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An optically integrated NH_3 sensor using WO_3 thin films as sensitive material

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Abstract

We analyze the optical response of WO_3 sputtered thin films to NH_3 gas sensing through transmittance changes. By sputtering, films with a combination of monoclinic and triclinic crystalline structure were obtained. The films show sensitivity to NH_3 presence at the wavelengths $\lambda = 980$ nm and 1550 nm and at low temperature, $T = 90\,^{\circ}C$. The optical constants (refractive index (n) and absorbant coefficient (α)) were calculated using the transmittance spectra and the model of a simple resonator. According to these results, an integrated optical NH_3 sensor based on a glass waveguide with a WO_3 thin film deposited at the surface was designed and experimentally characterized.

Keywords: gas sensors, optic waveguide, optic integrated

(Some figures in this article are in colour only in the electronic version)

1. Introduction

Tungsten trioxide (WO_3) is a promising material for gas sensing applications. Different authors have shown the sensitivity of WO_3 thin films to detect a broad range of oxidizing and reducing gases, such as CO, CO_2, NO_2, NH_3, with detection levels of a few ppm or less. Due to the semiconductive characteristics of WO_3, these works are based on electrical transduction methods [1–3]. Among all the sensors developed during this last 20 years, optical devices have proved their ability to meet drastic requirements such as strong immunity to electromagnetic noise, high stability, and compatibility with explosive environments [4]. The importance of optical gas sensing has motivated numerous research works to improve their performances with higher integration to *in situ* measurement applications. To the best of our knowledge, only the change in electrical properties of WO_3 thin films upon gas adsorption has been reported [5]. Moreover, we are not aware of previous efforts of making WO_3 thin film sensing properties compatible with integrated optics devices.

In this paper we optically characterize WO_3 sputtered thin films for ammonia gas (NH_3) detection, according to the thermochromism phenomena involved during the sensing process. The optical constants are experimentally obtained under the conditions of measurement. Finally, an integrated optical structure is designed, taking into account the WO_3 optical characterization to calculate the spatial redistribution of the optical field within the optically integrated structure, which directly influences the sensing function.

2. WO_3 thin film characterization

2.1. Structural and morphological WO_3 characterization

The WO_3 thin films were deposited using a reactive sputtering method in a mixture of argon and oxygen using a DC magnetron sputtering and a 3 inch metal tungsten target (Lesker, 99.95%). The pre-cleaned glass substrates were placed in a vacuum chamber evacuated to a base pressure of about 1×10^{-6} mbar. The working pressure was 3×10^{-3} mbar. The substrate to target distance was fixed at 60 mm. We grew 15 different samples but we analyzed the sample (M4) which had the best performance. It was deposited using a DC power of 250 W, at a temperature of 300 °C for 10 min, obtaining a thickness of 1809 nm.

The crystalline structure of the thin films was determined using a Raman spectrometer (Nicolet Almega XR). In

