ARCHIVES OF ACOUSTICS
18, 1, 157–161 (1993)

BRIEF NOTES

AN INFLUENCE OF VAPOURS OF SOME ORGANIC COMPOUNDS AND WATER ON ACOUSTIC PROPERTIES OF SELECTED POLYMER LAYERS

W. JAKUBIK and M. URBAŃCZYK

Institute of Physics, Silesian Technical University
(44-100 Gliwice)

The present paper deals with an investigation of the interaction of thin polymer layers with on ambient atmosphere in view to using them to design gas sensors.

The changes in physical properties of a polymer layer were recorded as a change in a differential frequency of dual acoustic delay line with a surface wave. The preliminary results demonstrate a selective sensitivity of polymer layers to gases in the ambient atmosphere.

1. Introduction

The development of polymer technology has permitted scientists to obtain compounds which change their properties as a result of interaction with ambient atmosphere. This fact creates possibilities for using polymer compounds as selective sensors of various gases. The change of physical properties of specially prepared thin polymer layers affect the conditions for propagation of a surface acoustic wave (SAW) in a layered structure: piezoelectric waveguide — polymer layer. Particularly, as a result of a change of mass and the electrical conductivity of the polymer layer, the velocity of propagation of a SAW undergoes a change [1]. This phenomenon has been used for the investigation on the influence an ambient gas medium on acoustic properties of selected polymer layers.

The changes of physical properties of the investigated polymer layer under the influence of some organic compounds and water vapour have been observed as a change in the differential frequency of dual acoustic delay lines: the delay line with an active polymer layer and the reference delay line. The experimental setup secured autocompensation of the temperature influence on the acoustic properties of the waveguide medium, which enabled acquisition of a high time stability [2].

For setting the initial conditions, the reference path has a metallic surface between transmitting and receiving transducers which ensured the electric short-circuit of the surface regardless of the condensation level of the interacting molecules on it.

The oscillator frequency of the frequency generating with the acoustic delay line in the positive feedback loop of a signal amplifier is specified by phase dependence [5]:

$$\Phi_A + 2\Phi_{\mathrm{tr}} + 2\pi f t = 2\pi n \tag{1}$$

where n is an integer, and gives the number of frequency modes of the oscillator, Φ_A and Φ_{tr} are the phase shift introduced by the amplifier and transducer, respectively.

It results from the expression (1), that the oscillator frequency is:

$$f = \frac{2\pi\nu - \Phi_e}{2\pi l} v \tag{2}$$

where v is the velocity of propagation of acoustic wave on the piezoelectric waveguide surface, and

$$\Phi_e = \Phi_A + 2\Phi_{tr} \tag{3}$$

A differential frequency of two acoustic paths (the measuring and reference delay lines) is specified by the following formula:

$$\Delta f = f - f_0 = \frac{2\pi n - \Phi_e}{2\pi l}(v - v_0) \tag{4}$$

From the expression (4) results an increase in the propagation velocity of acoustic wave in the measuring path under a constant velocity v_0 in the reference delay line, and leads to a positive increase of the differential frequency Δf. This situation occurs during a change of electric conditions on the surface of the piezoelectric waveguide as a result of condensation of polar molecules of the investigated substance.

This effect will be referred to as the electrostatic effect (EE). The size of the electrostatic effect depends on the electromechanic coupling coefficient of the waveguide material.

Apart from the EE there is also a mass effect connected with the mass loading of the acoustic waveguide surface with the condensating molecules. The increase in the mass loading of the acoustic waveguide causes a decrease of the propagation velocity in the acoustic wave. The expression (4) shows a negative increase in differential frequency Δf in this case.

During the interaction of vapours of the investigated organic compounds and water on polymer layers, the magnitude of the differential frequency depends on the resultant effect of the electrostatic and mass interaction.

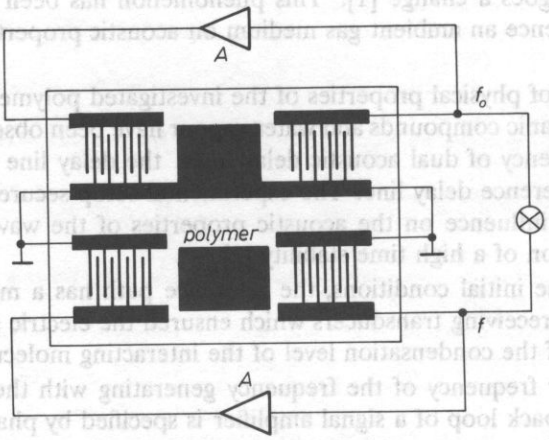

FIG. 1. Experimental system diagram.

2. Experimental setup

The experimental system is shown in the Fig. 1. The main parts of this setup were two acoustic waveguides fabricated on the piezoelectric substrate $LiNbO_3$. The transducers of the surface wave, made by the photolitography method, have 15 electrode pairs each, and were placed at 20 mm apart. The oscillation frequency was about 20 MHz. The acoustic path formed two generating systems. The generating frequency of the measuring delay line, in which an active polymer layer was placed, was influenced by the adsorption of organic compound molecules in a thin polymer layer. The frequencies obtained from each oscillator were mixed in a double balance mixer to provide the low-frequency differences signal. This signal was the measure of the interaction between vapours of organic compounds or water vapours with the polymer layer.

3. Experimental results

The experiments were carried out on the polymer layers: PVAC — poly(vinylacetate), PBA — poly n — butylakrylate, P(VAC-CO-BA), PVAC-PBA shell, PBA-PVAC shell.

The preparation of the layers to the experiments consisted in a uniform spreading of a polymer liquid drop on the area of about 5 × 3 mm. When the polymer was dry, the experimental system together with the reagent (whose vapours were to interact with the polymer) were placed on an open dish and put into a closed chamber. The pressure in the chamber was decreased to about 1 Tr. During evaporation the differential frequency of acoustic paths was measured.

The influence of acetone and methanol vapours is shown in Fig. 2, 3 and 4. Fig. 5 shows the influence of the humidity of the medium on acoustic properties of PVAC polymer. The frequency f_0 corresponds with the differential frequency for the stipulated instant $t = 0$.

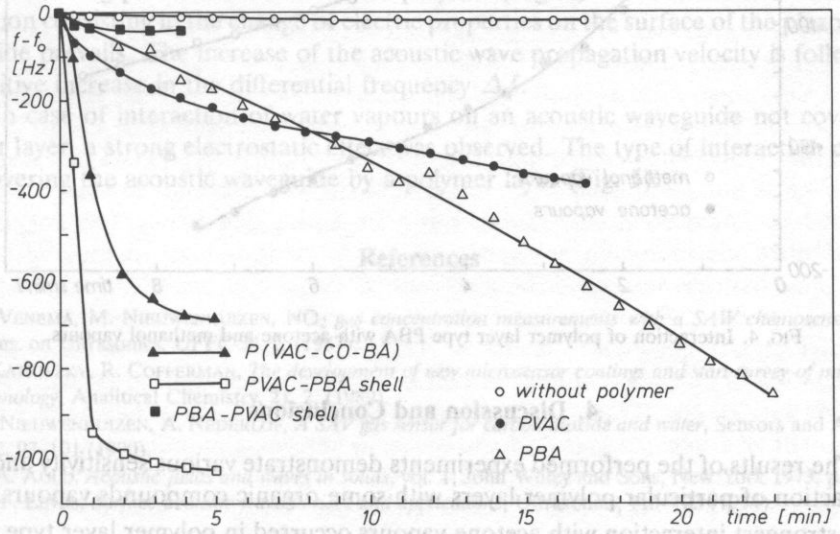

FIG. 2. Interaction of acetone vapours and the polymer layers.

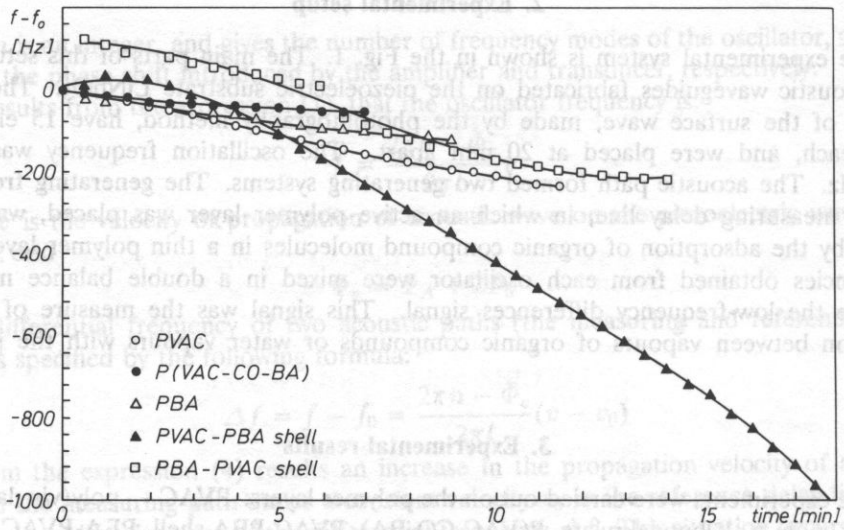

FIG. 3. Interaction of methanol vapours and the polymer layers.

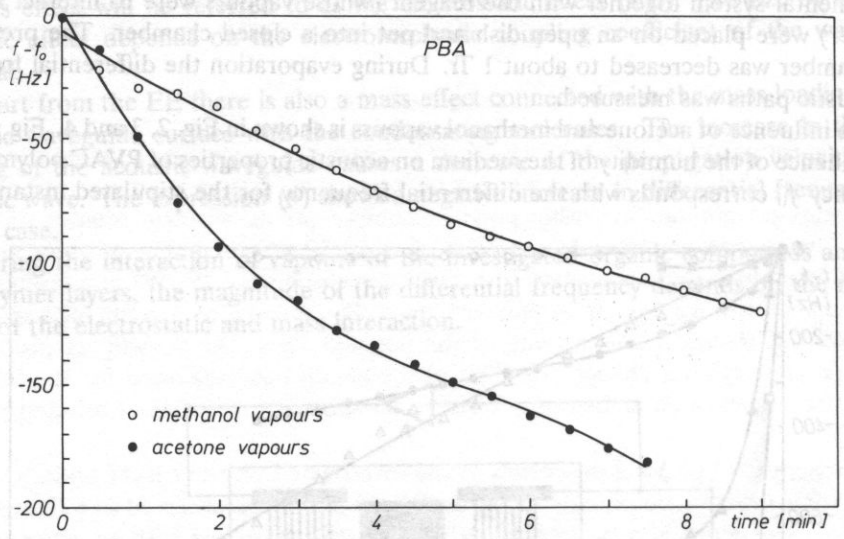

FIG. 4. Interaction of polymer layer type PBA with acetone and methanol vapours.

4. Discussion and Conclusions

A. The results of the performed experiments demonstrate various sensitivity and speed of interaction of particular polymer layers with some organic compounds vapours.

The strongest interaction with acetone vapours occurred in polymer layer type PVAC-PBA shell. The polymer type PBA is sensitive to acetone vapours, while its interaction with methanol vapours is weak.

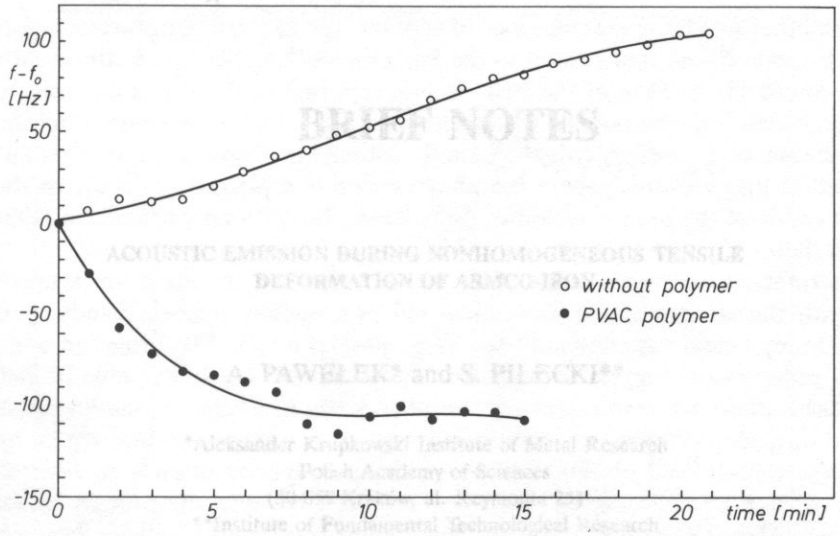

FIG. 5. Influence of water vapour on polymer layer type PVAC.

B. The negative values of differential frequency point to a mass character of the polymer layer interaction with vapours of the chemical compound used in the experiment. The interaction causes a decrease in the acoustic wave propagation velocity, and results in a decrease in the oscillation frequency in the measuring path.

C. The positive magnitude of the differential frequency has been observed as well. In one instance, it appeared during the interaction of the polymer layer type PVAC-PBA shell with methanol vapours (Fig. 3), and during condensation of water vapour molecules on the measuring path not covered by the polymer (Fig. 5). In this case the electrostatic interaction consisting in the change of electric properties on the surface of the piezoelectric waveguide prevails. The increase of the acoustic wave propagation velocity is followed by the positive increase in the differential frequency Δf.

D. In case of interaction of water vapours on an acoustic waveguide not covered by polymer layer, a strong electrostatic effect was observed. The type of interaction changed after covering the acoustic waveguide by a polymer layer (Fig. 5).

References

[1] A. VENEMA, M. NIEUWENHUIZEN, NO_2 *gas concentration measurements with a SAW chemosensor*, IEEE Trans. on Ultrasonics, UFFC-34, 2, (1987).

[2] J. KATRITZKY, R. COFFERMAN, *The development of new microsensor coatings and start survey of microsensor technology*, Analitical Chemistry, **21**, 2, (1989).

[3] M. NIEUWENHUIZEN, A. NEDERLOF, *A SAV gas sensor for carbon dioxide and water*, Sensors and Actuators, B, 2, 97–101 (1990).

[4] B. A. AULD, *Acoustic fields and waves in solids*, vol. 1; John Willey and Sons, New York 1973, p. 285.

[5] M. F. LEWIS, *Surface acoustic wave devices and applications*, Ultrasonics, 115–123 (1974).

Received on February 6, 1992