ORIGINAL RESEARCH PAPER

# Effects of N Doping on Structure and Improvement Photocatalytic Properties of Anatase TiO<sub>2</sub> Nanoparticles

# F. Azizi, F. molani

Young researchers and elite club, Sanandaj branch, Islamic Azad University, Sanandaj, Iran.

# ARTICLE INFO.

Received 10/11/2015 Accepted 16/12/2015 Published online 01/01/2016

# KEYWORDS

MO decomposition N-doped TiO<sub>2</sub> nanoparticles Photocatalyst Sol-gel method

# ABSTRACT

In order to improve UV and visible lights photocatalytic activities of the pure anatase TiO<sub>2</sub>, a novel and efficient N-doped TiO<sub>2</sub> photocatalyst was prepared by sol-gel method. N-doped titania is prepared using triethylamine (with difference molar ratios) as the nitrogen source. The crystalline structure, morphology, particle size, absorbance and band-gap and chemical structure of N-doped TiO, was characterized by X-ray diffraction, diffuse reflectance spectra, scanning electron microscopy, energy dispersive spectrometry and Fourier transform infrared techniques, respectively. Results indicate that the doping of N, cause absorption edge shifts to the visible light region compare to the pure TiO<sub>2</sub>, reduces average size of the TiO<sub>2</sub> crystallites, enhances desired lattice distortion of Ti, promotes separation of photo-induced electron and hole pair, and thus improves pollutant decomposition under UV and visible lights irradiation. The photocatalytic activities of N-doped TiO, nanoparticles were evaluated using the photodegradation of methyl orange (MO) as probe reaction under the irradiation of UV and visible light and it was observed that the N-TiO, photocatalyst shows higher visible photocatalytic activity than the pure TiO<sub>2</sub>. The optimal N/TiO<sub>2</sub> concentration to obtain the highest photocatalytic activity was 2:1 of triethylamine

# **INTRODUCTION**

As one of the most promising photocatalysts for the degradation of organic pollutants,  $\text{TiO}_2$  has attracted significant attention and it has biologically and chemically inert, mechanically robust, nontoxic, cheap, environmental freindliness and therefore a perfect candidate for wide scale application with high efficiency [1-4]. However, TiO<sub>2</sub> nanoparticles due to the band-gap of 3.0 and 3.2 eV for rutile and anatase which requires near ultraviolet irradiation ( $\lambda$ <388 nm) which is about 3 % of the solar spectrum are excited by photons to produce electron-hole pairs for photocatalytic activation [1, 4-6]. It is commonly

\*Corresponding author Email address: Farshidazizi90@gmail.com Tel.: +98 9187846380 believed that anatase  $\text{TiO}_2$  has higher photocatalytic activity than rutile  $\text{TiO}_2$ . To improve the photocatalyst efficiency of  $\text{TiO}_2$ , it is necessary to reduce the bandgap by doping with a nonmetal atom has been introduced [4, 6]. Recently, many efforts have been made to modify titanium dioxide with nonmetals, such as nitrogen [7-9], carbon [10, 11], boron [12], sulfur [13], phosphorus [14, 15], fluorine [16], chlorine and bromine [17], iodine [18] to achieve enhanced visible light photocatalytic activities. Doping TiO<sub>2</sub> photocatalyst with a nonmetal element becomes a hot research topic and opens up new possibilities for development of photocatalytic materials with high photoinduced activity [1]. Nitrogen can be incorporated into the crystal lattice and more attractive among all of these anionic elements due to its comparable atomic size with oxygen, small ionization energy, metastable center formation, and stability [4, 19]. At present, N-doped TiO, has been prepared by various methods such as sputtering [7, 20], ion implantation [21], mechanochemical [22], plasma process [23, 24], chemical vapor deposition [23], solgel method [2, 25-27], oxidation of titanium nitride [28], sintering process [29], spray pyrolysis [30], electrospinning [31], infiltrating organic materials [32], precipitation method [33], wet chemical impregnation [34], hydrothermal and solvothermal methods [35] and sonochemistry [36-38]. Some organic compounds were used as nitrogen sources such as triethylamine [2], urea and ammonium [39-41], thiourea and hydrazine hydrate [2], N,N,N',N'-tetramethylethane-1,2diamine<sup>[4]</sup>, ethylenediamine<sup>[19]</sup>, nitric acid and ammonium nitrate [42].

In this work, nitrogen-doped nanocrystalline anatase  $TiO_2$  was successfully synthesized by sol-gel method. The photocatalytic performance of  $TiO_2$  nanoparticles was greatly enhanced due to the narrowed  $TiO_2$  bandgap by N doping. Organic compound was used as nitrogen source is triethylamine. At the same time, the catalytic activity of the N doped  $TiO_2$  catalyst is compared with that of pure anatase  $TiO_2$ . Then, photocatalytic activity of the N-doped catalyst was tested in removal of methyl orange dye under UV and visible light irradiation. Therefore, various factors affecting the photocatalytic degradation of the dyes were also discussed.

#### MATERIALS AND METHODS

The tetraisopropylorthotitanate (TTIP), acetic acid, ethanol and polyvinylpyrrolidone (PVP) were purchased from Merck and were used without any further purification. Deionized water was prepared by an ultra pure water system (Smart-2-Pure, TKA Co., Germany). Methyl orange (MO, M.W. = 695.58 g mol<sup>°°1</sup>) dye was provided by Alvan Co., Iran.

#### Synthesis of N-doped TiO, nanoparticles

The pure anatase  $\text{TiO}_2$  and the N-doped  $\text{TiO}_2$  used as photocatalyst were prepared by sol–gel method followed by annealing. TTIP was used as  $\text{TiO}_2$  source and triethylamine was used as N dopant, respectively, water as solvent and the acetic acid as catalyst were selected for preparation. The preparation process was as follows: TTIP, water and acetic acid with ration of 1:25:2 were mixed together and the mixed solution was stirred for 3.0 h. The pH of the mixture was adjusted to about 3.0 using acetic acid to prevent the formation of TiO<sub>2</sub> precipitates. After that, requisite amount of triethylamine (the molar ratio of N/TiO, is 0.1, 0.5, 1.0, 1.5, 2.0 and 2.5), deionized water, PVP and ethanol with ration of 10:1:1.5 were mixed together then added slowly to the mixed solution. The resultant solution was kept under continuous stirring to perform hydrolysis reaction for a further 2.0 h and under irradiation with a high intensity ultrasonic of 20 kHz in a sonication cell for 15 min, resulting in the formation of a transparent solution of TiO<sub>2</sub> sol. The prepared light-yellow solution was kept in the dark for nucleation process for 24.0 h. After this period, the gel was dried at 100 °C, and subsequently the catalyst was crushed into fine powder and calcined in a muffle furnace at 500 °C for 2.0 h. The nanosized N-doped TiO, powders were obtained after adequate rubbing.

# Characterization of photocatalysts

X-ray diffraction (XRD) patterns were recorded by a Philips-X'Pert Pro, X-ray diffractometer using Ni-filtered Cu K $\alpha$  radiation at scan range of 10 < 20 < 80. Scanning electron microscopy (SEM) images were obtained on LEO-1455VP equipped with an energy dispersive X-ray spectroscopy. The energy dispersive spectrometry (EDS) analysis was studied by XL30, Philips microscope. The diffused reflectance UV-visible spectrum (DRS) of the sample was recorded by an Ava Spec-2048TEC spectrometer. Fourier transform infrared spectroscopy (FT-IR) spectra of the samples were recorded on a Nicolet Magna IR 550 spectrometer, USA.

#### Photocatalytic decomposition of methyl orange

Photocatalytic activity of undoped and N-doped  $\text{TiO}_2$ nanoparticles were evaluated by the decomposition of MO solution in water under UV and visible light irradiation. In each experiment, the recyclable photocatalyst (0.1 g) was added into 100 mL of 11 mg/ L methyl orange aqueous solution (pH 2-3). The decomposition of MO was performed in a glass vessel with a diameter of 10 cm. A Xe lamp (500 W) was used as light source and hang perpendicularly above the vessel. A filtration glass that only allowed the wavelength >420 nm to pass through was placed above the vessel to get the visible light. The distance between the lamp and solution was around 30 cm. The solution was magnetically stirred before and during illumination and oxygen was bubbled into the suspension during illumination and oxygen was bubbled into the suspension during the photoreaction. The MO oxidation experiments were carried out in a Teflon cell equipped with a quartz window.

# **RESULTS AND DISCUSSION**

Fig. 1 shows the FT-IR spectra of pure TiO<sub>2</sub> and Ndoped TiO<sub>2</sub> powders calcined at 500 °C. The FT-IR spectrum of the N-doped TiO<sub>2</sub> catalyst showed a strong peak at 3000–3700 cm<sup>--1</sup> and narrow band at 1628 cm<sup>--1</sup> was assigned to the O-H stretching and H-O-H bending vibrations. The peaks observed in 1384, 1163 and 1019 cm<sup>-1</sup> are typical of N–O stretching and O–N– O bending vibrations, respectively [43, 44]. Additionally, the peak at 514 cm<sup>-1</sup> for N-doped TiO<sub>2</sub> resulted from Ti–O–Ti bending vibrations, being redshifted compared with the peak for TiO2 at 539 cm<sup>-1</sup> and 653–550 cm<sup>-1</sup> is ascribed to the Ti–O stretching vibration [36, 45].



Fig. 1. FT-IR spectra of  $TiO_2$  nanoparticles: (a) pure  $TiO_2$ , (b) N/TiO\_2 : 0.1, (c) N/TiO\_2 : 0.5, (d) N/TiO\_2 : 1.0, (e) N/TiO\_2 : 1.5 and (f) N/TiO\_2 : 2.0.

XRD patterns for pure TiO<sub>2</sub> and N-doped TiO<sub>2</sub> nanoparticles are shown in Fig. 2. In all the XRD patterns, TiO<sub>2</sub> anatase diffraction lines could be seen and no other crystal phase could be detected. It could also be seen from the XRD patterns that N-doped TiO<sub>2</sub> showed peak broadening compared with pure TiO<sub>2</sub>. Characteristic peaks of anatase ( $2\theta = 25.2$ , 37.76, 48.02, 54.05, 55.03, 62.80, 68.85, 70.19, and 75.07), were observed. This indicates that the supplied doped TiO<sub>2</sub> and undoped TiO<sub>2</sub> were anatase structure (JCPDS no. 36-1451). The average crystallite size of pure TiO<sub>2</sub> and N-doped TiO<sub>2</sub> were calculated using the Scherrer equation. Pure TiO<sub>2</sub> had a particle size of 10.3 nm; doped TiO<sub>2</sub>, about 7.6 nm. N-doped TiO<sub>2</sub> powders showed smaller size than pure  $\text{TiO}_2$  prepared at the same calcination temperature. In general, crystallite growth in  $\text{TiO}_2$  is considerably affected by the dopant [46]. This smaller crystallite size enhanced the photocatalytic activity of N-doped TiO<sub>2</sub> [5].



Fig. 2. XRD patterns of TiO<sub>2</sub> nanoparticles: (a) pure TiO<sub>2</sub>, (b) N/TiO<sub>2</sub> : 0.5, (c) N/TiO<sub>2</sub> : 1.0, (d) N/TiO<sub>2</sub> : 1.5, (e) N/TiO<sub>2</sub> : 2.0, and (f) N/TiO<sub>2</sub> : 2.5.

The surface morphology of the N-doped TiO<sub>2</sub> nanoparticles have been investigated by SEM, respectively, shown in Figs. 3. It is observed that the  $N/TiO_2$ : 2.0 sample is composed of large quantity of relatively uniform particles with diameter from 20 to 30 nm, which indicates sample could have good dispersion in solution. Further analysis also shows that these big particles are composed of small particles.



Fig. 3. SEM images of N/TiO<sub>2</sub> : 2.0 sample.

The EDS data of  $N/TiO_2$ : 2.0 sample (Fig. 4) shows a peak around 0.4 and 0.5 keV and another intense peak appears at 4.5 and 4.9 keV for Ti [47]. The peaks due to nitrogen and oxygen are clearly distinct at 0.3 and 0.6 keV, respectively. These results confirm that Ti, O, N exist in the catalyst structure.

Fig. 5a shows the DRS spectra of the undoped TiO,

and N-doped TiO<sub>2</sub> samples. The undoped TiO<sub>2</sub> is black in color and shows absorption only in the UV region. The N-doped TiO<sub>2</sub> samples are other color and their optical absorption was extended to the visible region. It is noted that the band-gap was expanded from 380 to 480 nm upon N doping. Noticeable shifts of the absorbance shoulder from a wavelength below 400 nm to the visible light region were observed for the Ndoped TiO<sub>2</sub>. The main absorption edges of the N-doped TiO<sub>2</sub> change significantly compared to that of the undoped sample. It is likely that nitrogen doping creates a new N 2p state slightly above the valence band top consists of O 2p state, and this pushes up the valence band top and leads to visible light response as a consequence [6].

In addition, the bandgap of the titania was determined from the Eq. (1)

$$\alpha h \nu = A (h \nu - E_q)^{\gamma} \tag{1}$$

where A is a constant, hí is the photon energy, Eg is the optical energy gap of the material and  $\tilde{a}$  is characteristic of the optical transition process, which is equal to 2.0 for an indirect allowed optical transition of an amorphous semiconductor. The bandgap of Ndoped TiO<sub>2</sub> has changed from 3.38 eV (undoped TiO<sub>2</sub>) to 3.26 for N/TiO<sub>2</sub> : 2.0 sample is shown in Fig. 5b. The first bandgap reflects the effect of N-doping on the main band edges of the oxide. The second gap, which is narrower than the original value, suggests that nitrogen doping contributed to the red shift of the bandgap [48]. Accordingly, it can be presumed that the N-doped TiO<sub>2</sub> sample may exhibit high photocatalytic activity under visible irradiation.



Fig. 4. EDS spectrum of N/TiO<sub>2</sub> : 2.0 sample.

The photocatalytic degradation of MO under UV and visible lights were measured for pure and doped TiO<sub>2</sub> samples. The results in Fig. 6 and tabulated in



**Fig. 5 (a)** Diffuse reflectance spectrum of pure  $\text{TiO}_2$  and N-doped  $\text{TiO}_2$  nanoparticles with the different molar ratio of nitrogen source and (b)The band-gap for samples pure  $\text{TiO}_2$  and N/TiO<sub>2</sub> : 2.0 sample.

Table 1 clearly show that under the irradiation of UV and visible, the photocatalytic performance of anatase  $TiO_2$  is greatly improved with the doping of N. Fig. 6 shows that N/TiO<sub>2</sub> : 2.0 sample higher activity than other samples under UV and visible irradiation. The higher photocatalytic activity of N-doped TiO<sub>2</sub> than undoped TiO<sub>2</sub> under UV and visible irradiation may be due to the substitution of nitrogen for oxygen atoms in the crystal structure of TiO<sub>2</sub> that improves the visible light sensitivity by introducing a mid-gap (N 2p) level, which formed slightly above the top of the (O 2p) valence band [49].



**Fig. 6.** Photodegradation of MO by pure  $\text{TiO}_2$  and N- $\text{TiO}_2$  with various N doping concentrations under UV (a) and visible (b) irradiation.

#### J. Nanostruct., 6(1): 55-60, Winter 2016

Photocatalyst type UV irradation time (min) 5 10 15 20 30 0 Pure TiO; 21.1 47.3 57.8 65.7 71.2 N/TiO<sub>2</sub>:0.1 23 5 50.4 0 36.5 58.7 70.8 74 6 N/TiO<sub>2</sub>:0.5 0 35.4 47.7 61 69.4 77.7 75.4 N/TiO<sub>2</sub>:1.0 0 25.1 43.3 57.0 66.8 74.0 80.1 55.8 78.6 84.0 N/TiO2:1.5 0 23.5 39.3 62.5 N/TiO<sub>2</sub>:2.0 31.2 65.8 76.7 83.1 0 49.1 872 N/TiO<sub>2</sub>: 2.5 27.5 38.8 57.8 69.1 9.0 81.1 visible irradation time (min) 30 60 90 0 120 180 240 52.4 22.8 41.2 Pure TiO<sub>2</sub> 0 6.2 14.1 29.3 N/TiO<sub>2</sub>:0.1 7.5 29.9 0 16.1 20.7 43.8 58.6 N/TiO<sub>2</sub>:0.5 9.2 15.8 33.7 0 27.2 52.6 67.3 N/TiO<sub>2</sub>:1.0 0 10.1 12.6 21.1 32.2 45.6 N/TiO2:1.5 0 12.0 20.7 33.9 43.2 59.8 70.0 13.5 N/TiO<sub>2</sub>:2.0 23.1 32.2 42.9 60.1 76.4 0 N/TiO<sub>2</sub>:2.5 2.2.3 36.4 45.6 0 10.062.2 72.0

 Table 1. Photocatalytic degradation of MO using pure TiO2 and N-TiO2 nanoparticles under UV and visible light irradiation.

#### CONCLUSION

The studied report that N-doped titania nanophotocatalyst with a spherical shape was prepared using triethylamine as the nitrogen source by the solgel method. The doping mechanism was explained by XRD, FT-IR, EDS, SEM and UV-visible absorption analyses. The photocatalytic performance of pure TiO<sub>2</sub> was greatly improved by the N-doping. The nitrogen doping had predominant effects on the improvement of the photocatalytic activity: on one hand, it could narrow the band-gap of titania to extend its absorption to the visible light region; on the other hand, it could increase the separation efficiency of the photoinduced electron and hole. The as-prepared N/TiO<sub>2</sub> : 2.0 sample shows a great potential as a catalyst for photocatalytic applications.

# ACKNOWLEDGEMENT

The financial support of this work by Research Council of Islamic Azad University of Sanandaj is gratefully acknowledged.

#### **CONFLICT OF INTEREST**

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

#### REFERENCES

- [1] T. Huang, S. Mao, J. Yu, Z. Wen, G. Lu, and J. Chen, RSC Advances, 3 (2013) 16657-16664.
- [2] Y. Cong, J. Zhang, F. Chen, and M. Anpo, The Journal of Physical Chemistry C, 111 (2007) 6976-6982.
- [3] A. Fujishima, T. N. Rao, and D. A. Tryk, Journal of Photochemistry and Photobiology C: Photochemistry Reviews, 1 (2000) 1-21.

- [4] M. J. Powell, C. W. Dunnill, and I. P. Parkin, Journal of Photochemistry and Photobiology A: Chemistry, 281 (2014) 27-34.
- [5] H. Wang, X. Yang, W. Xiong, and Z. Zhang, Research on Chemical Intermediates, 41 3981-3997.
- [6] P. He, J. Tao, X. Huang, and J. Xue, Journal of sol-gel science and technology, 68 (2013) 213-218.
- [7] R. Asahi, T. Morikawa, T. Ohwaki, K. Aoki, and Y. Taga, science, 293 (2001) 269-271.
- [8] M. Sathish, B. Viswanathan, R. Viswanath, and C. S. Gopinath, Chemistry of materials, 17 (2005) 6349-6353.
- [9] C. Burda, Y. Lou, X. Chen, A. C. Samia, J. Stout, and J. L. Gole, Nano letters, 3 (2003) 1049-1051.
- [10] S. Sakthivel and H. Kisch, Angewandte Chemie International Edition, 42 (2003) 4908-4911.
- [11] H. Irie, Y. Watanabe, and K. Hashimoto, Chemistry Letters, 32 (2003) 772-773.
- [12] S. In, A. Orlov, R. Berg, F. García, S. Pedrosa-Jimenez, M. S. Tikhov, et al., Journal of the American Chemical Society, 129 (2007) 13790-13791.
- [13] T. Umebayashi, T. Yamaki, H. Itoh, and K. Asai, Applied Physics Letters, 81 (2002) 454-456.
- [14] J. C. Yu, L. Zhang, Z. Zheng, and J. Zhao, Chemistry of Materials, 15 (2003) 2280-2286.
- [15] Q. Shi, D. Yang, Z. Jiang, and J. Li, Journal of Molecular Catalysis B: Enzymatic, 43 (2006) 44-48.
- [16] T. Yamaki, T. Sumita, and S. Yamamoto, Journal of materials science letters, 21 (2002) 33-35.
- [17] H. Luo, T. Takata, Y. Lee, J. Zhao, K. Domen, and Y. Yan, Chemistry of Materials, 16 (2004) 846-849.
- [18] Z. Wang, W. Cai, X. Hong, X. Zhao, F. Xu, and C. Cai, Applied Catalysis B: Environmental, 57 (2005) 223-231.
- [19] H. Li, Y. Hao, H. Lu, L. Liang, Y. Wang, J. Qiu, et al., Applied Surface Science, 344 (2015) 112-118.
- [20] Y. Nakano, T. Morikawa, T. Ohwaki, and Y. Taga, Applied Physics Letters, 86 (2005)
- [21] O. Diwald, T. L. Thompson, E. G. Goralski, S. D. Walck, and J. T. Yates, The Journal of Physical Chemistry B, 108 (2004) 52-57.
- [22] S. Yin, H. Yamaki, M. Komatsu, Q. Zhang, J. Wang, Q. Tang, et al., Journal of Materials Chemistry, 13 (2003) 2996-3001.
- [23] M. Maeda and T. Watanabe, Journal of the Electrochemical Society, 153 (2006) C186-C189.
- [24] C. Chen, H. Bai, S.-m. Chang, C. Chang, and W. Den, Journal of Nanoparticle Research, 9 (2007) 365-375.
- [25] S. Sakthivel, M. Janczarek, and H. Kisch, The Journal of Physical Chemistry B, 108 (2004) 19384-19387.
- [26] J. L. Gole, J. D. Stout, C. Burda, Y. Lou, and X. Chen, The journal of physical chemistry B, 108 (2004) 1230-1240.

- [27] Z. Lin, A. Orlov, R. M. Lambert, and M. C. Payne, The Journal of Physical Chemistry B, 109 (2005) 20948-20952.
- [28] T. Morikawa, R. Asahi, T. Ohwaki, K. Aoki, and Y. Taga, Japanese Journal of Applied Physics, 40 (2001) L561.
- [29] R. Nakamura, T. Tanaka, and Y. Nakato, The Journal of Physical Chemistry B, 108 (2004) 10617-10620.
- [30] H. Irie, Y. Watanabe, and K. Hashimoto, The Journal of Physical Chemistry B, 107 (2003) 5483-5486.
- [31] S. K. Choi, S. Kim, S. K. Lim, and H. Park, The Journal of Physical Chemistry C, 114 (2010) 16475-16480.
- [32] J. Chen, G. vonFreymann, SY Choi, V. Kitaev and GA Ozin, Adv. Mater, 18 (2006) 1915-1919.
- [33] Z. Xiong, L. L. Zhang, J. Ma, and X. Zhao, Chemical Communications, 46 (2010) 6099-6101.
- [34] W. Zhang, L. Zou, and L. Wang, Applied Catalysis A: General, 371 (2009) 1-9.
- [35] G. Halasi, I. Ugrai, and F. Solymosi, Journal of Catalysis, 281 (2011) 309-317.
- [36] N. Sharotri and D. Sud, Desalination and Water Treatment, (2015) 1-13.
- [37] D. Li, J. Wang, X. Li, and H. Liu, Materials Science in Semiconductor Processing, 15 (2012) 152-158.
- [38] H. Zhang, L. Sun, and Q. Sun, International Power, Electronics and Materials Engineering Conference, 2015.
- [39] J. Yuan, M. Chen, J. Shi, and W. Shangguan, International Journal of Hydrogen Energy, 31 (2006) 1326-1331.
- [40] Y. Yamamoto, S. Moribe, T. Ikoma, K. Akiyama, Q. Zhang, F. Saito, et al., Molecular Physics, 104 (2006) 1733-1737.
- [41] A. Khataee, M. Zarei, L. Moradkhannejhad, S. Nourie, and B. Vahid, Advanced Chemistry Letters, 1 (2013) 24-31.
- [42] T. C. Jagadale, S. P. Takale, R. S. Sonawane, H. M. Joshi, S. I. Patil, B. B. Kale, et al., The Journal of Physical Chemistry C, 112 (2008) 14595-14602.
- [43] Y.-F. Chen, C.-Y. Lee, M.-Y. Yeng, and H.-T. Chiu, Journal of crystal growth, 247 (2003) 363-370.
- [44] K. Di, Y. Zhu, X. Yang, and C. Li, Colloids and Surfaces A: Physicochemical and Engineering Aspects, 280 (2006) 71-75.
- [45] R. Kralchevska, M. Milanova, D. Hristov, A. Pintar, and D. Todorovsky, Materials Research Bulletin, 47 (2012) 2165-2177.
- [46] M. Hamadanian, A. S. Sarabi, A. M. Mehra, and V. Jabbari, Applied Surface Science, 257 (2011) 10639-10644.
- [47] M. Hamadanian, A. Reisi-Vanani, and A. Majedi, Materials Chemistry and Physics, 116 (2009) 376-382.
- [48] J. Ananpattarachai and P. Kajitvichyanukul, Journal of Environmental Science and Health, Part B, 50 (2015) 247-260.
- [49] A. Selvaraj, S. Sivakumar, A. Ramasamy, and V. Balasubramanian, Research on Chemical Intermediates, 39 (2013) 2287-2302

# AUTHOR (S) BIOSKETCHES

Azizi, F., M.Sc., Young researchers and elite club, Sanandaj branch, Islamic Azad University, Sanandaj, Iran. Email: Farshidazizi90@gmail.com

molani, F., Young researchers and elite club, Sanandaj branch, Islamic Azad University, Sanandaj, Iran. Email: f.molani@iausdj.ac.ir

#### How to cite this article:

Azizi F, molani F. Effects of N Doping on Structure and Improvement Photocatalytic Properties of Anatase TiO<sub>2</sub> Nanoparticles. J. Nanostruct. 2016; 6(1):55-60.

DOI: 10.7508/jns.2016.01.00\*

URL: http://jns.kashanu.ac.ir/article\_13645\_2332.html