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SnO_2 Nanoparticles Deposited on Optical Fibers and Glass Substrate for Gas Sensors Applications

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Tin oxide (SnO_2) is an n-type wide band gap (3.6 eV) semiconductor which has been used for various applications as catalytic support materials, transparent electrodes, in solar cells and solid-state gas sensors [1]. During the last two years, novel gas nanosensors have been proposed using the luminescent properties of metallic oxides (ZnO, SnO_2) where luminescence intensity is modified according to the nature and concentration of adsorbed gases [2]. On the other hand, the optical fiber sensor is based on the evanescent-wave absorption which has potential to monitor a leakage over wide area. In this case, the material absorbs the wavelengths carried by the fiber and modifies the absorption as a function of gas concentration to be detected [3]. In this work, SnO_2 nanoparticles (NPs) were deposited on optical fibers and glass substrates. A morphological and chemical analysis were performed on the obtained samples.

SnO_2 nanoparticles were prepared using 3.0 g of $SnCl_4 \cdot 2H_2O$ dissolved in 25 ml of anhydrous ethanol. 4 ml glacial acetic acid was added as chelating agent. The solution became clear and homogeneous after stirring during 20 min. The cleaned glass substrate and optical fibers (10 µm of diameter) were independently dipped into $SnCl_4$ solution. After that, they were removed from the solution (pull rate of 200 mm/min). Another reduced optical fiber (120 µm of diameter) were also fabricated using the flame-brushing technique [4] upon which a drop of $SnCl_4$ solution was deposited. All samples were dried at 250 °C for 20 min.

Figure 1a) shows a SEM image of spherical SnO_2 fine particles deposited on glass substrate having diameters of 20-30 nm. The typical photoluminescence (PL) spectrum of SnO_2 NPs is presented in the inset the figure 1a). The visible emission (550 nm) is generally suggested that come from defects such as oxygen vacancies and tin interstitial or dangling bonds [5]. Figure 1b) shows the XPS survey spectrum of SnO_2 NPs, which revels the presence of carbon, sodium, chlorine, oxygen and tin. The peaks of C 1s and Na (KLL) are attributed mainly to contamination during storage of samples. The peaks of Sn 3d, 4d, 3p, 4p and 4s from SnO_2 also are observed. Two XPS peaks located at 486.15 and 494.55 eV are related to Sn $3d_{5/2}$ and Sn $3d_{3/2}$ spin orbit peaks of SnO_2, confirming the formation of SnO_2 NPs. However, traces of $SnCl_2$ (487.39 eV) and metallic Sn (484.90 eV) were also found on the surface of the sample. This could be due to an incomplete oxidation of tin precursor salt during thermal annealing. On the other hand, the surface morphology of reduced optical fiber exhibits a cluster morphology with varying cluster sizes and random distribution across the surface (Fig. 2a). The average cluster size is 200 nm, which was estimated from inset Fig. 2a). In addition, the clusters might be formed by SnO_2 NPs (20-30 nm). Fig 2b) shows a SEM image of the optic fiber (120 µm) surface morphology after the deposition of the SnO_2 NPs using the drop-casting method. The surface was uniformly covered after thermal annealing. The rough region on the surface of the optical fiber is possibly produced by a bad cleaning process. However, SnO_2 NPs were also deposited on this rough region. Elemental mapping of the optical fiber,

shown in Fig. 2 c-d), reveals that Si and Sn atoms are present on the optical fiber surface.

In this investigation SnO_2 NPs were deposited on glass substrate and optical fibers by deep-coating and drop-casting techniques, respectively. Obtained particles have a spherical morphology with diameters near 20-30 nm. This particle size would highly improve the gas sensitivity due to the significant numbers of surface-active sites for oxygen adsorption and surface reaction, resulting in larger changes in the intensity of evanescent field wave or luminescent properties of semiconductor [6].

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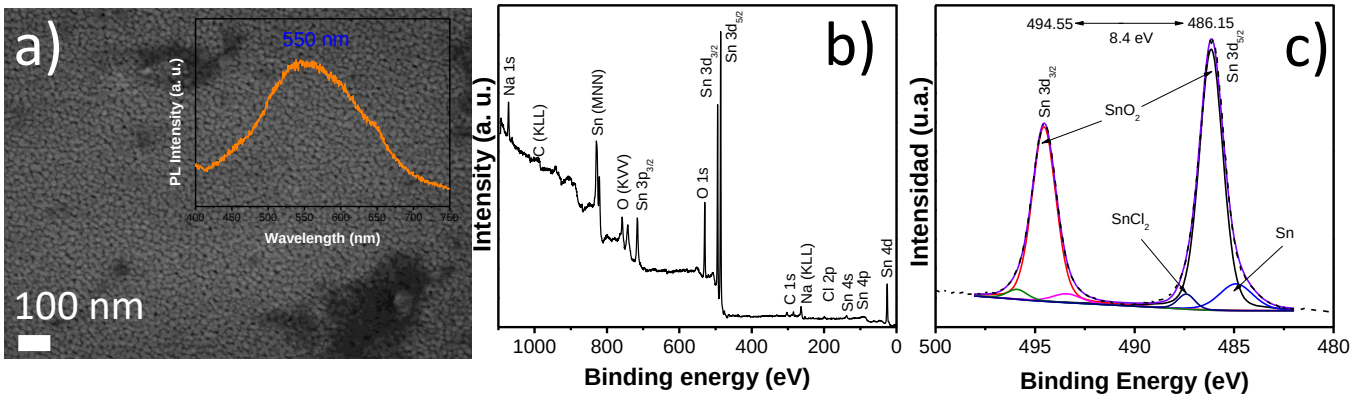

Figure 1. a) SEM image and PL spectrum (inset), b) XPS survey spectrum, and c) Sn 3d XPS spectrum of SnO_2 NPs deposited on glass substrate.

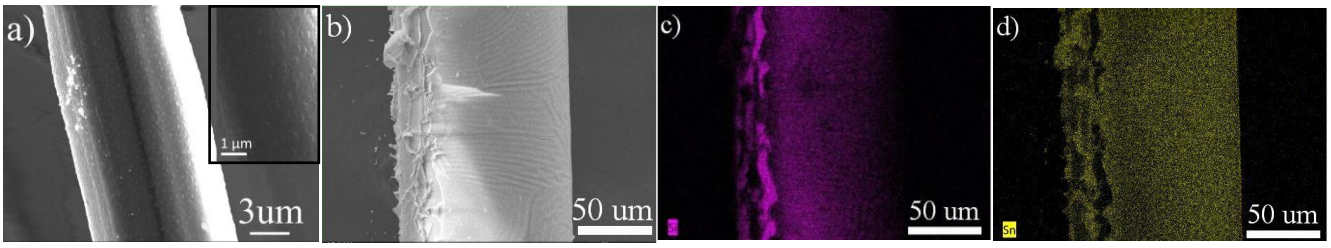

Figure 2. a) SEM imagen of SnO_2 NPs deposited on reduced optical fiber (10 µm). Inset: SEM imagen of SnO_2 NPs at higher magnification, b) SEM imagen of SnO_2 nanoparticles deposited on optical fiber (120 µm) and their corresponding elemental mapping images of c) Si, and d) Sn.

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