Ultrasonics 68 (2016) 29–32

Contents lists available at ScienceDirect

Ultrasonics

journal homepage: www.elsevier.com/locate/ultras

Acoustic Plate Mode sensing in liquids based on free and electrically shorted plate surfaces ☆

V.I. Anisimkin [a], C. Caliendo [b,*], E. Verona [a,c]

[a] Kotel'nikov Institute of Radio Engineering & Electronics, Russian Academy of Sciences (IRE-RAS), Mokhovay Str., 11/7, 125009 Moscow, Russia
[b] Institute of Acoustics and Sensors, Italian National Research Council (IDASC-CNR), Via del Fosso del Cavaliere, 100 I-00133 Roma, Italy
[c] Institute for Photonics and Nanotechnologies, Italian National Research Council (IFN-CNR), Via Cineto Romano, 42, I-00156 Roma, Italy

ARTICLE INFO

Article history:
Received 4 December 2015
Received in revised form 4 February 2016
Accepted 8 February 2016
Available online 12 February 2016

Keywords:
SAW sensors
Acoustic Plate Modes
Liquid-phase sensors
Viscosity sensor
$LiNbO_3$

ABSTRACT

The sensing behavior to liquids for Acoustic Plate Modes (APMs) propagating along 64°*Y*, 90°*X* $LiNbO_3$ plate was investigated vs. two electric boundary conditions. The changes in the APMs phase velocity and attenuation were measured upon exposure to different liquids wetting one of the surfaces of the plate, either free or electrically shorted by a thin conductive Al layer. The experimental data confirm that the presence of a metallic layer covering one of the plate surfaces affects the viscosity and temperature sensitivity of the device. The differences between the sensor response for various liquids, with free or metalized faces, are interpreted in terms of the APM polarization.

© 2016 Elsevier B.V. All rights reserved.

1. Introduction

Microwave acoustic sensors based on APM propagation along piezoelectric plates are capable to detect a number of chemical and biological species by measuring the relevant changes in the density, viscosity, conductivity, permittivity, and temperature of liquids. These sensors show small dimensions, ~100 mm^3, together with small amounts, ~100 μL, of required sample liquid. Moreover, for each test, they provide an output signal containing two independent information: the amplitude and phase [1–9]. The response of APM sensors can be application oriented by simply changing the material and orientation of the single crystal substrate (plate cut and in-plane propagation) and the plate thickness, without use of any sorbent material layer at the plate surface [10]. Since the penetration depth of the acoustic waves into the liquid under test is quite small, approximately 1–10 μm [1,11,12], any inhomogeneity in its thickness has no influence on the measurement, thus enabling use of a simple brush or syringe to deposit the liquid under test onto the sensor surface. For each propagation direction the number of suitable modes of operation is approximately from 10 to 15 [13], thus providing the possibility to optimize the mode choice, depending on the specific application. APM sensors response can be affected by undesirable effects such as actuation, internal flow, atomization and heating of the liquid sample when exposed to the acoustic field [14,15], that can be prevented by operating the devices at low acoustic power levels. Furthermore the mechanical amplitude profiles within the piezoelectric plates are modified by the presence of thin metal layers at one or both the free surfaces [16], that can affect the APM sensor response. The purpose of this paper is an experimental investigation of the effects produced on the APM sensing operation by a thin metal layer placed at one of the plate surfaces.

2. Experimental

Experiments have been performed using an APM delay line implemented on 64° rotated *Y*-cut $LiNbO_3$ plate, with propagation at 90° off the *X* direction (64°*Y*, 90°*X* $LiNbO_3$); the corresponding Euler angles are: 0°, −26°, 90°. Details on the experimental test device are reported in Table 1; both input and output interdigital transducers (IDTs) are located on the plate surface not facing the liquid, in order to avoid any possible interference to the IDTs operation. Both phase velocity and acoustic field amplitude profiles have been calculated using the PC software from McGill University and a MatLab routine [17], together with the $LiNbO_3$ material constants reported in Ref. [18]. The corresponding phase velocity dispersion curves, in the normalized thickness (h/λ) range from 0 to 1 are reported in Fig. 1.

☆ This work was supported by Grant 15-19-20046 from Russian Science Foundation, Russia.
* Corresponding author.

http://dx.doi.org/10.1016/j.ultras.2016.02.007
0041-624X/© 2016 Elsevier B.V. All rights reserved.

Table 1
Characteristics of the test delay line implemented on 64°*Y*, 90°*X* $LiNbO_3$ plate.

Plate thickness h (μm)	IDT				h/λ	Phase delay φ_0 (°)
	Period λ (μm)	Aperture (μm)	n° of finger pairs	Center-to-center distance l (μm)		
350	488	13,000	20	18,000	0.72	13,279

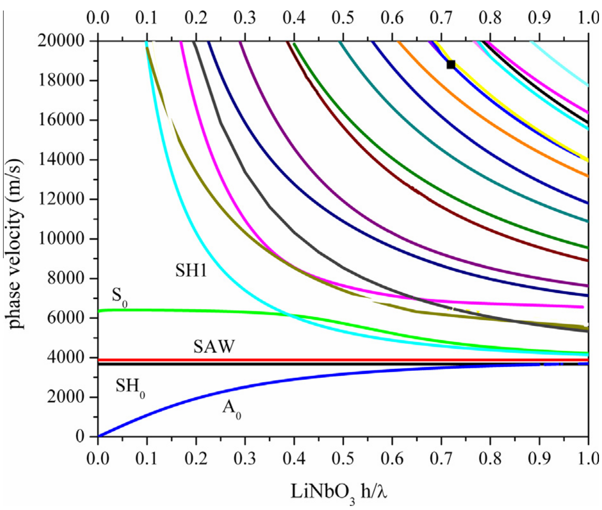

Fig. 1. Phase velocity dispersion curves for APM propagating along 64° rotated *Y*-cut $LiNbO_3$ plate, propagation at 90° off the *X* direction (Euler angles: 0°, −26°, 90°). The marker represents the experimental tests conditions.

All the measurements have been carried out exploiting the 15th mode at $h/\lambda = 0.72$ whose velocity is 18,807 and 18,761 m/s, for the bare plate and for the plate with one surface electrically shorted by an ideal conductive layer, respectively. For free and shorted faces the mode has three mechanical field components, the shear horizontal component being negligible, the shear vertical one being about 20% of the longitudinal one, and the longitudinal component being dominant. The latter component is mainly responsible for the sensitivity of the mode to the viscosity of the surrounding liquid, while the shear vertical one for the acoustic radiation into the liquid [12]. $LiNbO_3$ was selected as a substrate because of its high piezoelectric efficiency, while the mode and h/λ parameter have been properly selected so that the amplitude of the shear vertical component is sufficiently small in order to allow the sensor operation in the liquid environment without an excessive acoustic damping. All the measurements have been carried out at atmospheric pressure and room temperature, while the operation frequency for an IDT periodicity λ of 488 μm is 38.5 MHz.

The device response was tested upon exposure to different liquids wetting the top surface of the plate, either free or electrically shorted by a thin (120 nm) conductive Al layer. Like in Refs. [7,9,12,16,19], deionized (DI) water, showing a viscosity η of 1.03 cP and an electric conductivity $\sigma \ll 10^{-3}$ S/m, water solutions of glycerin ($1 < \eta < 1490$ cP, $\sigma \ll 10^{-3}$ S/m), and water solutions of NaCl ($\eta \sim 1$ cP, $10^{-3} < \sigma < 1.2$ S/m) were used as reference, viscous, and conductive liquids, respectively, all deposited along the acoustic propagation path by a brush; details of the measurements are discussed elsewhere [1,7,8]. Both the phase shifts ($\Delta\varphi$) and insertion loss (*IL*) at the output of the delay line versus the test liquid were measured using a network analyser (HP 8753E, Agilent Technologies, Santa Clara, CA) giving information on the fractional velocity change $\Delta v/v_0 = -\Delta\varphi/\varphi_0$ and attenuation α (dB/mm) of the mode, respectively. The temperature dependence of the response was evaluated by performing the measurements into a thermal chamber (MLW U10, Sintz Friental, Medingen, Germany) which allowed to control the temperature in the 0–100 °C range with an accuracy better than 0.1 °C. Experimental errors are estimated as ±5% for free surface and ±10% for shorted one. The lower precision for the surface coated by metal layer is due to increased electromagnetic leakage affected the measurements.

3. Results and discussion

Response in phase velocity and attenuation upon exposure to different weight concentrations of NaCl in deionized (DI) water are shown in Fig. 2. Nonzero response is observed for the un-shorted line, only, being the response itself related to the changes in the electrical conductivity σ of the solution, vs. NaCl concentration [20]. The behavior is similar to that observed exploiting different acoustic modes and plate thicknesses (h/λ) [21].

Velocity and attenuation response to the viscosity η is shown in Fig. 3; as expected, a different response is observed for the two conditions of free and shorted surface. For example, in case of

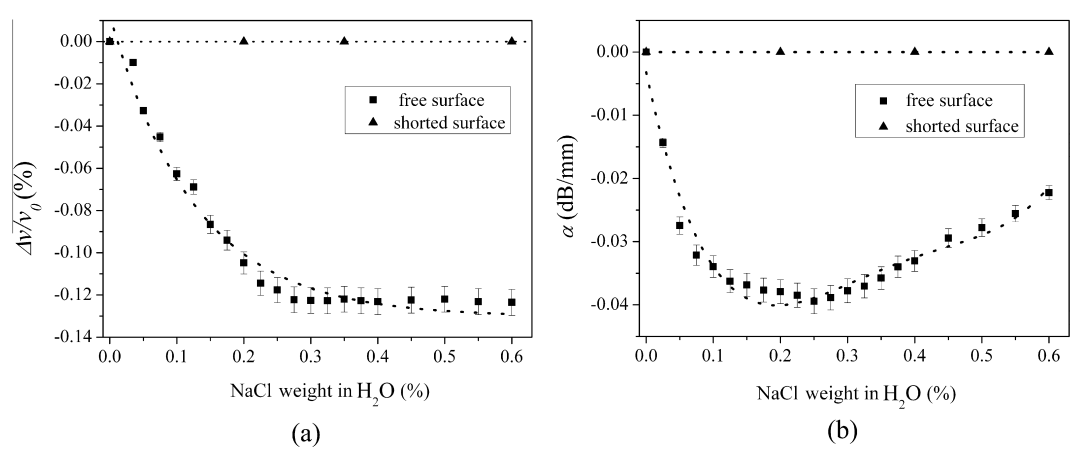

Fig. 2. Phase velocity fractional change (a) and attenuation (b) vs. per cent weight of NaCl in DI water, referred to the values in water (weight percent 0.6 corresponds to a conductivity $\sigma \approx 1.2$ S/m [20]).

Download English Version:

https://daneshyari.com/en/article/8130355

Download Persian Version:

https://daneshyari.com/article/8130355

Daneshyari.com