

# Acoustoelectric effect in ZnO-based SAW delay lines induced by UV light adsorption

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## Summary:

Thin c-ZnO piezoelectric films were grown by rf reactive magnetron sputtering technique onto fused silica substrates at 200°C. Split finger Al interdigitated transducers (IDTs) with periodicity of 80 μm were photolithographically implemented onto the free surface of the ZnO layer to excite the propagation of the fundamental Rayleigh mode as well as of its third harmonic. The acoustoelectric effect (AE), the waves velocity changes induced by the UV light adsorption in the photoconductive ZnO layer, was experimentally investigated by measuring the wave velocity in dark and under UV illumination at 365 nm at different power values. The AE effect induced in the ZnO/SiO<sub>2</sub> structure has been investigated theoretically by 2D finite element model.

**Keywords:** ZnO, acoustoelectric effect, SAW, phase velocity, insertion loss, electrical conductivity.

## Introduction

When the surface of the ZnO layer is subjected to ultraviolet illumination, the incident light is absorbed by the semiconductor and electron-hole pairs are generated which interact with the electric field accompanying the propagating surface acoustic wave (SAW). As a result, the SAW undergoes a downshift in its phase velocity and an upshift in its propagation loss; the changes of both the attenuation and phase velocity are correlated with the incident light power. The effects of the ZnO thin film conductivity changes on the SAW velocity and propagation loss are theoretically studied by 2-dimensional finite element model. The SAW velocity and insertion loss changes due to UV illumination at 365 nm are experimental measured.

## 1. Experimental

ZnO thin films were grown at 200°C onto fused silica substrates by rf reactive magnetron sputtering technique from a 4" diameter high-purity (99.999%) Zinc target (gas composition: Ar-O<sub>2</sub> 1:4 ratio; working pressure 3.7·10<sup>-3</sup> torr; rf power 200 W). Split finger IDTs were patterned onto the ZnO layer by conventional photolithographic and lift-off techniques (SAW wavelength 80 μm). The SAW devices were assembled on a printed circuit board with SMA

connectors to measure the delay line' scattering parameter S<sub>21</sub> by using a vector network analyzer. The sensitivity to UV light of the ZnO-based SAW delay line was tested by focusing the optical beam from a high power led (LEDMOD365.3500.HP from Omicron-Laserage Laser produkte GmbH) at 365 nm in between the two interdigital transducers (IDTs), by means of an optical fiber (LEDMOD.HP.3MM.LLG 3mm Liquid Light Guide).

### 1.1. Optical characterization

The absorption coefficient α of the ZnO films (from 100 up to 400 nm thick) was measured in the optical wavelength range from 200 to 450 nm by using a Deuterium-Tungsten Halogen Light Source (Mikropack DH-2000) and a Horiba Jobin Yvon monochromator. The UV penetration depth δ vs the optical wavelength curve was derived as δ=1/α. α and δ at 365 nm wavelength were around 3.1·10<sup>-6</sup> m<sup>-1</sup> and about 325 nm. Transmittance measurements performed onto the bare SiO<sub>2</sub> substrate confirmed its optical transparency in the 250 - 450 nm optical spectrum [1]. The Tauc plot method ZnO was used to calculate the ZnO band gap energy whose value, 3.362 eV, closely agrees the 3.37 eV of the bulk material [1].

## 1.2. Acoustic measures

The AE effect induced by the absorption of UV light at 365 nm in ZnO/SiO<sub>2</sub> substrates was studied for different light power values ranging from about 10 mW up to about 1.2 W. Figure 1 and 2 show the measured S<sub>12</sub> scattering parameter phase and insertion loss vs time curves at different UV power values [2, 3] for the third harmonic at about 104 MHz working frequency.

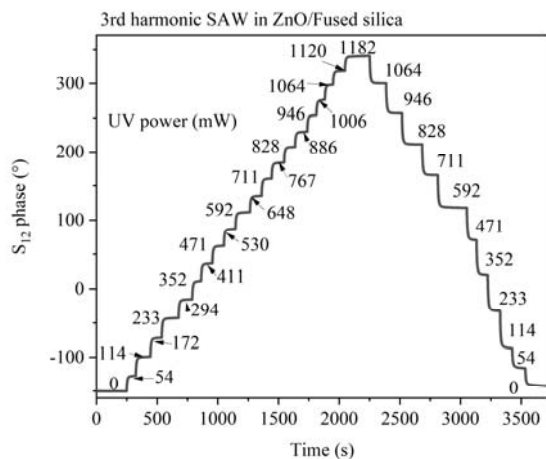


Fig. 1. The phase of the S<sub>12</sub> scattering parameter vs time at different UV power values from 0 to 1.2 W, and from 1.2 to 0 W.

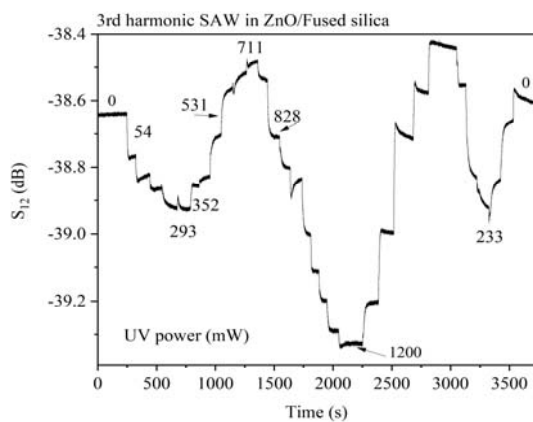


Fig. 2. The insertion loss of the S<sub>12</sub> scattering parameter vs time at different UV power values from 0 to 1.2 W, and from 1.2 to 0 W.

With increasing the UV power, the wave velocity decreases, and the insertion loss (IL) firstly increases up to a peak and then decreases. The response and recovery times were quite short (about 10 s).

## 2. Theoretical study

2D frequency domain study was performed by using Comsol Multiphysics to simulate the S<sub>12</sub>-dB vs frequency curve for different ZnO electrical conductivity values, under the assumption that the ZnO layer conductivity undergoes an in-depth inhomogeneous change

according to an exponential decay law, with a penetration depth of 325 nm. The ZnO was assumed to have a central domain with variable permittivity,

$$\epsilon_r - j \cdot \frac{[\sigma(x,y)]}{2 \cdot \pi \omega \epsilon_0} \quad (1)$$

where

$$\sigma(x,y) = A(x) \cdot e^{-y/\delta_{UV}} \quad (2)$$

is the ZnO electrical conductivity which changes according to an exponentially decreasing function with respect to the depth and according to a gaussian function with respect to the x axis,

$$A(x) = \frac{e^{-\frac{(x-x_c)^2}{2\sigma^2}}}{\sigma \cdot \sqrt{2\pi}} \quad (3)$$

where  $x_c$  and  $\sigma$  are the centre and the standard deviation of the gaussian function. Figure 3 shows the phase and IL changes vs the ZnO  $\sigma$  curves at fixed frequency; the insets show the electric potential distribution inside the layer at some  $\sigma$  values [2, 3]. The ZnO layer is supposed to be illuminated from the back side, through the SiO<sub>2</sub> substrate.

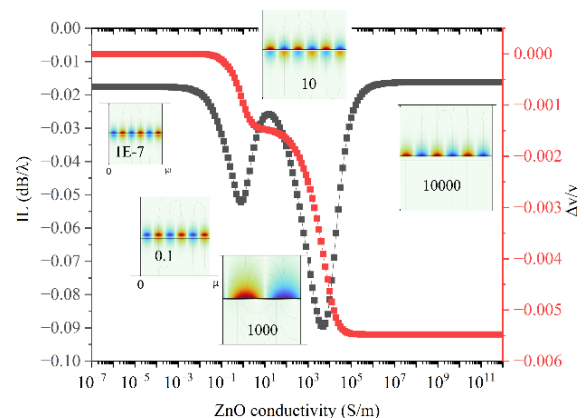


Fig. 3. The phase and IL changes vs the ZnO  $\sigma$  curves.

## References

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