European Journal of Molecular & Clinical Medicine
ISSN 2515-8260 Volume 07, Issue 07, 2020

An Overview On Structural, Morphological And Optical Properties Of Titanium–Dioxide Nanoparticles

Ansh Gupta[1], Ankush Thakur[2]

[2]*Department of Physics, Lovely Professional University, Phagwara, India*

Abstract: This review reports the major characteristics associated with titanium–dioxide nanoparticles for different methodology. Titanium dioxide has drawn attention worldwide for large scale manufacturing due to its properties along with nontoxic behavior for various applications. Titanium dioxide is considered as suitable for materials for pollution degradation and helps to promote the rate of photosynthesis. Structural properties were discussed with help of X-ray diffraction that helps to investigate physical characteristics. The estimated crystallite size found to be increase with increase in temperature. Morphological analysis was done with the help of scanning electron microscopy and transmission electron microscopy. The morphological behavior shows the formation of homogeneous spherical nanoparticles and agglomeration obtained for sample calcinated at higher temperature.

Keywords: TiO_2 nanoparticles, XRD, SEM, TEM

1. INTRODUCTION

Today's generation is surrounded by a large number of problems such as air pollution, water pollution, water treatment, energy crises and much more. From decades ago large numbers of solutions were proposed and executed in order to tackle problems but none of them was such efficient enough to minimize the problems. Scientists looked at a large number of materials either naturally existing or synthesized in laboratories to reduce environmental issues and energy crises such ZnO, SnO, graphene oxide, and various oxide materials. Titanium dioxide (TiO_2) nanoparticles were found to be more efficient and then highly researched topic owing to its properties [1-4]. During the development of nanotechnology it was observed that at nanoscale, properties analysis and their alterations can be precisely performed in a controlled manner. In this prospective, researchers decided to synthesize nanoparticles of TiO_2 for desired properties and take the advantage of titanium dioxide properties at commercial level. Nanorods, nanotubes and nanowires are some of the known morphologies in which TiO_2 can be obtained under controlled manner in laboratory [5]. There are large number of synthesis method available in laboratories such as hydrothermal method, chemical vapor deposition technique, microwave heat treatment method, solvothermal method, sol-gel technique out of which sol-gel is most convenient, affordable and controllable method for synthesizing TiO_2 nanoparticles [5,6]. It was known from the past that TiO_2 exists in many phases and among them anatase and rutile are well explored phases because of their stability to retain their unique properties for high temperature [6-9]. Therefore, a large number of products in a market contain TiO_2 as one of the important ingredients in it such as paints, food, solar cells, drug carriers, plastic, rubber, antibiotics, sunscreen and other cosmetics [10-13]. It is also observed that suitable dopant enhances its properties in every aspect from structural properties to catalytic which ultimately leads to material of interest to scientists [14-18]. In present research work discussed about the major characteristics associated with TiO_2 nanoparticles.

2. RESULTS AND DISCUSSION

E. P. Melian et al. [9] were used the sol-gel route for synthesizing TiO_2 nanoparticles where structural analysis reveals the crystalline nature of titanium dioxide nanoparticles. Diffraction peaks confirmed anatase phase at the temperature range 120-500 ^oC and rutile phase at the temperature range 600-700 ^oC. The estimated crystallite size for 120, 400, 500, 600, 650 and 700 ^oC were 5, 9, 14, 29, 34, 40 nm and 39, 45, 45 nm (rutile temperature range). Moreover, for hydrothermal treatment, the estimated crystallite size for 120, 400, 500, 600, 650 and 700 were 7, 9, 15, 33, 34, 36 nm and 39, 49, 50 nm (rutile temperature range). Morphological analysis of TiO_2 nanoparticles was done by transmission electron microscopy (TEM). TEM images bare the synthesize of TiO_2 nanoparticles via sol-gel method and hydrothermal treatment possess homogeneous spherical shape with estimated particle size 5-6 nm & 8-9 nm. Similarly, calcinated TiO_2 nanoparticles via sol-gel method and hydrothermal treatment possess 34-45 nm estimated diameter. The estimated band gap of TiO_2 nanoparticles were closed to commercial band gap 3.09 eV. M. Boutinguiza et al. [10] were investigated the laser ablation technique for synthesizing TiO_2 nanoparticles. Results report the controlled morphology and crystallite size by laser parameter. The obtained particles were found to be the spherical in shape at nanometer regime. Estimated particle diameter of about 600 particles was ~ 13 nm. High resolution transmission electron microscopy images confirm the crystalline nature of prepared nanoparticles and confirmed formation of lattice fringes. Fast Fourier transform clears the formation of polycrystalline nanoparticles. M. M. El-Nahass et al. [11] were reported the sol-gel spin coating method for the preparation titanium-dioxides films. Electron diffraction pattern confirmed the formation of polycrystalline tetragonal system with lattice constant a=4.53 Å and c=2.92Å. XRD diffraction peak position corresponding to (210), (111), (002) and (210) diffraction planes confirm rutile phase of TiO_2 film. The estimated crystallite size was 19-46 nm using TEM data. The estimated direct and in-direct band gap was found to be 3.721 and 3.47 eV respectively. Q. Wang et al. [12] were discussed the effect of heat treatment for the synthesis of TiO_2 nanoparticles. Structural analysis confirms the crystalline nature with confirmed anatase phase for sample annealed at 450 ^oC and the estimated particle size using Scherrer formula for samples annealed at 450 ^oC were 11.8 nm. Morphological analysis of TiO_2 nanoparticles had done by scanning electron microscopy (SEM) and shows agglomeration for heat treated at 450 ^oC along with estimated particle size 5-15 nm whereas TiO_2 nanoparticles annealed at 550 ^oC possess spherical with estimated particle size 16-20 nm. XPS data revealed binding energy 464.34 eV & 458.59 eV and 464.38 eV & 458.63 eV corresponds to Ti $2p_{1/2}$ & Ti $2p_{3/2}$ when annealed at 450 ^oC and 550 ^oC. A. O. Araoyinbo et al. [13] were analyzed the prepared nanoparticles through sol-gel technique for samples at different pH 3, 7 and 8 calcined at different temperature. Crystalline nature of TiO_2 nanoparticles confirms the presence of anatase phase for heat treatment at 350 ^oC. Although, sample calcined at 750 ^oC showed rutile phase in crystal where as intermediate calcinations (550 ^oC) reveals the existence of anatase along with some percent of rutile phase. Morphological analysis illustrates the irregular morphology with estimated particle diameter 0.22 µm, 0.32 µm and 0.18 µm for pH 3, 7 and 8.

3. CONCLUSION

TiO_2 nanoparticles play an essential role in a wide range of applications such as sunscreen, paints and air purification that's why the rapid use of nanoparticles subjected in large-scale industrial production for technological benefits at low cost. Moreover, TiO_2 nanoparticles help in reducing the unwanted oxides from the environment to overcome indoor pollution which definitely improves health of living beings. TiO_2 features a wide bandgap which helps in improving efficiency of solar cells by embedding TiO_2 nanoparticles in it because this improves the electron conductivity during photocatalytic process in solar cells which can withstand at high temperature as well when continuously exposed to sunlight. Thus improvement in solar cell efficiency brings a revolutionary change in the utilization of renewable source of energy which ultimately helps in tackling energy crises in many developing and developed country.

REFERENCES

[1] M. A. Behnajady, H. Eskandarloo, N. Modirshahla, M. Shokri, "Investigation of the effect of sol–gel synthesis variables on structural and photocatalytic properties of TiO_2 nanoparticles", Desalination, **278** (2011), 10-17.

[2] Mukherjee, R., Lawes, G., & Nadgorny, B. (2014). Enhancement of high dielectric permittivity in CaCu3Ti4O12/RuO2 composites in the vicinity of the percolation threshold. Applied Physics Letters, *105*(7), 072901.

[3] Mukherjee, R., Huang, Z. F., & Nadgorny, B. (2014). Multiple percolation tunneling staircase in metal-semiconductor nanoparticle composites. Applied Physics Letters, *105*(17), 173104.

[4] Mishra, D., Mandal, B. P., Mukherjee, R., Naik, R., Lawes, G., & Nadgorny, B. (2013). Oxygen vacancy enhanced room temperature magnetism in Al-doped MgO nanoparticles. Applied Physics Letters, *102*(18), 182404.

[5] [5] B. K. Mutuma, G. N. Shao, W. D. Kim, H. T. Kim, "Sol–gel synthesis of mesoporous anatase–brookite and anatase–brookite–rutile TiO_2 nanoparticles and their photocatalytic properties", Journal of Colloid and Interface Science, **442** (2015), 1-7.

[6] [6] F. Loosli, L. Vitorazi, J.-F. Berret, S. Stoll, "Towards a better understanding on agglomeration mechanisms and thermodynamic properties of TiO_2 nanoparticles interacting with natural organic matter", Water Research, **80** (2015), 139-148.

[7] [7] D. G. Calatayud, M. Rodríguez, T. Jardiel, "Controlling the morphology of TiO_2 nanocrystals with different capping agents", Boletín de La Sociedad Española de Cerámica y Vidrio, **54** (2015), 159-65.

[8] [8] D. Zhao, Y. Yu, H. Long, Y. Cao, "Improved photocatalytic activity of self-assemble TiO_2 nanobelts with Au nanoparticles", Applied Surface Science, **315** (2014), 247-251.

[9] [9] Mukherjee, R. (2020). Electrical, thermal and elastic properties of methylammonium lead bromide single crystal. Bulletin of Materials Science, *43*(1), 1-5.

[10] [10] Mukherjee, R., Chuang, H. J., Koehler, M. R., Combs, N., Patchen, A., Zhou, Z. X., & Mandrus, D. (2017). Substitutional Electron and Hole Doping of WSe 2: Synthesis, Electrical Characterization, and Observation of Band-to-Band Tunneling. Physical Review Applied, *7*(3), 034011.

[11] [11] E. P. Melián, O. G. Díaz, J. M. D. Rodríguez, G. Colón, J. A. Navío, J. P. Peña, "Effect of hydrothermal treatment on structural and photocatalytic properties of TiO2 synthesized by sol–gel method", Applied Catalysis A: General, **411-412** (2012), 153–159.

[12] [12] M. Boutinguiza, B. R. Gonzalez, J. del Val, R. Comesaña, F. Lusquiños, J. Pou, "Production of TiO2 crystalline nanoparticles by laser ablation in ethanol", Applied Surface Science, **258** (2012), 9484–9486.
[13] [13] M. M. El-Nahass, M. H. Ali, A. El-Denglawey, "Structural and optical properties of nano-spin coated sol–gel porous TiO2 films", Transactions of Nonferrous Metals Society of China, **22** (2012), 3003–3011.
[14] [14] Q. Wang, X. Wei, J. Dai, J. Jiang, X. Huo, "Influence of annealing process on ferromagnetism of undoped TiO2 nanoparticles prepared by sol–gel method", Materials Science in Semiconductor Processing, **21** (2014), 111–115.
[15] [15] A. O. Araoyinbo, M. M. A. B. Abdullah, M. A. A. M. Salleh, N. N. A. Aziz, A. I. Azmi, "Phase study of titanium dioxide nanoparticle prepared via sol-gel process", IOP Conference Series: Materials Science and Engineering, **343** (2018), 012011.
[16] [16] Kumar, P., Khatri, T., Bawa, H., & Kaur, J. (2017, July). ZnO-Fe2O3 heterojunction for photocatalytic degradation of victoria blue dye. In *AIP Conference Proceedings* (Vol. 1860, No. 1, p. 020065). AIP Publishing LLC.
[17] [17] KUMAR, P., SAMIKSHA, S., & GILL, R. (2018). Carbon Monoxide Gas Sensor Based on Fe-ZnO Thin Film. *Asian Journal of Chemistry*, *30*(12), 2737-2742.
[18] [18] Thakur, A., Kumar, A., Kumar, P., Nguyen, V. H., Vo, D. V. N., Singh, H., ... & Kumar, D. (2020). Novel synthesis of advanced Cu capped Cu2O nanoparticles and their photo-catalytic activity for mineralization of aqueous dye molecules. *Materials Letters*, *276*, 128294.
[19] [19] Gill, R., Ghosh, S., Sharma, A., Kumar, D., Nguyen, V. H., Vo, D. V. N., ... & Kumar, P. (2020). Vertically aligned ZnO nanorods for photoelectrochemical water splitting application. *Materials Letters, 277,* 128295.