Figure 8 is a photograph of the miniaturized stator transducer which was fabricated on trial. The size of the transducer was 5 x 50 x 0.5 mm³. The volume became a seventh of the previous one. Resonance frequency of the IDT, the operating frequency, was 49.76 MHz. Figure 9 shows the schematic view of the miniaturized SAW linear motor. The stator transducer was arranged on an iron plate. Dimension of the silicon slider was 2 x 2 x 0.3 mm³. The diameter of the projections was 20 µm. A magnet whose dimension was φ4 x 3 mm³ was arranged on the silicon slider. Figure 10 is a photograph of the silicon slider combined with the magnet. The slider total weight was 0.18 g. The preload, magnetic force added to the gravity force, was 0.13 N.

ESTIMATION

Performance of the miniaturized SAW motor was estimated. If the driving voltage is 60 V₀p, the tangential vibrating velocity is 1 m/s. This estimation was carried out by using the relation between the driving voltage and the velocity at the operating frequency of 10 MHz, because the voltage-velocity relation at 50 MHz can not be observed due to the frequency height. When the vibrating speed was 1.0 m/s, 10 MHz motor speed was 0.8 m/s, namely, 80 %
of the vibrating velocity. Therefore, we can estimate the 50 MHz motor speed of 0.8 m/s.

When the pre-load is 0.13 N, the novel motor output force will be 0.022 N, for output force of previous 10 MHz motor was about 17 % of the pre-load. The 50 MHz motor has no linear guide. Therefore, the output force will be more than 17 %.

**EXPERIMENT**

The miniaturized SAW linear motor was driven for 8 msec. Driving voltage was varied form 40 to 60 $V_{0-p}$. The slider motion was observed by using a laser Doppler displacement meter.

Figure 11 shows the transient response with the change of driving voltage. The maximum traverse speed of 0.7 m/s was obtained when the driving voltage was 60 $V_{0-p}$. This is 70 % of the tangential vibration velocity.

The maximum acceleration of 200 m/s$^2$ was observed from the figure. The maximum output force of 0.036 N was calculated from the acceleration and the slider weight. This force was 28 % of the pre-load. The 50 MHz motor has no guide. It seems that the increase of the ratio is due to the linear guide.

**CONCLUSION**

The first trial and the first success of the miniaturized SAW linear motor driven at 50 MHz was demonstrated. The stator transducer could be miniaturized into a seventh. The maximum traverse speed was 0.7 m/s. The maximum output force was 0.036 N.

**FUTURE**

The miniaturized SAW linear motor with much higher operating frequency will be fabricated for further miniaturization. We will demonstrate possibility of a "micro linear motor". The pre-load and the projections condition will be optimized for higher performance. Moreover, our miniaturized linear motor will be combined with an energy circulation method which has been already reported [3], a micro linear motor driven at lower input voltage such as a few volts will be developed.

**REFERENCE**

