Nanocomposite based on gold nanoparticles embedded into ZnO films

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Metal-dielectric nanocomposites have attracted much attention in the last years because is a very promising approach towards multifunctional materials since they combine the unique electromagnetic properties of noble metal nanoparticles (NPs) with the characteristics of polymeric or metal-oxide host matrices [1,2]. As a result, nanocomposite thin films show high potential in diverse fields such as sensing [2] and photovoltaics [3], as many other. The control of the size and shape of NPs as well as their concentration and distribution within the host solid matrix is compulsory to achieve high-performance multifunctional materials for most of these applications.

Among the existing metal oxide matrices, ZnO has received enormous interest, because it exhibits various superior properties applicable to devices, such as wide direct band gap, large exciton binding energy, high optical transparency in the visible range, good electrical conductivity and piezoelectricity. Thus it has been widely used as a transparent electrode in optoelectronic devices, resistive gas sensors and SAW devices [4]. In this work we report on a novel sol-gel method for the synthesis of a nanocomposite based on Au NPs embedded into ZnO thin films. The procedure consists of spincoating an aqueous solution of $Zn(CH_3COO)_2$ and $HAuCl_4$ followed by a thermal annealing above 300 °C for several minutes (Figure 1). Both ZnO and Au NPs are synthesized in-situ during the hard bake. Film thickness and density of NPs in the resulting nanocomposite can be controlled by the concentration of the precursors in the wet process. Figure 2a shows the optical characterization of ZnO and Au-ZnO thin films. ZnO films show an absorption band at 362 nm, attributed to the exciton absorption peak, which corresponds to a bandgap energy of ≈3.4 eV (deduced by using an appropriate excitonic model for this direct gap semiconductor). On the other hand, the Au-ZnO nanocomposite nanocomposite exhibits two bands at around 350 and 553 nm, which are associated to the exciton absorption of ZnO (with a similar bandgap energy) and the localized surface plasmon resonance due to the presence of Au NPs, respectively. Therefore, ZnO conserves its intrinsic structural (demonstrated by X-Ray diffraction not shown here) and optical properties after the introduction of Au NPs in the film. A similar observation can be said with respect to the case of the electrical properties (Figure 2b): the conductivity of ZnO layers was found to be around 0.24 S/cm, whereas that of Au-ZnO films decreased by a factor two, may be due to a reduction of free carriers at ZnO grains or to an increase of potential walls at grain boundaries. The presence of Au NPs is clearly confirmed by TEM (Figure 3a), being their size around 40-60 nm in diameter, depending on the precursor concentration and baking temperature. We also observed a nanostructuring of the ZnO surface (see the SEM image in Figure 3b), in this case attributed to an average surface roughness (grain size) of ZnO of the order of 50 nm.

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References

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Figure 1: Procedure of the synthesis of Au-ZnO nanocomposite thin film.

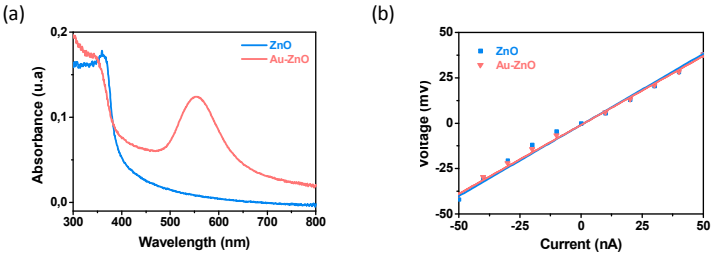

Figure 2: Optical and electrical characterization. a) UV-Vis spectra and of b) V-I Curve of ZnO and Au-ZnO films.

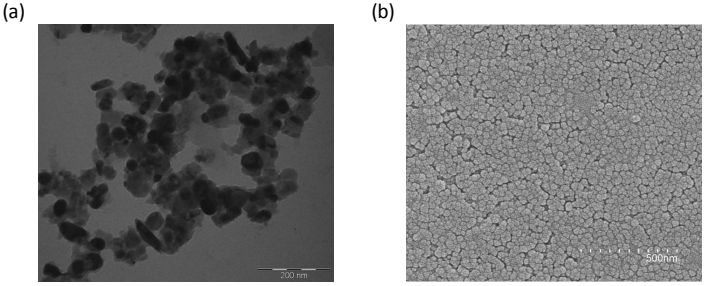

Figure 3: TEM (a) and SEM (b) images of Au-ZnO nanocomposite thin film.