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Research Article

Optoelectronic Properties of Platinum Doped TiO_2/Si Structures for Photocatalysis

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Abstract

This article covers little specific outcomes and connotations related to the photocatalytic properties of titanium oxide films distinctively doped by platinum, and deposited on a silicon substrate by means of the PLD technique. Through I-V spectroscopic investigates, laser-beam-induced current (LBIC), optical reflectivity and impedance spectroscopy, it is followed that an ideal percentage somewhere in the range of 0.2% and 0.3% of Pt invites updating an extremely fascinating photocatalytic execution of such structures against methylene blue photodegradation (MB) as a dye in the UV-visible spectral tape.

Keywords: Ti; Platinum; Impedance Spectroscopy; Reflectivity; Current-Voltage; Light Beam Induced Current (LBIC)

Introduction

The modern turns of events and the diverse human exercises these days have delivered numerous natural issues, to be specific contamination of the air, soil and furthermore groundwater. The outcome is a pressing interest for environmental protection and the ecologic creation of energy. Semiconductor based photocatalysis measures have shown an exceptional potential to beat the issue and presents extra central focuses related to sensibility, cost-suitability and cleanness. Among different sorts of semiconductors, titanium dioxide is the most alluring one as a photocatalyst attributable to its high reactivity, extraordinary synthetic solidness, simple accessibility and modest cost [1-7]. In spite of enormous endeavors having been made toward the creation of Titanium oxide materials, just as the examination of their photocatalytic properties, genuine applications in photocatalysis are still generally hampered by the wide band gap (eV for anatase and Brookite, eV for rutile), which can just retain ultraviolet radiation (representing < 5% of solar light) and the quick recombination of induced charge transporters, which prompts low quantum efficiency [8-13]. It is as yet an interesting issue in the field of examination material science and photocatalysis to control from one view point the morphology and engineering of titanium oxide, and then again, its electronic and optical properties for acquiring a drawn out light reaction and encourage electron-hole photogeneration separation, consequently accomplishing a photocatalytic movement strikingly improved [14]. In all actuality, numerous boundaries are associated with the cycle of surface photocatalysis of materials. Titanium oxide can use in various cases. It was shown that TiO_2 films don't defile silicon wafer after an adequately long time of high temperature treatment. In any case, a thin passive layer of SiO_2 can create at the point of interaction TiO_2|Si through a concise oxidation after the deposit cycle [15]. The most prevailing are the band gap and the species Red-Ox potentials, the age pace of electrons and hole

within the sight of reasonable light, the lifetime and diffusion length of these carriers, the surface state of materials, geometric factors, such as layer thicknesses, yet in addition the nature of the substrate [14,16-18]. From a quick reviewing literature, it is noticed that there is a few attempts on Ti(Si, N…) structure for photocatalysis application. TiO_2 nanoparticles deposited on the ITO substrate were doped through the LPD process with nitrogen and used in solar cells sensitive to dyes (DSSC) [19,20]. Furthermore, samples were likewise employed as photovoltaic materials in lightly sensitivephoto-electrochemical cells using N-719, N-3 and Z-907 dyes, respectively. Even so, it has been shown that the PV parameters including short-circuit current density (J_{ac}), open circuit voltage (V_{oc}), structure factor (FF) and power conversion efficiency (η) are fundamentally impacted by a portion of the organic dyes. Appropriately, the altered cells were upheld with the N-719 dye which gave the best PV parameters. These large numbers of results were upheld by UV-visible spectroscopy, which showed that the dye N-719 has a more extensive absorption band and the most elevated absorption peak in the visible. Arrays of nanorod (synthesized by the hydrothermal process were operated as electron transfer layers. They introduced a power conversion most extreme which comes to 11.1% more prominent than those not doped in N, and they decreased the gap from 3.03 eV to 2.74 eV, as well as a low conduction resistance through the doping shown by EIS [21]. A few creative methodologies to improve performance of anatase films in indoor air sanitization applications have been examined. Some results have been observed that included mechanical subtleties of the interaction between CHO and films, as well as fed films [22-24]. The significance of film development lies in the role of crystal equilibrium and exposed crystal surfaces. The impact of response process conditions, such as, humidity, catalyst temperature and light power on the photocatalytic action of anatase assume a noticeable part [25]. Besides, Ma, Ning., *et al*. [26] reported that Si doped Ti enhanced the photocatalysis in water medium when incorporated it in an inorganic membrane. Moreover, it is found that N-doped Ti microspheres and Si/N- synthesized through hydrolysis technique exhibited removal efficiency as high as 53% of 1.0 of Cr (VI) solution during 120 min [27]. This work focuses on the photocatalytic properties of titanium oxide thin film doped with various platinum concentrations along with the study of the optoelectronic properties of such structures.

Results and discussion

The samples are TiO_2 thin films deposited by methods of pulsed-laser deposition (PLD) on a silicon substrate. The active layer of titanium oxide is once unadulterated and multiple times doped with Pt element under various percentages (0.1%..., 0.4%). The impact of platinum on the structure and on the band gap of such samples was reported previously [28]. Herein, the photocatalytic properties of these samples have been carried out the impedance spectroscopy (IS), the light beam induced current (LBIC) as well as by using I-V characterization. In the literature, it is well known that the component of surface photocatalysis includes the Red-Ox potentials of interface and the abilities of the semiconductor layer to deliver electron combines free openings, and able to play out a surface oxidation-reduction response with these contaminants [17,29]. The current voltage characteristics of the TiO_2: Pt-Si thin films are repotted in the figure 1. Note that the saturation current is the same in forward polarization for all of TiO_2 films. This shows that the platinum doping effect has no impact on the maximum concentration of carriers in the material which proves that it is an insertion doping.

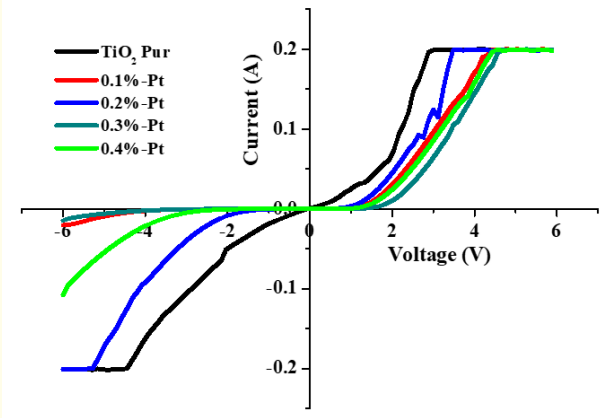

Figure 1: Diagrams I-V of TiO2: Pt/Si thin films.

However, in inverse polarization, the current is very low for the two concentrations: 0.1% and 0.3%, which proves the existence of a strong resistance to conduction phenomenon. This result is beneficial for the sensation of surface photocatalysis, for the reason that for these two concentrations, the carriers are favored to migrate to the surface of TiO_2.

Besides, the I-V characteristic makes it possible to infer that the electrical behavior of the samples is similar that of a diode where the space charge zone (ZCE) is located at the interface of the ampilated layers.

The impedance curves displayed in figure 2 show that the electrokinetic behavior of the various films can be demonstrated by an equal circuit (R_f// C) in series with a resistance, represents the spillage resistance of TiO_2 Si interface, its ability is C. Besides, the resistance is identified with the conduction of TiO_2 layer toward the path normal to the interface.

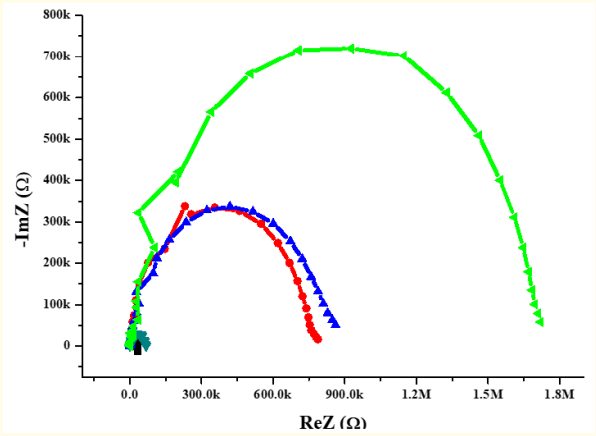

Figure 2: Nyquist Diagram of TiO2:Pt|Si thin film.

Percentage of Pt (%)	(kΩ)	*(Ω)*	C (nF)
0	1.27	199	84.5
0.1	6.09	37.3	120
0.2	620	6.67	196
0.3	68.7	8.19	68.2
0.4	1500	51.2	105

Table 1: Electrical values for each equivalent circuit of the thin doped film.

The values related to, C and for the various samples are listed in table 1 and in figure 1 Note that the part esteems change with the platinum doping rate. Resistance has diminished for the doped TiO_2 layers contrasted with the un-doped layer, which shows that carrier's mobility has expanded. In any case, the base estimation of is acquired for a level of doping of 0.2% and its value is close to 0.3%. The resistance modeling the spillage of charge carriers through the potential of interfaces TiO_2|Si increments with the level of the doping by methods for a fall for the concentration of 0.3% Pt which can be linked with the difference in the anatase phase to the rotule. The limit estimations of the charging zone show that the base is gotten for a platinum doping level of 0.3%. The ideal physical circumstance for a decent working of the photocatalysis cycle is what relates to the least conceivable estimation of and the most elevated estimations of and C. This circumstance was unambiguously observed for the sample containing 0.2% Pt. It very well may be additionally upgraded for the level of Pt doping somewhere in the range of 0.2% and 0.3%, if the creation method remains dependable to appropriately alter the basic concentrations. Nonetheless, we have examined the impact of this doping on the spectral reflectivity as a function of the frequency in the visible field and the outcomes are collected in figure 3.

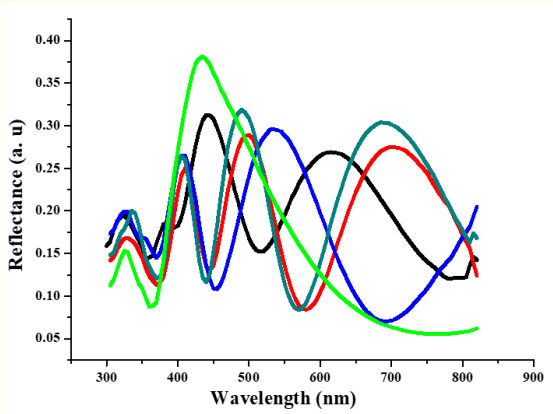

Figure 3: Reflectivity Spectra of the TiO2: Pt-Si thin film.

It is known in optics that the reflective intensity of the layers of filled materials relies upon the optical index and furthermore on their thicknesses as indicated by the interference fringes.

In the same line, the presence of the interference fringes stands for homogeneous deposited Ti film's on Si substrates. Realizing that in typical rate, the reflection coefficient is given by this formula r≃(N_(TiO_2)-N_Si)/(N_(TiO_2)+N_Si (in a similar case, t ≃⟦2 N⟧_(TiO_2)/(N_(TiO_2)+N_Si) for the mean yellow frequency, we notice that in every one of these figures for the obvious range, the change for a length of an all-around characterized wave of this force reflector as per the level of Pt doping which clarifies the alteration

of the area of the minima and maxima in all these spectra. In any case, the base reflection that we are concerned about is that set in the active frequency zone of TiO_2 that is to state in the region of the gap. As it is seemed in the reference [30], doping diminishes the gap from 3.21 eV for unadulterated TiO_2 up to an estimation of 2.75 eV for a platinum level of 0.4%, and this band gap relates to an optical activity in the UV.

As per the reflectivity range, the most reduced estimation of the reflection coefficient relates to the 0.2% Pt. However, it's not a long way from different estimations of the 0.3% Pt separately in the region of 441 nm and 450 nm. The good circumstance for a photocatalytic activity of the Ti layer is what reacts to a moderate circumstance between the various boundaries.

As an examination with past outcomes, a concentration somewhere in the range of 0.2% and 0.3% is the most ideal. As well, silicon having a gap on the request for 1.21 eV can create under the activity of noticeable light, electron-hole sets which can produce

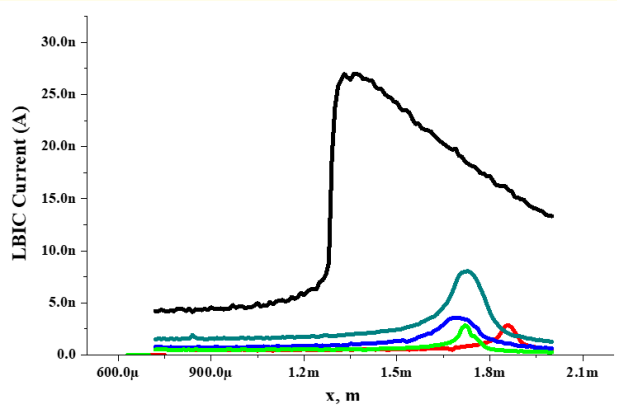

Figure 4: Light Beam Induced Current Diagrams (step = 100 µm).

the action of the Ti layer on the photocatalysis process.

To reinforce the optoelectronic investigations on Pt doped TiO_2|Si structures, it is well known that the carriers transport phenomenon at the interface between TiO_2 and Si-substrate play a crucial role in the photocatalytic performance of this structure. Thus, LBIC measurements may be of interest to understand the mechanism of the photocatalysis. The analysis of the samples by the LBIC current strategy with red laser (λ 632 nm) as it is appeared in the figure 4; that this current declines a ton for doped TiO_2 than for that without doping, and this outcome ends up being predictable with our test. Also, to strengthen the conclusion of these results, we performed the photodegradation of methylene blue in the presence of UV light. In view of that, Figure 5 shows the photocatalytic performance of TiO_2: Pt films deposited at 500 °C, studied as a function of their platinum content by analyzing their ability to degrade the methylene blue molecules under UV illumination. UV illumination is provided by an OSRAM germicidal lamp (16W, λ = 256 nm). The initial concentration of the methylene blue solution is 10 mg and the study of the photocatalytic performance is affected for 30 min. The concentration of methylene blue remaining in the solution after degradation is analyzed by UV-vis spectroscopy.

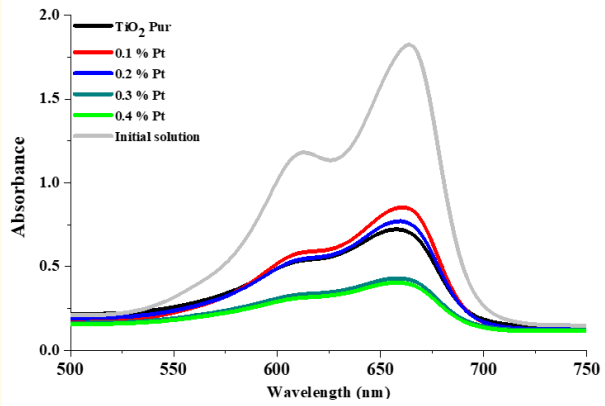

Figure 5: UV-Vis absorption spectra of methylene blue before and after the photocatalytic test of pure TiO2 and doped in Pt.

After 30 mn under UV illumination, the methylene blue solution shows rapid discoloration.

Indeed, figure 5 shows the UV-Vis spectra of methylene blue solutions before and after photocatalysis process using Ti: Pt films. As a result, photocatalytic tests show that films doped with 0.2% and 0.3% platinum exhibit the best photocatalytic activities. This result has been shown before by something else altogether from the one we drew closer [28]. It very well may be obliged as a second examination on the platinum values fundamental for better photocatalytic action.

Conclusion

In summary, this paper presents an overview of the optoelectronic of Ti thin film deposited by PLD technique on Si substrate and its prospects as a photocatalytic agent when doped with platinum for various contents: 0.1, 0.2, 0.3 and 0.4%. It is found that only 0.2% and 0.3% Pt doped samples exhibit photocatalytic

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