



Optoelectronic Properties of Platinum Doped TiO₂/Si Structures for Photocatalysis

M. Kassmi^{1*}, R. Samti², A. Hajjaji¹, W. Dimassi¹ and M. Amlouk³

¹Centre de Recherche et des Technologies de l'Energie, Tunisia

²Institut Préparatoire des Études Scientifiques et Techniques, IPEST la Marsa, Université Tunis Carthage, Tunisia

³Laboratoire de Nanomatériaux, Nanotechnologie et Energie (L2NE), Faculté des Sciences de Tunis, Université de Tunis El Manar, Tunisia

*Corresponding Author: M Kassmi, Centre de Recherche et des Technologies de l'Energie, Tunisia.

Received: February 20, 2022

Published: March 24, 2022

© All rights are reserved by M Kassmi, et al.

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 investigations, 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 TiO₂ films don't defile silicon wafer after an adequately long time of high temperature treatment. In any case, a thin passive layer of SiO₂ can create at the point of interaction TiO₂/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. TiO₂ 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 sensitive photo-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_{sc}), 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 TiO₂ 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 TiO₂: Pt-Si thin films are repotted in the figure 1. Note that the saturation current is the same in forward polarization for all of TiO₂ 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.

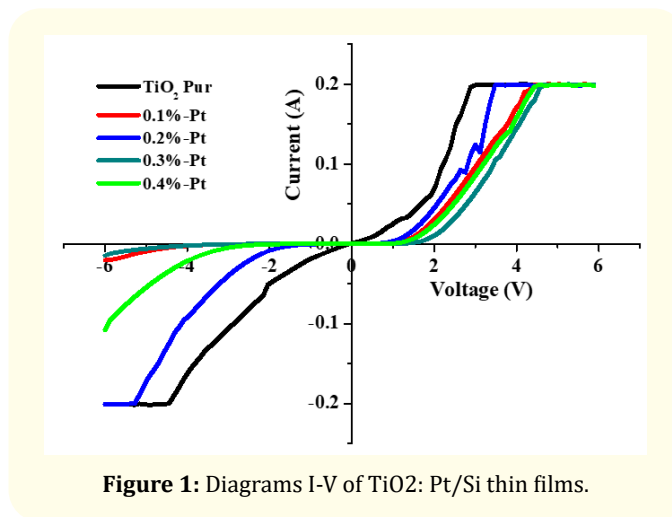


Figure 1: Diagrams I-V of TiO₂: Pt/Si thin films.

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 TiO₂.

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 amplified 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_i//C) in series with a resistance, represents the spillage resistance of TiO₂/Si interface, its ability is C. Besides, the resistance is identified with the conduction of TiO₂ layer toward the path normal to the interface.

to 0.3%. The resistance modeling the spillage of charge carriers through the potential of interfaces TiO₂/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 rutile. 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.

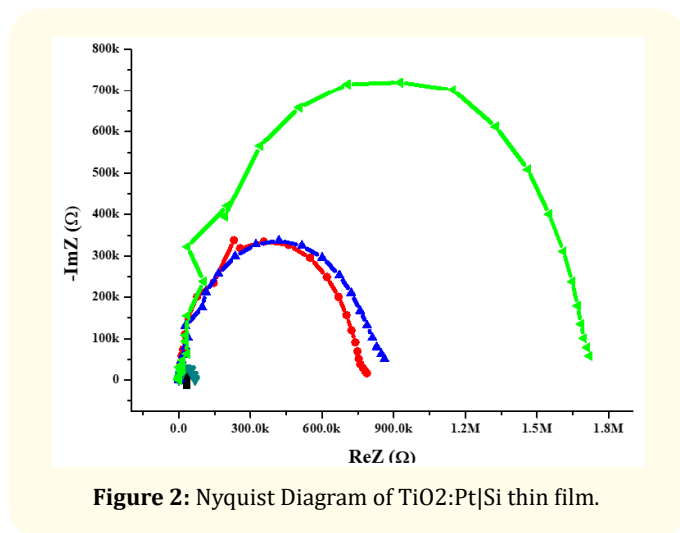


Figure 2: Nyquist Diagram of TiO₂:Pt/Si thin film.

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 TiO₂ 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

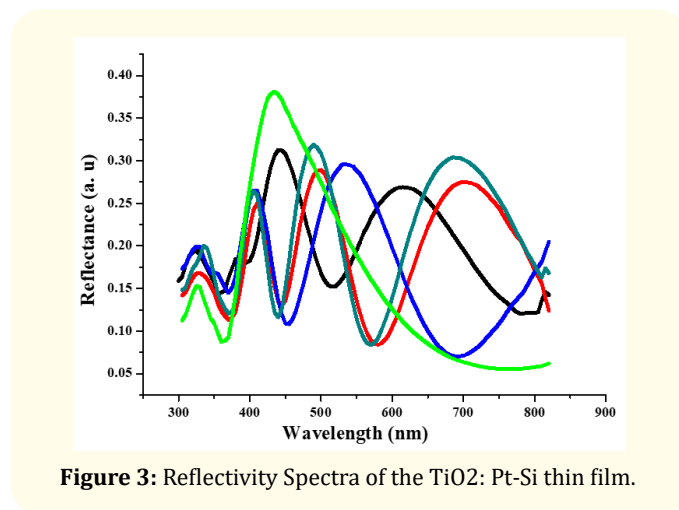


Figure 3: Reflectivity Spectra of the TiO₂: Pt-Si thin film.

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 $r \approx (N_{TiO_2} - N_{Si}) / (N_{TiO_2} + N_{Si})$ (in a similar case, $t \approx [(2N)_{TiO_2} / (N_{TiO_2} + N_{Si})]$ 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 TiO₂ 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 TiO₂ 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

the figure 4; that this current declines a ton for doped TiO₂ 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 TiO₂: 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.

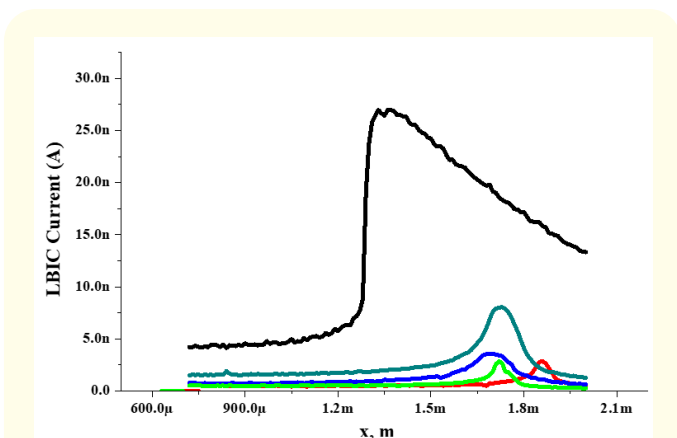


Figure 4: Light Beam Induced Current Diagrams (step = 100 μm).

the action of the Ti layer on the photocatalysis process.

To reinforce the optoelectronic investigations on Pt doped TiO₂/Si structures, it is well known that the carriers transport phenomenon at the interface between TiO₂ 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

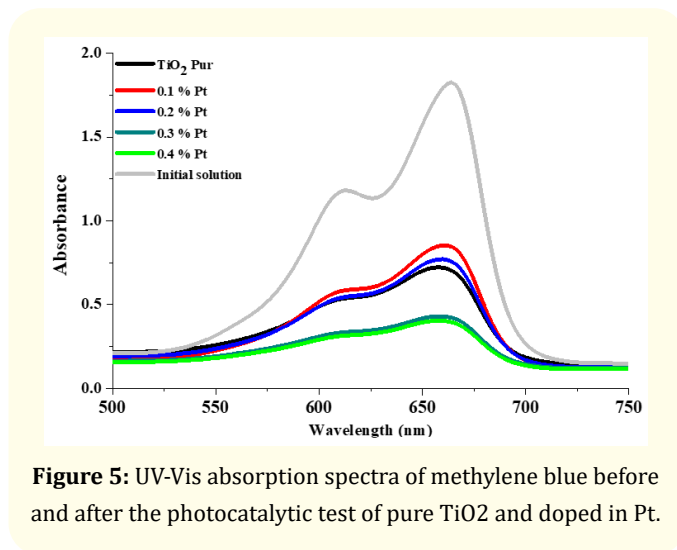


Figure 5: UV-Vis absorption spectra of methylene blue before and after the photocatalytic test of pure TiO₂ and doped in Pt.

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

Bibliography

- Nakata K and Fujishima A. "TiO₂ photocatalysis: Design and applications". *Journal of Photochemistry and Photobiology C: Photochemistry Reviews* 13.3 (2012): 169-189.
- Lan Y., *et al.* "Mini review on photocatalysis of titanium dioxide nanoparticles and their solar applications". *Nano Energy* 2.5 (2013): 1031-1045.
- Schneider J., *et al.* "Understanding TiO₂ photocatalysis: mechanisms and materials". *Chemical Reviews* 114.19 (2014): 9919-9986.
- Asahi R., *et al.* "Nitrogen-doped titanium dioxide as visible-light-sensitive photocatalyst: designs, developments, and prospects". *Chemical Reviews* 114.19 (2014): 9824-9852.
- Ma Y., *et al.* "Titanium dioxide-based nanomaterials for photocatalytic fuel generations". *Chemical Reviews* 114.19 (2014): 9987-10043.
- Kapilashrami M., *et al.* "Probing the optical property and electronic structure of TiO₂ nanomaterials for renewable energy applications". *Chemical Reviews* 114.19 (2014): 9662-9707.
- Wang X., *et al.* "One-dimensional titanium dioxide nanomaterials: nanowires, nanorods, and nanobelts". *Chemical Reviews* 114.19 (2014): 9346-9384.
- Pelaez M., *et al.* "A review on the visible light active titanium dioxide photocatalysts for environmental applications". *Applied Catalysis B: Environmental* 125 (2012): 331-349.
- Park H., *et al.* "Surface modification of TiO₂ photocatalyst for environmental applications". *Journal of Photochemistry and Photobiology C: Photochemistry Reviews* 15 (2013): 1-20.
- Zhang G., *et al.* "Visible light driven photocatalysis mediated via ligand-to-metal charge transfer (LMCT): an alternative approach to solar activation of titania". *Energy and Environmental Science* 7.3 (2014): 954-966.
- Etacheri V., *et al.* "Visible-light activation of TiO₂ photocatalysts: Advances in theory and experiments". *Journal of Photochemistry and Photobiology C: Photochemistry Reviews* 25 (2015): 1-29.
- Colmenares JC., *et al.* "Sustainable hybrid photocatalysts: titania immobilized on carbon materials derived from renewable and biodegradable resources". *Green Chemistry* 18.21 (2016): 5736-5750.
- Zhou W and Fu H. "Mesoporous TiO₂: preparation, doping, and as a composite for photocatalysis". *ChemCatChem* 5.4 (2013): 885-894.
- Gomes J., *et al.* "N-TiO₂ photocatalysts: a review of their characteristics and capacity for emerging contaminants removal". *Water* 11.2 (2019): 373.
- Richards BS., *et al.* "Novel uses of TiO₂/sub 2/in crystalline silicon solar cells". In: Conference Record of the Twenty-Eighth IEEE Photovoltaic Specialists Conference-2000 (Cat No 00CH37036): IEEE (2000): 375-378.
- Spurr RA and Myers H. "Quantitative analysis of anatase-rutile mixtures with an X-ray diffractometer". *Analytical Chemistry* 29.5 (1957): 760-762.
- Yasmina M., *et al.* "Treatment heterogeneous photocatalysis; factors influencing the photocatalytic degradation by TiO₂". *Energy Procedia* 50 (2014): 559-566.
- TITANIA PBO. "Study on the factors affecting photocatalytic behavior of titania coatings using different plasma spray process". *International Journal of Technical Research and Applications* 3.4 (2015): 255-265.
- Rahman M., *et al.* "Effect of dye on the performance of nitrogen doped TiO₂ solar cell prepared via ammonia treated liquid phase deposition technique". 17.1 (2014): 033-037.
- Gao C., *et al.* "Titanium dioxide coated zinc oxide nanostrawberry aggregates for dye-sensitized solar cell and self-powered UV-photodetector". *Journal of Power Sources* 239 (2013): 458-465.
- Zhang Z-L., *et al.* "Enhancement of perovskite solar cells efficiency using N-doped TiO₂ nanorod arrays as electron transfer layer". *Nanoscale Research Letters* 12.1 (2017): 1-7.
- Stefanov BI., *et al.* "Acetaldehyde adsorption and condensation on anatase TiO₂: Influence of acetaldehyde dimerization". *Journal of Molecular Catalysis A: Chemical* 381 (2014): 77-88.
- Topalian Z., *et al.* "Adsorption and photo-oxidation of acetaldehyde on TiO₂ and sulfate-modified TiO₂: Studies by in situ FTIR spectroscopy and micro-kinetic modelling". *Journal of Catalysis* 307 (2013): 265-274.

24. Stefanov B and Österlund LJC. "Tuning the photocatalytic activity of anatase TiO₂ thin films by modifying the preferred< 001> grain orientation with reactive DC magnetron sputtering". 4.3 (2014): 587-601.
25. Stefanov BI, *et al.* "Quantitative relation between photocatalytic activity and degree of< 001> orientation for anatase TiO₂ thin films". *Journal of - Materials Chemistry A* 3.33 (2015): 17369-17375.
26. Ma N, *et al.* "Integration of separation and photocatalysis using an inorganic membrane modified with Si-doped TiO₂ for water purification". *Journal of Membrane Science* 335.1-2 (2009): 58-67.
27. Jin C-Z, *et al.* "Visible photocatalysis of Cr (VI) at g/L level in Si/N-TiO₂ nanocrystals synthesized by one-step co-hydrolysis method". *Chemical Engineering Journal* 398 (2020): 125641.
28. Trabelsi K, *et al.* "Optoelectronic and photocatalytic properties of in situ platinum-doped TiO₂ films deposited by means of pulsed laser ablation technique". *Journal of Materials Science: Materials in Electronics* 28.4 (2017): 3317-3324.
29. Chen X and Mao SSJCr. "Titanium dioxide nanomaterials: synthesis, properties, modifications, and applications". *Chemical Reviews* 107.7 (2007): 2891-2959.
30. Wang K, *et al.* "Morphology-and crystalline composition-governed activity of titania-based photocatalysts: Overview and perspective". 9.12 (2019): 1054.

Assets from publication with us

- Prompt Acknowledgement after receiving the article
- Thorough Double blinded peer review
- Rapid Publication
- Issue of Publication Certificate
- High visibility of your Published work

Website: www.actascientific.com/

Submit Article: www.actascientific.com/submission.php

Email us: editor@actascientific.com

Contact us: +91 9182824667