Optical and Acoustical Methods in Science and Technology

Applicability of Different SAW Oscillators' Topologies for High Frequency Gas Sensors Construction

M. Pasternak*

Institute of Radioelectronics, Military University of Technology, 00-490 Warsaw, Poland

In general, there are three possible kinds of surface acoustic wave devices that may be applied for high frequency gas sensor construction: delay lines, one- and two-port resonators. Choice among them depends on individual preferences and sometimes it is the matter of chance. In the paper the key differences among the surface acoustic wave devices important from the gas sensors technology point of view are described.

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1. Introduction

The comparison between applicability of surface acoustic wave (SAW) delay lines and SAW resonators for gas sensors construction is described in [1]. It is concluded that in gas sensors application cases the SAW resonators are better than delay lines. The conclusion was generally formulated based on the differences between frequency stability of the devices. Usually the SAW sensor frequency change contains the information about gas concentration being under detection and that is why the frequency stability is important in such applications. This fact has to be taken into consideration especially for higher frequencies high sensitivity gas sensors. The better frequency stability of the oscillators with SAW resonators in comparison with delay lines comes from the slope of phase characteristics that is much steeped for resonators (Fig. 1).

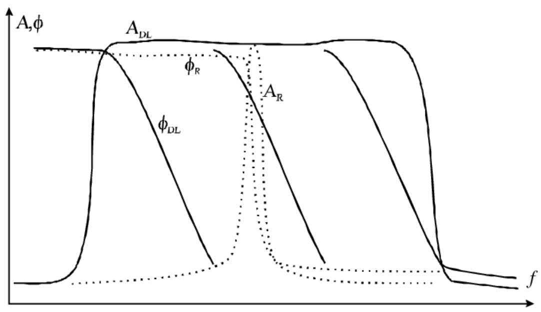

Fig. 1. Comparison of typical amplitude A and phase ϕ characteristics of SAW delay line (solid line) and resonator (dotted line).

It is worth to mention that delay lines where the chemisensitive layers may be deposited, have much wider area than resonators. It relates to the situation when they cannot be placed over the interdigital transducers (Fig. 2). In the certain applications such a feature may be profitable.

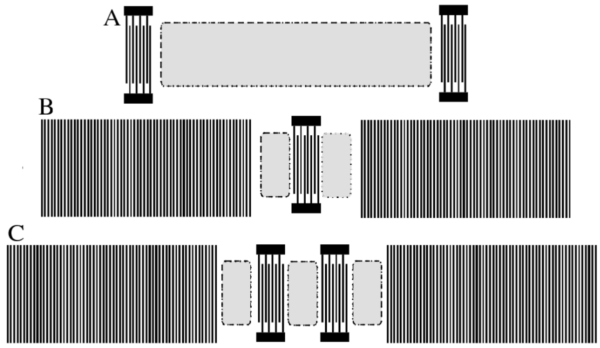

Fig. 2. Schemes of the four kinds of SAW devices applicable for gas sensors. The chemisensitive layer may be deposited in the marked areas; (A) delay line, (B) one--port resonator, (C) two-port resonator.

2. Topologies of SAW oscilator

As it was illustrated in Fig. 2 there are three kinds of SAW resonators. These are as follows: delay line (DL), one- (OPR) and two-port (TPR). There are two possible oscillators topologies suitable to the configurations of them. In the first one the independent liquid crystal (LC) oscillator is stabilized by one-port resonator and in the second one the resonator closes the positive feedback loop of the amplifier. The systems play role of the oscillators when the oscillating conditions are fulfilled. Both configurations are useful in different fields of electronics but the second one seems to be more suitable for SAW sensors applications. There are at least two reasons of such the conclusion. First of all the oscillators utilising TPRs are generally known as more frequency stable. The fact is important from the spurious frequency shift point of view. The second reason is connected with the resonator equivalent circuit (Fig. 3) [2, 3].

* corresponding author; e-mail: MateuszPasternak@we.wat.edu.pl

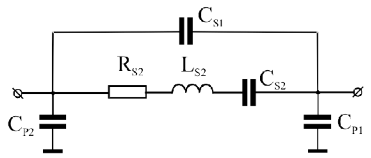

Fig. 3. Simplified universal equivalent circuit for OPR and TPR.

3. Numerical results

The equivalent circuit from Fig. 3 is generally correct for both resonator types. The difference between OPR and TPR is connected with the C_{Si} and C_{Pi} values. If C_{S1} is a parasitic capacitance and capacitors C_{Pi} have considerable values it is the equivalent circuit valid for TPR. Otherwise it is valid for OPR. The elements R_{S2}, L_{S2} and C_{S2} in the TPR are responsible for the center frequency value only after matching the main resonance branch. In the OPR case the additional capacitance C_{S1} that cannot be compensated is connected to the main resonance branch and only the serial elements determine the phase characteristic slope. In the OPR case the value of C_{S1} is usually in order of pF and it is much lower than for TPR. This difference leads to the diferent slope of resonators phase characteristics close to the center frequency (Fig. 4).

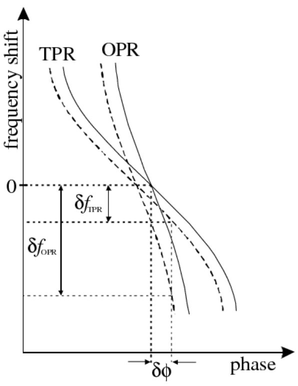

Fig. 4. Phase changes for OPR and TPR close to the resonant frequency [4].

The slowest phase change leads to the bigger frequency shift that seems to be profitable from the SAW sensors point of view. Unfortunately, on the other hand it leads also to the undesired bigger frequency instability that may overwhelm the SAW sensor response and decrease its sensitivity. The effect is important especially for sensors operating in higher frequencies range. When the surface of the resonator is loaded by a dissipative layer its phase characteristic is shifted to the lower frequencies as well as it is flattened due to change of the equivalent circuit all serial elements values (especially serial resistance). It causes the increase of the sensitivity for both kinds of devices and also their frequency instabilities. The process

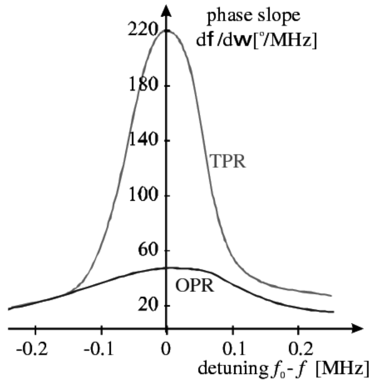

Fig. 5. The phase slope of the TPR and OPR with deposited layers loading of the surface of the devices.

in the OPR case is faster than for the TPR and earlier reaches an unacceptable level (Fig. 5).

The properties of the phase characteristic slope for both kinds of the SAW resonators allow to conclude that the TPR is more suitable for the gas sensor applications. Such a device has also an additional advantage since it is possible to significant increase its inter-transducer area and in that way to combine the advantages of the TPR and delay line in one device. Moreover, the frequency break point of the Leeson broken line (Fig. 6) moves left when distance between transducers in TPR increases, thus the frequency stability for the TPR with wide inter-transducers distance also increases.

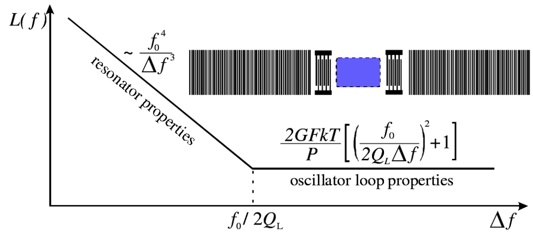

Fig. 6. TPR with wide inter-transducer distance and Leeson broken line for the device; f_0 — central frequency, Δf — detuning, G — gain of the oscillator loop, F — noise figure of the oscillator loop amplifier, k — Boltzmann constant, T — temperature, P — oscillator loop power, Q_{L} — 50 Ω loaded TPR Q-factor.

The mentioned above features of TPR with wide inter-transducer distance predestine the device to gas sensors applications. The laboratory measurements carried out with the different models of gas sensors have proved the advantages written in [5, 6].

4. Conclusion

The proper choice of the SAW device as a base for gas sensing system construction determines the frequency stability of the final detector. Comparing different SAW devices possible to use one can conclude that the most suitable in such an applications is the TPR with wide inter-transducer distance. The device in a natural way combines the advantages of the ordinary TPR and delay line. Of course the distance between transducers cannot be arbitrarily widened. The width of the inter-transducer gap is limited by device dimensions and insertion loss. The parameter is a result of the trade-off among chemisensitive layer area, frequency stability and insertion loss of the final gas sensor.

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