Opto-electronic devices: Potential tools for the development of novel nanobiosensing devices

Abstract: TiO_2 thin films covered by luminescent cadmium telluride quantum dots were conjugated to IGg protein and anti-IGg antibody, resulting in a new nanostructured platform with very unique properties. The obtained results strongly point to the potential use of this opto-electronic nanocomposite for the development of novel nanobiosensing devices.

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1.Introduction

Sensitization of nanostrucutured TiO_2 thin films can be achieved through modification of the oxide with quantum dots (QDs) of lower band gap. The use of QDs enables band gap tuning by controlling the QDs' size, allowing the adjustment of some key features, such as light absorption and resulting emission wavelength. Additionally the QD sensitized nano-TiO_2 can benefit from both large QD extinction coefficients and the multiple exciton generation phenomenon, which shall lead to an enhancement of the conversion efficiency in photoelectronic based devices [1,2]. The attachment of the QDs to the oxide matrix has been largely investigated and seems to play a fundamental role in the efficiency of the electronic mechanisms involved. In this work, the functionalization of the QD sensitized TiO_2 with IGg protein, as well as its attachment to monoclonal anti IGg antibody was investigated in order to expand the application range of this class of opto-electronic devices as nanobiosensing tools.

2. Materials and Methods

Otherwise mentioned, all reagents were purchased from Sigma and used without further purification. Titanium isopropoxide IV (Ti [OCH ($2CH_3$)]$_4$) was used as Titanium source for the obtention of TiO_2 thin films by MOCVD technique, in which the metalorganic source temperature was at 37^{o}C, the deposition time interval used was 5 minutes with a working temperature of 500^{o}C. The water soluble core-shell cadmium telluride/cadmium sulfide (CdTe/CdS) QDs were prepared as described elsewhere [3]. The TiO_2 thin films were vaporized with CdTe/CdS QDs containing aqueous suspension and after that, the solvent was evaporated at room temperature. Functionalization of the samples with IGg protein was performed by direct immersion of the samples in IGg containing solution. Energy Dispersive X-ray Spectroscopy (EDS), Scanning and transmission electronic microscopies (SEM and TEM), X-ray diffractometry (DRX), reflectance and absorbance in UV-visible spectroscopy, Fourier transform infra-red spectroscopy (FTIR), Raman Spectroscopy, and electrochemical experiments were performed in order to determine the resulting properties of the samples.

3. Results

Some of the results obtained are presented in this section. Excitation and emission spectra of the synthesized CdTe/CdS quantum dots are presented in Figure 2 (top) as well as an x-ray diffractogram (botton), in which the zinc-blend structure can be observed. In the same figure (top, right), a high resolution transmission electronic microscopy (HRTEM) image of the quantum dots is shown.

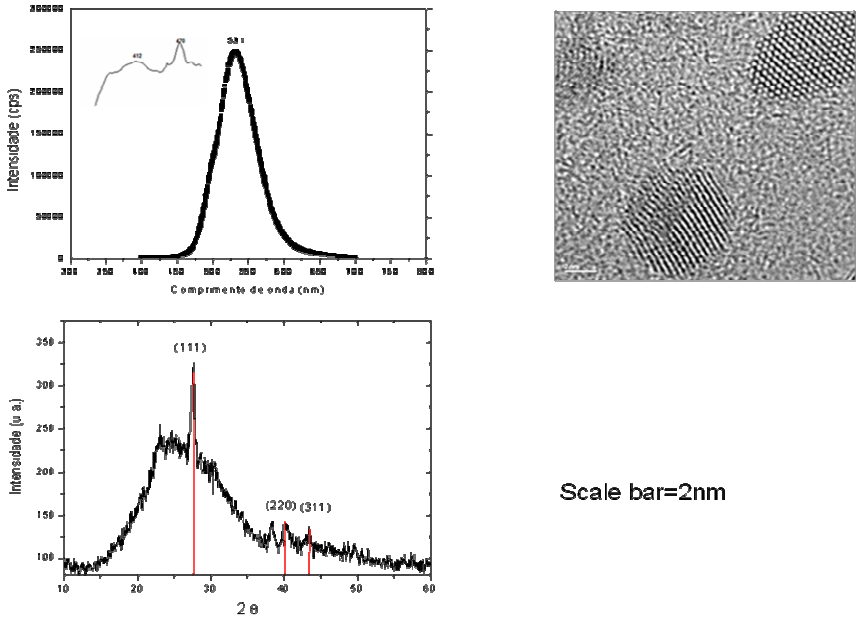

Figure 2. Top: Excitation and emission spectra (left) obtained for the synthesized CdTe/CdS quantum dots. HRTEM image (scale bar: 2nm) in which can be noticed that the QDs size is about 3 nm. Botton: X-ray diffractogram.

Distinct metalorganic source temperature, time of deposition and working temperature combinations were tried in order to obtain homogeneous and thick anatase/rutile TiO_2 nanostructured thin films. Figure 3 shows electronic microscopy (TEM and SEM) images of TiO_2 thin films without (left and center) QDs covering and with QD covering (right), which were obtained with the following conditions: metalorganic organic source temperature: 37°C, deposition time interval: 5 minutes and a working temperature of 500°C.

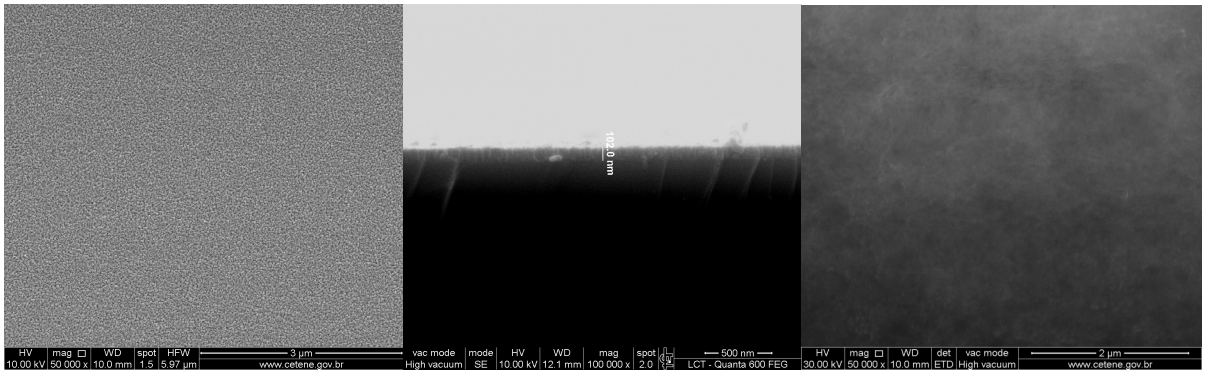

Figure 3-Left: TEM image of TiO_2 thin film (metalorganic souce temperature: 37°C, deposition time interval=5minutes, working temperature: 500°C); Center: TiO_2 thin film high-resolution cross-section SEM image. Thickness of TiO_2 layer is 102 nm; Left: CdTe QDs deposited over TiO_2 thin film.

Figure 4 shows typical absorption and reflectance spectra obtained for TiO_2 thin films with and without the coverage of QDs.

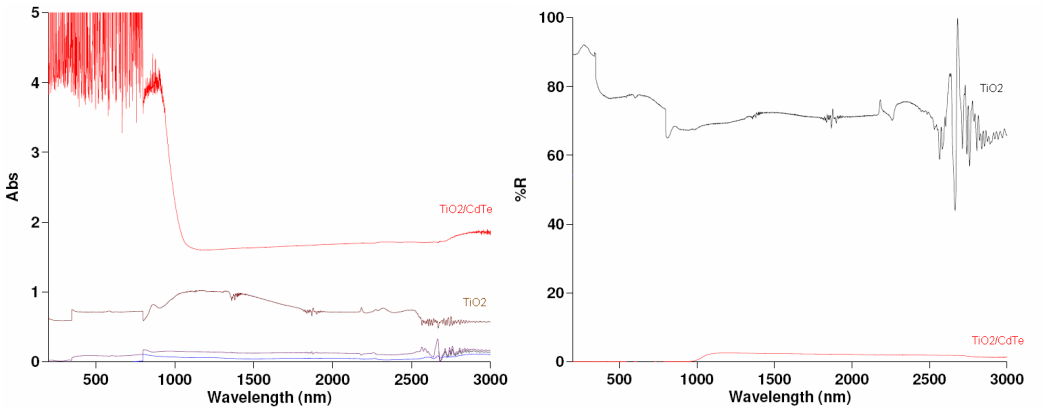

Figure 4. Left: Absorption spectra; Right: Reflectance spectra.

The electrochemical behavior of nonfunctionalized TiO_2/QD surface and IGg functionalized TiO_2/QD surface is represented in Figure 5 An increased conductivity can be observed for the IGg functionalized sample. When the functionalized sample is conjugated to monoclonal antibody anti-IGg, the conductivity intensity is increased to 120 nA (nanoAmper). Further experiments are being performed with distinct proteins (troponin and myoglobin) in order to evaluate the sensibility and specificity level of the system as well as to evaluate its range of application as opto-eletronic nanobiosensor .

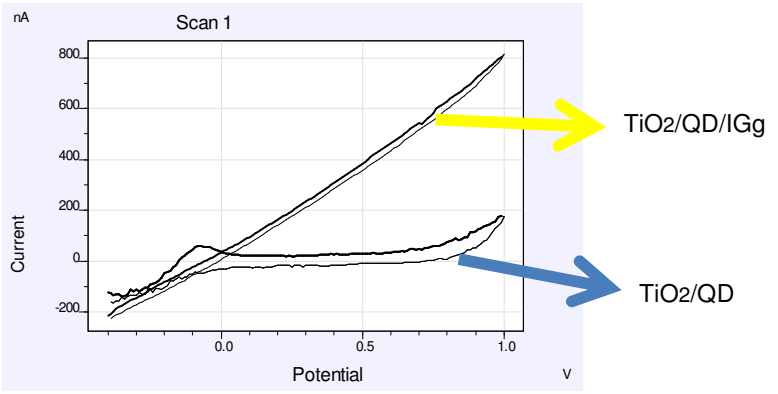

Figure 5. Conductive behavior of TiO_2/QD non functionalized sample and TiO_2/QD functionalized with IGg protein.

Conclusions

TiO_2 nanostrucutred thin films were obtained by MOCVD technique and covered by colloidaly prepared water soluble core-shell CdTe/CdS quantum dots (QDs). The TiO_2/QD surface was functionalized with IGg protein and further, monoclonal anti-IGg antibody was conjugated to the nanostructred surface. The resulting nanocomposites presented opto-electronic properties which confirmed the sensitization of the TiO_2 thin film as well as its potential application as a nanobiosensing device for protein detection and quantification.

References

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