Phase shift of Rayleigh wave beneath slider with preload

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1. INTRODUCTION

An extremely high performance surface acoustic wave (SAW) linear motor operating at 10 MHz has been already demonstrated\cite{1,2}. However, the efficiency from the electrical input to mechanical output is still low. To improve the efficiency, an energy circulation driving method has proposed and demonstrated\cite{3}. For the energy circulation driving method, forward scattering beneath a silicon slider was found to be a problem, due to the shift of the phase relation. Numerical simulation was carried out to investigate the relationship between the phase shift and slider parameters using the finite element method.

2. ENERGY CIRCULATION AND WAVE SCATTERING

The schematic view of the Rayleigh wave motor stator using the energy circulation driving method is shown in Fig. 1.\cite{3} The traveling SAW is excited by putting a sine signal and a cosine signal into the driving IDTs respectively. The excited traveling wave is received by one unidirectional IDT, and converted into electric energy. The converted electric energy is returned to the after unidirectional IDT. Using this electric energy, the other unidirectional IDT excites a circulated traveling wave. The circulated wave is propagated, and received by the initial unidirectional IDT again. Then the circulated wave and the initially excited wave are superposed. It is very important that these two waves are in phase at a designed value to efficiently excite the Rayleigh wave.

On the other hand, many projections were fabricated on the contact surface by dry etching. Because of these projections, the sufficient contact pressure is generated and the better contact condition is obtained. The Rayleigh wave beneath the slider is scattered by these projections when the slider is preloaded. As the result, the phase of the wave at the rear of the slider shifts from the designed value. This phase shift affects on the superposition of the circulated wave and the initially excited wave. Namely, the power of the Rayleigh wave decreases compared to the complete accord phase condition. As a result, this phase shift decreases the efficiency of the motor.

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Fig. 1: Schematic view of Rayleigh wave motor stator using an energy circulation driving method.

Fig. 2: FEM simulation mesh model of Rayleigh wave propagation.

3. SIMULATION

To investigate the phase shift of Rayleigh wave, simulation was carried out using the finite element method. The software was ANSYS 7.0.

The FEM stator and slider model is shown in Fig. 2. The model consisted of slider, stator and damping block. To prevent the reflection wave, the left side of the model had symmetrical boundary condition and damping elements were attached on the bottom and the right side of the stator. The dimensions of the damping element areas were 1.8 x 7.6 mm² on the bottom and 1.0 x 1.9 mm² on the right. Four nodes 2-D plane elements were used in the whole model. The mesh size of the surface of the stator was 5 μm, that was 1/80 of the 400 μm wave length.

The stator was made of 127.8 degrees Y-rotating X-propagation LiNbO₃\cite{4}. The slider was made of silicon. Its density was 2.33 x 10³ kg/m³, Young’s modulus was 1.66 x 10¹¹ Pa, shear modulus was 0.639 x 10¹¹ Pa. Many projections whose height were 1 μm were fabricated on the surface of the slider.
The diameter of the projections was 50 μm, the pitch of the projections was 100 μm. Contact elements were mounted the surface of the slider and the surface of the slider projections. Its contact stiffness was 0.001.

The simulation type was two dimensional strain structural-piezoelectric analysis, transient analysis. The amplitude of 20 nm vertical sinusoidal displacement at 9.945MHz was given at 5 driving points.

4. RESULTS OF SIMULATION

The integral time span was 3ns which was about 1/30 of 1 cycle of the wave. The simulation was carried out for about 1.7 msec, that was the 17 cycles of the wave motion. On this condition, we could obtain the traveling Rayleigh wave. The phase velocity of the Rayleigh wave of this simulation was 4150 m/sec with no slider.

The deformation model of the simulation result with slider preload at 1.875 MPa is shown in Fig. 3. The phase shift against the preload is shown in Fig. 4. The large preload caused the large phase shift.

Fig. 5: Phase shift against gap between the stator and the slider caused by the slider projections.

When the preload was too low, the slider was pushed by Rayleigh wave and took off the stator. So soft damping block was mounted on the slider and the upper surface of the block was fixed. The preload could be controlled by changing the gap between the stator surface and the slider projections. Phase shift against gap between the stator and the slider is shown in Fig. 5. Large gaps, namely low preloads, caused the minus phase shit.

5. CONCLUSION

The FEM simulations were carried out to investigate the relationship between the phase shift and the projection parameters of the slider. Phase shift was caused by the contact of the slider projections. It is necessary to determinate the relationship between the phase shift and the projection parameters of the slider quantitatively for the next step.

REFERENCE