Design and Simulation of a Fast SAW Waveguide with Comsol Software

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Abstract

In this paper, the structure of SAW has been studied. In previous work in SAW, materials such as lithium niobium, lithium tantalite and gallium nitride were used in the structure of SAW, and thus had a low operating frequency and the highest reported operating frequency was about 4 GHz. In this paper, aluminum nitride and gallium nitride in the SAW structure are used in combination. The electrodes used in the structure are also made of aluminum. Comsol software was used to simulate the structure, and for the structure, the operating frequency was 7.02 GHz.

Keywords: Nitride Aluminum, Surface Waves, Waveguide, Finite Element Method, Micro electro mechanical Systems, Gallium Nitride

1- Introduction

SAW waves are waves that propagate on the surface of solids. In SAW waves, the wave amplitude decreases exponentially from the surface, and the depth of the wave penetration into the material is proportional to the frequency. In Fig1 is shown a picture of a SAW waveguide. As shown in Fig 1, the SAW waveguides include a piezoelectric substrate and an IDT (metal electrode for producing and receiving pulses of SAW) or several, IDTs if separate inputs and outputs. The IDT consists of two interlocked metal faces that have been modeled and developed through the lithography process on a surface of the piezoelectric substrate and are in fact the most important component of the SAW and its precise design results in a desirable response and lower losses [1].

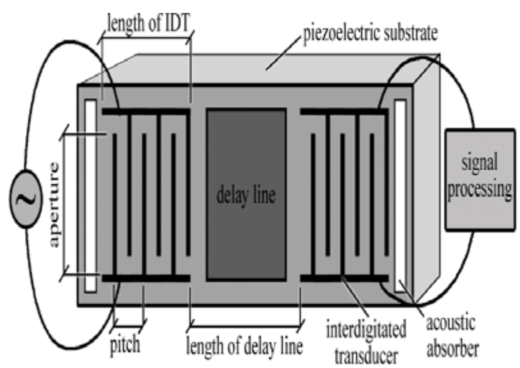

Fig.1. SAW waveguide

When the voltage is applied between the input terminals of metal electrodes, an electric field is formed around metal electrodes. The electric field is reflected to the piezoelectric material through metallic electrodes, and the piezoelectric material converts the electric field into mechanical energy and oscillates on the surface, resulting in acoustic signaling .The velocity of the SAW waves is much smaller compared to the electromagnetic waves, and thus, the

SAW wavelength is smaller as well. Reducing the wavelength causes the smaller size, but the frequency increases. The velocity of the SAW waves is much smaller compared to the electromagnetic waves, and thus, the SAW wavelength is smaller as well. Reducing the wavelength causes the smaller size, but the frequency increases. The over-dimensional fragmentation of the parts is associated with manufacturing problems, so more acoustic speeds are needed to overcome the problems of bedding. Since the acoustic velocity depends on the type of piezoelectric material, then the piezoelectric material should be considered as a substrate. Various materials have been reported for SAW waveguides, the most important of which are lithium niobium, lithium tantalite and gallium nitride [2-4]

2- Design Method

As previously mentioned, the most important part of the SAW structure is the substrate. In this design, a combination of aluminum nitride and gallium nitride is used. To design, the surface velocities of the surface waves in the composite substrate of aluminum nitride and gallium nitrate are obtained .In design, we first assume that the surface velocity of surface waves in aluminum nitride is 5600 m / s and the central frequency is 7 GHz. The corresponding wavelength is equal to:

$$\lambda = \frac{V}{f} = \frac{5600\text{m/s}}{7\text{GHz}} = 800 \times 10^{-9} = 0.8\,um \qquad (1)$$

So is the wavelength corresponding to 0.8 micrometers. The length and width of the structure is respectively 8 and 0.8 micrometers. The distance between the electrodes is also equal to:

$$p = \frac{\lambda}{2} = \frac{0.8\text{um}}{2} = 0.4 \qquad (2)$$

The distance between the electrodes is 0.4 micrometers. The electrode width of 2.0 micrometers and height is assumed 0.05 micrometers. The material of aluminum electrodes is assumed.

3- Simulation Results

To simulate, the frequency mode analysis was carried out at frequencies close to 7 GHz on the structure. After piece analysis, special frequencies were obtained near 7 GHz. Fig 2 and 3 show superficial sound wave propagation along the piezoelectric sub surface under two frequencies of 6.88 GHz and 7.2 GHz.

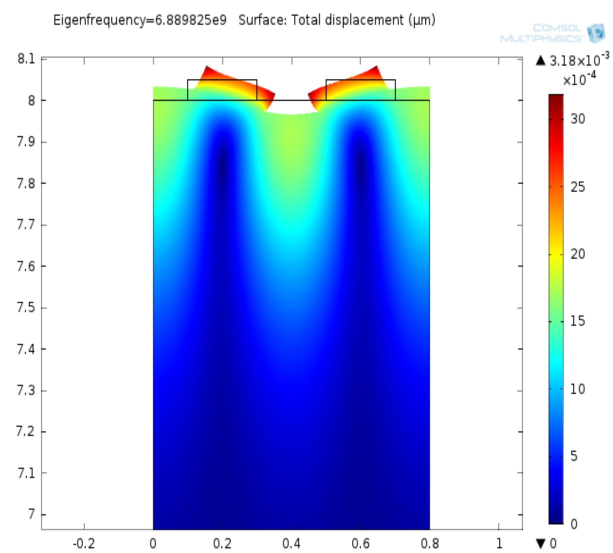

Fig.2. Resonant mode in the substrate of aluminum nitride and gallium nitride

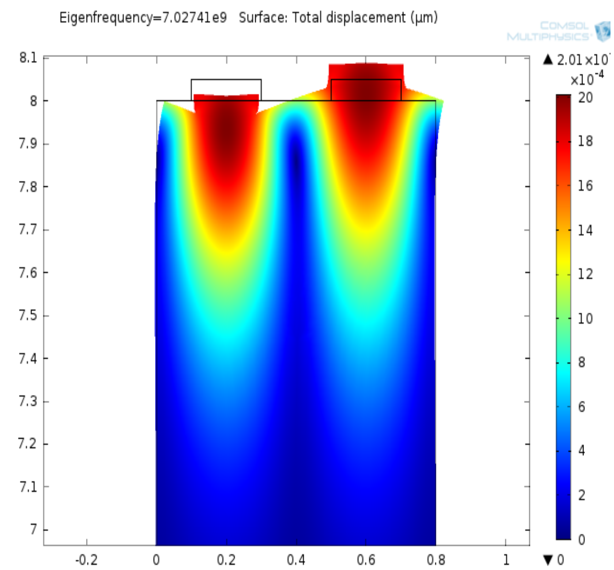

Fig.3. Mode aluminum nitride and gallium nitride anti-resonance in the substrate mix

Fig 4 shows the structure response at other frequencies. Depending on the shape, the wave at this frequency is also volumetric.

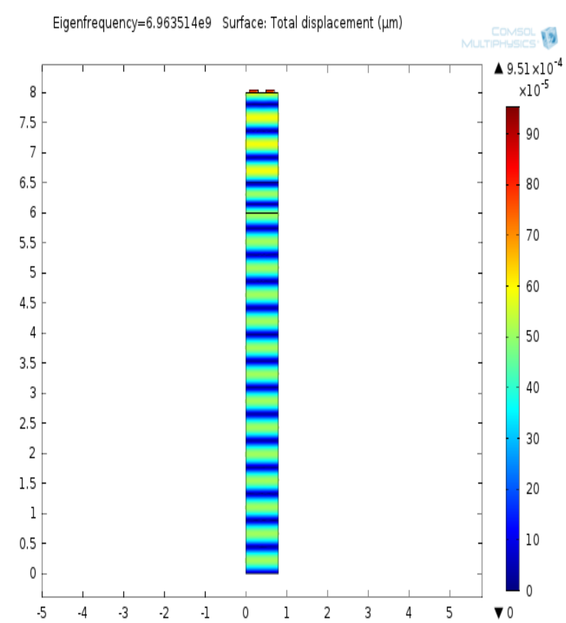

Fig.4. The structure response at a frequency of 6.96 GHz and viewing volumetric waves

The actual amount of surface wave propagation speed is obtained from the following equation:

$$v = (f_{sc+} + f_{sc-}) = (7.027 \times 10^9 + 6.889 \times 10^9) \times 0.4 \times 10^{-6} = 5.566 \times 10^3 \quad (3)$$

So the velocity of surface waves in this structure is 5566 m / s. The potential electrical potential near the electrodes at a frequency of 7 GHz is shown in Fig. 5. Due to the shape of the displacement created in the structure, it produces a potential near the electrodes and produces the highest potential of 6.99 volts.

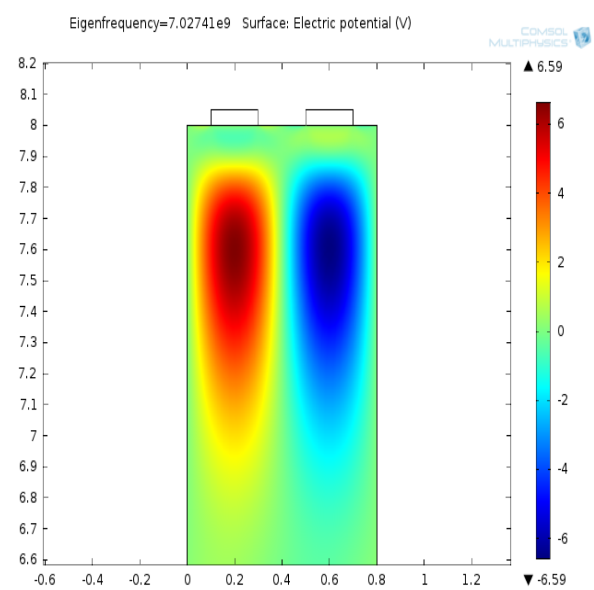

Fig.5. The electric potential at a frequency 7.027 GHz

Conclusion

The purpose of this treatise was to increase the frequency of the SAW resonator. In this design, therefore, a combination of aluminum nitride and gallium nitrate was used. After designing and simulating the structure, the operating frequency was 7.27 GHz. Table 1 compares the design structure with previous structures.

Table.1. Comparing the results with previous work

Specifications	substrate	Operating frequency
Work presented	Aluminum Nitride and Gallium Nitride	7 GHz
Source [5]	Quartz	0.4 GHz
Source [6]	Gallium Arsenide	1.5 GHz
Source [7]	Lithium Niobate	0.87 GHz

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