Empirical Model Dedicated to the Sensitivity Study of Acoustic Hydrogen Gas Sensors Using COMSOL Multiphysics®

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Abstract

Due to the increasing demand for hydrogen gas sensors for applications such as automation , transportation, or environmental monitoring, the need for sensitive and reliable sensors with a short response time is increasing [1-2]. The purpose of such gas sensors is to analyze the ambient atmosphere to detect any hydrogen accumulation or leaks in hydrogen reservoirs, for the purpose of insuring optimal security in hydrogen-fueled vehicles.

This paper presents a unique empirical model which allows studying the sensitivity of acoustic hydrogen gas sensors. To establish this model, a parametric study based on the variation of physical properties of sensitive layers has been implemented using COMSOL Multiphysics®. Palladium is used as sensitive layer because of its high ability to interact with hydrogen molecules [3-5]. This model can be easily transposed to any other gas sensor type.

One of the major issues with acoustic hydrogen gas sensors is to know which physical parameter of the sensitive layer change with hydrogen absorption. Two major effects are described in the literature: mass change [6] and change in electrical conductivity [7, 8] due to gas absorption. However, research has shown that the most dominant effect is none other than the change in mechanical properties, including Young's modulus [9]. In this context, a parametric study has been performed to establish a unique empirical model using COMSOL Multiphysics. This model shows that the variation of frequency depends simultaneously on the physical and mechanical parameters variations of a sensitive layer.

Most of the developed acoustic sensors are based on Surface Acoustic Waves (SAW) [10-12] using a Lithium Niobate ($LiNbO_3$) substrate. These devices present a good reliability and robustness in harsh environments, combined with low fabrication cost. Also, some work has been devoted recently to Lamb wave resonators [13] using Aluminum Nitrite (AlN) membranes, which have generated an interest for biological detection due to their improved mass sensitivity. The different characteristics of the acoustic modes used to emphasis the empirical model. The shape of these modes obtained by COMSOL is shown in Figure 1.

In this work, a parametric model was developed to analysis the sensitivity of acoustic hydrogen gas sensors. This study was performed considering acoustic delay lines operating in the ISM bands, at around 430 MHz and 920 MHz. Theoretical evaluations showed that, in the presence of 3 % hydrogen concentration [14, 15] that the model allows to determine the effect of hydrogen gas on the mechanical and physical parameters of the selective layer.

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Figures used in the abstract

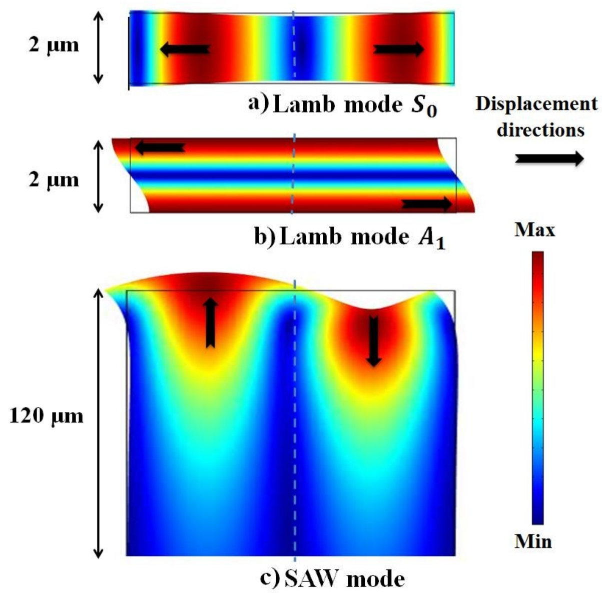

Figure 1: Substrate deformation for (a) S0 Lamb mode , (b) A1 Lamb mode and (c) Rayleigh mode.