Plasmonic layers based on noble metal nanoparticles embedded in oxides for photovoltaic applications

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Metal-dielectric nanocomposite (MNC) thin films have attracted much attention in the last years due to its unique electromagnetic behavior and high potential in diverse fields like photovoltaics [1] and sensing [2], other than metamaterials, photodetectors, catalysis, sub-wavelenght imaging, ... The special electromagnetic properties of the MNC are predominantly dominated by the localized surface plasmon resonance (LSPR) typical of noble metal nanoparticles (NPs). The control of the size, shape and density of these NPs embedded in a given solid matrix is needed for most of these applications.

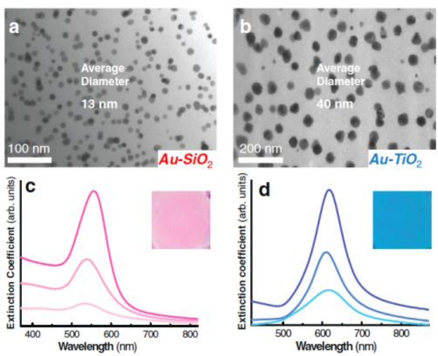

Figure 1

Recently, we have developed a novel sol-gel method implemented for spin-coating technique, in which metal NPs are synthesized in situ and their average size and density can be varied up to a certain extent with the concentration of the Au precursor solution [3]. MNC films doped with Ag and Au NPs have been successfully fabricated until date following this procedure over different substrates (glass and silicon) in order to investigate their optical properties. Figure 1 shows TEM images of SiO_2 (Fig. 1a) and TiO_2 (Fig. 1b) thin films containing Au NPs, other than the visual aspect and LSPR spectra (Figs. 1c-d). Larger Au NPs were synthesized (about 40 nm) in the TiO_2 matrix than in SiO_2; this may be important for photovoltaic applications because light scattering predominates over light absorption for larger metal NPs. Antireflective (AR) coatings are needed to increase light absorption by most solar cell designs. The inclusion of metal NPs in AR films can further reduce reflectance and increase light trapping at the short wavelength side of the LSPR. Further AR effect can be achieved by introducing a weak chemical etching process that leads to the formation of pores in the TiO_2 matrix (see SEM image in Fig. 2a). We obtain a minimum in the overall reflectance spectra in MNC films on Si-substrate (Fig. 2b). In glass-substrate samples we observe an intensity decrease and blue-shift of the LSPR, which is attributed to the reduction of the matrix effective refractive index associated to pore formation.

Given the extensive use of TiO_2 and ZnO materials as transparent conductive electrodes in organic and Si thin/ultrathin film solar cells we have also extended our sol-gel/spin-coating method to in situ synthesize Au NPs in ZnO. The conductivity of the so prepared ZnO layers is around $3.4\times10^{-2}\ \Omega^{-1}cm^{-1}$, whereas that in Au:ZnO films decreased by a factor two.

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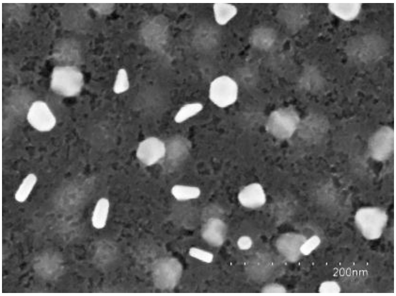
(a)



(b)

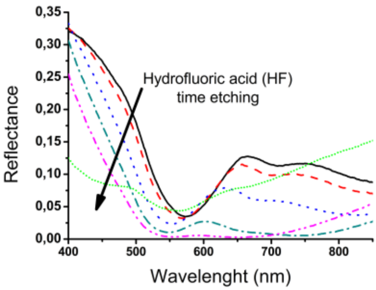


Figure 2

References

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