

OPTIMAL CONDITIONS FOR THE GENERATION SYSTEM OF A SAW GAS SENSOR

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The present paper describes the optimal conditions for generating a Surface Acoustic Wave (SAW) for a gas sensor system. For achieving stable operation it is necessary to assure the largest possible distance between the frequency modes. In order to attain this condition, the length between transducers should be decreased accordingly.

1. Introduction

The basic system for SAW gas sensors is a generator in which an acoustic delay line works in the positive feedback loop of the amplifier. The acoustic delay line assures the phase condition for generation whilst the amplifier assures the amplitude condition. The amplifier gain should be higher than delay — line insertion losses.

The SAW can be excited with the use of the interdigital transducers, one being a transmitter and the other one a receiver. The acoustic path of the delay line is usually covered in a vacuum by a thin chemical layer. This layer has some selective absorbing properties and can interact with gas molecules from the ambient atmosphere. Such layers are, for instance, macromolecular compounds, such as organic polymers [1] and phthalocyanines [2].

A change in the physical properties of these layers affects the SAW propagation in an acoustic delay line. Particularly, as a result of the change of mass and electrical conductivity of the layer, the velocity of a SAW undergoes a change. Consequently, as a result of the velocity change, the phase conditions undergoes a disturbance and a new frequency is generated depending on the gas concentration monitored in the ambient atmosphere [3].

2. The frequency and modal characteristic of a SAW generator

Taking into account the work of the SAW generator it is important to distinguish two essential parts which form the frequency characteristic of the generation system:

- a. the system: transmitter — receiver,
- b. the delay line system.

The interdigital Rayleigh wave transducers have a frequency characteristic of the $|\sin(x)/x|$ type [4], shown in Fig. 1, where:

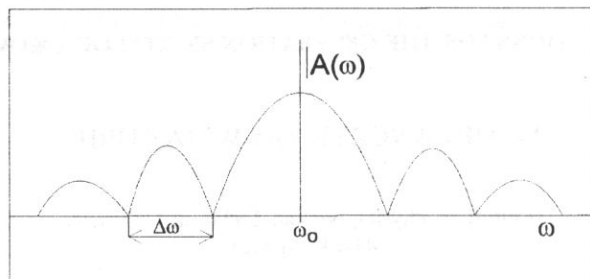


Fig. 1. Frequency response for an interdigital Rayleigh wave transducer.

$$x = \frac{N\pi(\omega - \omega_0)}{\omega_0}, \quad (2.1)$$

N — is the number of finger pairs in the transducer, ω_0 — is the fundamental resonant frequency.

The fundamental resonant frequency ω_0 is specified by the geometric dimensions of the transducer, that is, by the electrode width and the SAW velocity in a waveguide medium:

$$\omega_0 = \frac{2\pi v_0}{4p}, \quad (2.2)$$

where: v_0 — is the propagation velocity of SAW, p — is the finger width (equal to the spacing between electrodes).

The zeros of the frequency characteristic will be for ω_n given by the equation

$$\omega_n = \omega_0 \pm n \frac{\omega_0}{N}, \quad (2.3)$$

when $n = 1, 2, 3, \dots$

and the distance between them, $\Delta\omega$ is

$$\Delta\omega = \frac{\omega_0}{N}. \quad (2.4)$$

The acoustic line system specifies the frequencies when the generator oscillation is possible. The modal characteristic is specified by the following formula [5]:

$$\frac{\omega L}{v_0} + \Phi_T + \Phi_A = 2\pi n, \quad (2.5)$$

where: Φ_T, Φ_A — are the phase shifts in the transducers and amplifier, respectively, L — is the length of the delay line (distance between the middle point of the transducers), ω — is the generation frequency.

If the length, L , is sufficiently large, the phase shifts in the transducers and amplifier can be neglected. So, the frequency modes of the generator are equal:

$$\omega_n = n \frac{2\pi v_0}{L}, \quad (2.6)$$

where: $n=1, 2, 3, \dots$

with the distance between them:

$$\delta\omega = \frac{2\pi v_0}{L}. \quad (2.7)$$

In the fundamental resonant frequency range of the transducers system a certain number of mode frequencies can appear for which the amplitude condition of the generation will be fulfilled. The amplifier gain will be larger than the signal attenuation in this case (Fig. 2).

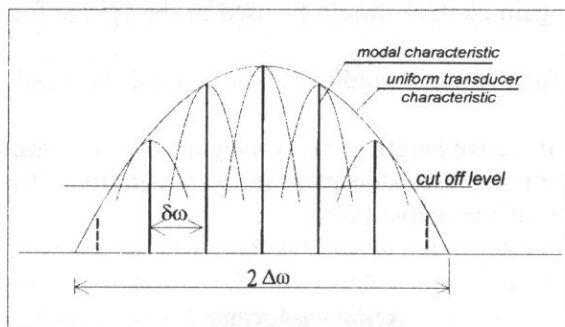


Fig. 2. The modal characteristic of the generation system.

An interaction between the gas and the active layer causes a change in the SAW propagation velocity and, consequently, in the general frequency. If the frequency change is too large, we observe a "jump" to the next frequency mode. For achieving a stable work of the generation system of the SAW sensor it is necessary to assure a possibly large distance, $\delta\omega$, between the frequency modes. In this case a large frequency range of the sensor work will be achieved.

In the case of the dual-delay line configuration there is a possibility to working at the fundamental frequency ω_0 . In this case, the following condition must be fulfilled:

$$\delta\omega = \Delta\omega. \quad (2.8)$$

The generator mode frequencies, except ω_0 , covers the "zeros" of the transducers frequency characteristic in this case.

Formulas (2.2), (2.4) and (2.7) imply that the condition (2.8) will be fulfilled when the distance between the transducers, L , will be equal to the length of one of them L_p , i.e.

$$L = 4pN = L_p. \quad (2.9)$$

The second transducer is a wideband with a small number of electrodes.

In practical the fulfilment of the condition (2.8) and (2.9) is rather difficult to achieve. The distance between the transducers has become so small that the active layer square placed between them is not sufficient for obtaining an adequate sensor sensitivity.

3. Conclusions

The main conclusion concerning optimal conditions for the generation system of the SAW sensor are:

1. The length between the transducers, L , should be decreased properly in order to fit the necessary generation frequency range change.
2. An automatic gain control should be used in the system for a wider frequency generation range.
3. A bandpass filter of a "window" type should be used with a bandwidth equal to $2\Delta\omega$.

When matching an active length of the waveguide, L , it is important to take into account that its reduction causes a decrease in the sensitivity of the sensor as a result of the area limitation of the active layer.

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