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Nanostructured Titanium Dioxide for Enhanced UV Protection and Sustainable Cleanliness on Glass Surfaces

Hariini Chandramohan [1] and Sethu Gunasekaran [2]

[1&2] Sophisticated Analytical Instrumentation Facility, St.Peter's Institute of Higher Education and Research, AVADI, Chennai, Tamil Nadu, India

Abstract: Novel materials for self-cleaning glass surfaces are being researched due to rising demand for environmentally friendly and self-cleaning glass surfaces. Titanium dioxide (TiO_2) nanoparticles have significant photocatalytic ability, making them a good fit for self-cleaning coatings on glass surfaces. The sol-gel synthesis is carried outsince the method allows for precise control of particle size and shape to formulate TiO_2 nanoparticles. The hydrolysis and condensation of titanium alkoxide precursors are followed by controlled heat treatment to yield TiO_2 nanoparticles. UV-Vis, FTIR-ATR, Particle size analysis, and SEM techniques were used to analyse the structural, morphological, and optical properties of the synthesised TiO_2 nanoparticles. The contact angle technique is used to assess the self-cleaning characteristics of nanoparticles and the results are compared with silica dioixide nanoparticles synthesised via the same sol gel route. By providing a sustainable method for preserving transparent surfaces, the present research has the potential to benefit a wide range of disciplines, including architecture, automobiles, and renewable energy.

Keywords: Self-cleaning surface, HydrophilicTiO_2, Contact angle of TiO_2 and SiO_2

1. Introduction

In today's nanotechnology dominion, Titanium dioxide nanoparticles have become the most recommended metal oxide nanoparticles in photo catalytic applications [1]. Fundamentally, titanium dioxide is a naturally occurring oxide of titanium with enhanced optical property, high stability and non-toxicity. Conventional surfaces lose their aesthetic appeal and functional efficiency as a result of accumulation of impurities. With the goal of developing materials that can automatically resist or shed hazardous chemicals, the idea of self-cleaning surfaces represents an important shift in materials research. The sol-gel method is a simple method that offers precise control over the synthesis of nanoparticles in the complex field of nanomaterial synthesis [2]. When applied to titanium dioxide, this method offers unique features that expand the uses of metal oxide nanoparticles by monitoring the changes in shape and size. Through the effective process of "sol-gel synthesis," a sol—a colloidal dispersion of nanoparticles—becomes a gel—a three-dimensional network of interconnected particles. For titanium dioxide nanoparticles, it involves the hydrolysis and condensation of titanium alkoxides, commonly titanium isopropoxide, in a solution. To obtain the finest crystalline nanoparticles, the gel that is produced is then subjected to thermal treatment. With its distinct photo catalytic abilities, titanium dioxide has emerged as an important metal oxide nanoparticle, especially when assessed by contact angle analysis. Wetting behaviour is the fundamental concept at the core of the contact angle method. The contact angle formed between a liquid droplet and a solid surface provides insights into the surface energy and wettability of the material [3]. It is necessary to calculate the band gap value of titanium dioxide nanoparticle as it plays a crucial role in determining the photo catalytic activity. Hence to determine the band gap value UV-Vis spectroscopic technique was employed. In order to confirm the presence of synthesised titanium dioxide nanoparticle FTIR ATR technique was employed. The average particle size of the titanium dioxide nanoparticles was calculated using particle size analyser and the morphological analysis was carried out using Scanning electron microscopic technique with EDAX analysis. The results obtained from the analysis techniques promises the nanoparticle formulation of titanium dioxide and its ability to be employed in self-cleaning applications.

2. Materials and Methods

Sol-gel technique is employed to synthesize uniform titanium dioxide nanoparticles. The chemical reagents utilized in the synthesis process were of analytical grade purity. Synthesis of titanium dioxide nanoparticles involves ethanol as a solvent, hydrochloric acid as a catalyst, and titanium tetra isopropoxide as a precursor material. Initially, Titanium tetra isopropoxide was mixed with HCl, ethanol and stirred for half an hour at room temperature [4]. 10ml of deionized water was added to the above mixture and stirred for 2 hours at room temperature. Finally, the solution was then dried and heated at 120°C for one hour to obtain fine titanium dioxide nanoparticles.

3. Results and Discussion

The Titanium dioxide nanoparticles is subjected to various characterization techniques and their structural, vibrational and self-cleaning properties are discussed below

3.1. Scanning electron Microscopy with EDAXanalysis

The Scanning Electron Microscopic (SEM) study results are shown in Figure 1. The titanium dioxide nanoparticles had an average size of 69.2 nm [5]. The comprehensive elemental analysis in figure 2 shows that the materials have notable weight percentages of titanium and oxygen. It is discovered that the percentages of purity weight for oxygen and titanium are 44.93% and 55.07%, respectively. Thus Scanning electron microscopy with EDAX analysis confirms the presence and average size of titanium dioxide nanoparticles at Nano level.

[Figure1SEMImage of Titanium dioxide Nanoparticles]
[Figure2EDAX of Titanium dioxide Nanoparticles]

3.2. Particle size Analysis

The result of the particle size analysis, to acalculate the poly dispersity index with the average size of the sample, is shown in Figure 3. It is found that titanium dioxide nanoparticles have an average size of 55.2 nm. Higher particle size measurements can also be attributed to particle agglomeration. The polydispersity index (PDI), which calculates the monodispersity of the sample, is found to be 0.05[6].

[Figure 3 Average size of Titanium dioxide Nanoparticles]

3.3. FTIR ATR Spectral Analysis

FTIR ATR Spectral analysis is carried out and the result is showcased in figure 4.The vibrational properties of Titanium dioxide were interpreted and peaks at 1594 cm−1 and 508 cm−1 correspond to Ti-O and Ti-OH modes of vibration [7]. Hence the FTIR ATR analysis confirms the presence of Titanium dioxide nanoparticles.

[Figure 4 FTIR ATR Spectrum of TiO_2 Nanoparticles]

3.4 UV-Vis Spectroscopy

Spectral analysis of the synthesised titanium dioxide nanoparticles were carried out in the UV-Visible region (200 to 700 nm) of the electromagnetic spectrum. The maximum absorption wavelength was found to be around 318 nm which falls in the visible region, and the cut off wavelength around 343nm [8]. The bandgap value

was obtained using the cut off wavelength value since titanium dioxide nanoparticles are efficient semiconductors. The estimated band gap energy using Planck's law was 3.6eV, which matches with the band gap of semiconductors according to W.Heitler's hypothesis. The maximal absorbance value is found to be 1.5, indicating substantial absorption. Thus from figure 5,UV-Vis analysis results reveal that titanium dioxide nanoparticles absorb UV light in the UV-A and UV-B regions and are capable of functioning as an opaque material to block UV light when adhered to the exterior of glass.
[Figure 5UV-Visible analysis of TiO_2 nanoparticles]

3.5 Contact angle Analysis

Contact angle measurements of titanium dioxide nanoparticles were carried and the results indicate the hydrophilic nature of titanium dioxide nanoparticles that possess a contact angle of less than 90 degrees [9]. The results were compared with silica dioxide nanoparticles synthesized via the same sol-gel method since its one of the major metal oxides used in glass industry. The results reveal the hydrophobic nature of silica dioxide and its contact angle of greater than 90 degrees [10]. On account of these results, it can be concluded that titanium dioxide has enhanced hydrophilic property over silica dioxide, making it a better material for self-cleaning applications.
[Figure 6 Contact angle analysis of TiO_2 nanoparticles]
[Figure 7 Contact angle analysis of SiO_2 nanoparticles]

4 Conclusions

Nanoparticles of Titanium dioxide are effectively synthesised by the sol-gel method. By using FTIR ATR technique, the vibrational properties of titanium dioxide nanoparticles are verified. The average particle size, which agglomerates over time and is roughly 55.2 nm, was determined using Particle size analysis. The aforementioned findings, such as the size and shape of the silica dioxide nanoparticles, are verified by scanning electron microscopy and complement results of other characterization methods. UV-Vis analysis results reveal that titanium dioxide nanoparticles arecapable of functioning as an opaque material to block UV light when adhered to the exterior of glass. Contact angle analysis reveals the hydrophilic nature compared to silica dioxide nanoparticles.The above discussion showcases that Titanium dioxide nanoparticles can act as an enhanced nanoparticle to provide self-cleaning in glass manufacturing.

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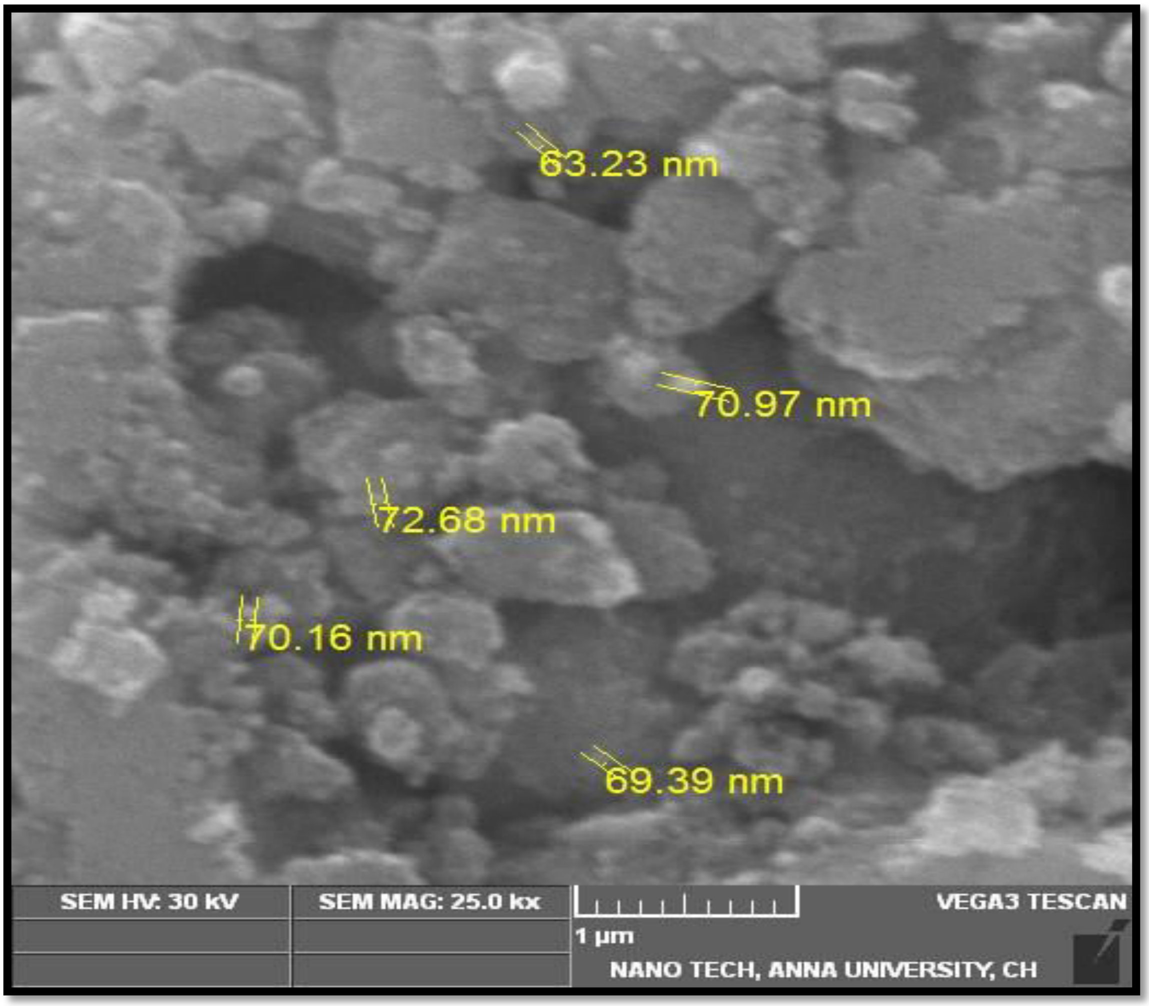

Figure 1 SEM Images of Titanium dioxide Nanoparticles

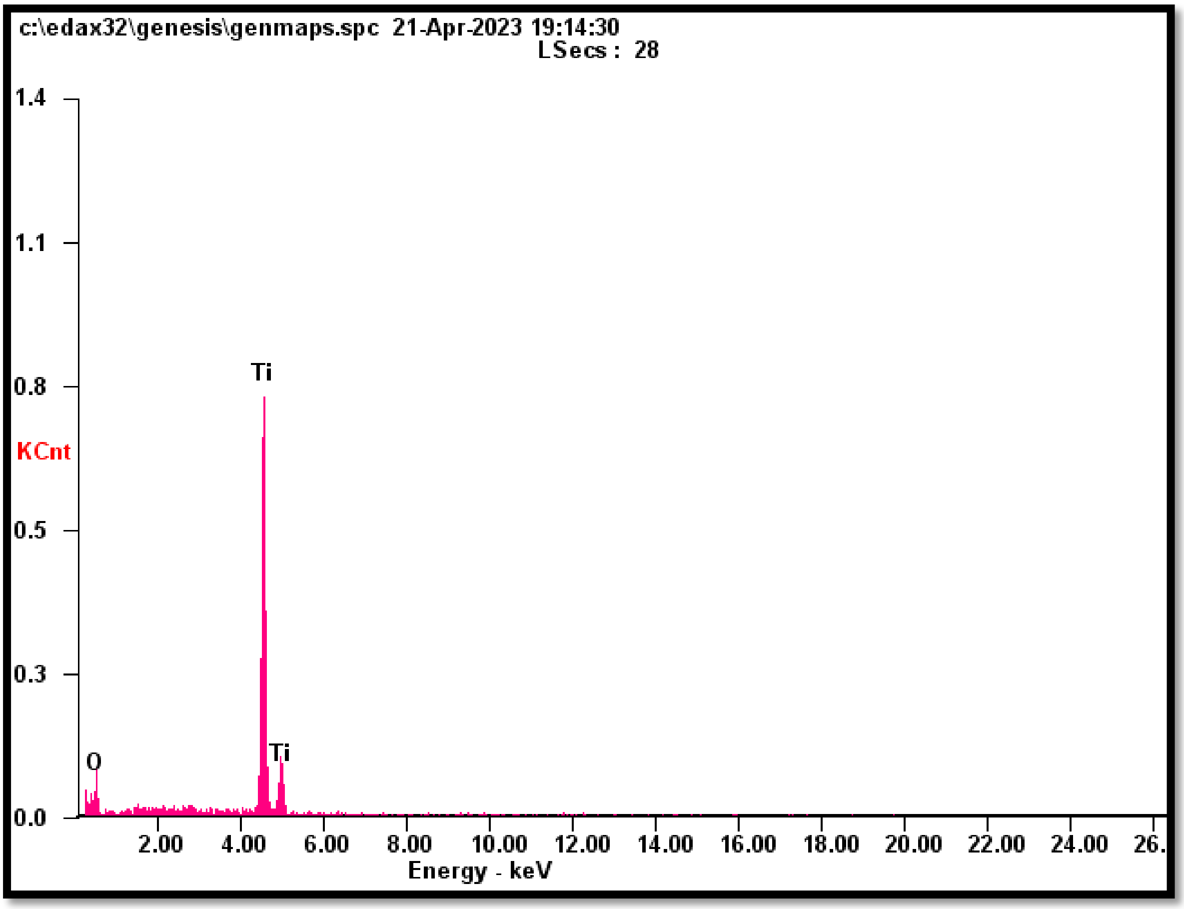

Figure 2 EDAX Image of Titanium dioxide Nanoparticles

Element	Wt%	At%
OK	44.93	70.96
TiK	55.07	29.04
Matrix	Correction	ZAF

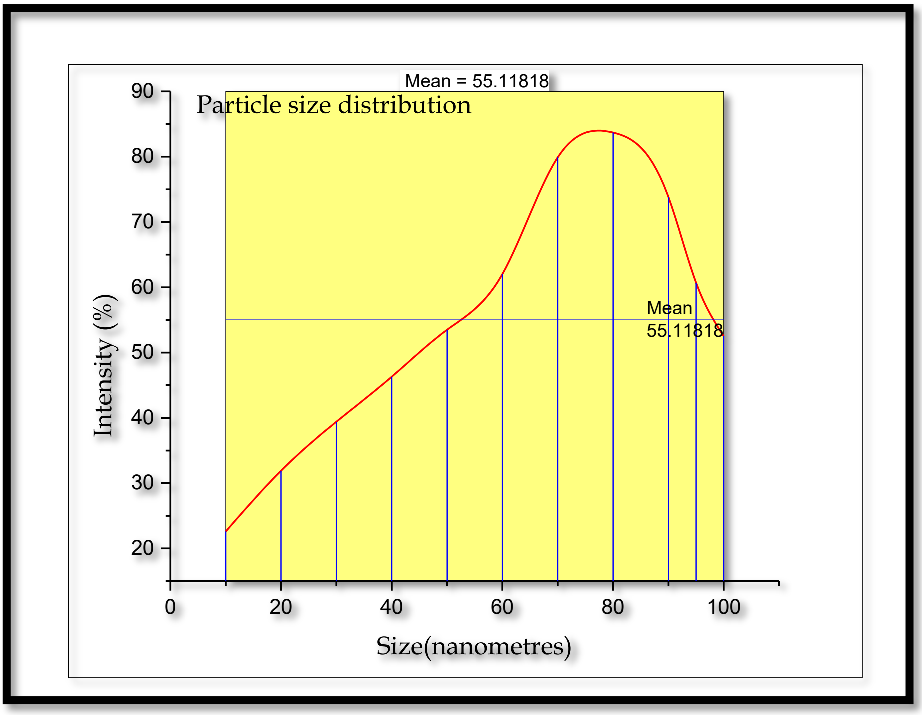

Figure 3: Average size of TiO_2 nanoparticles

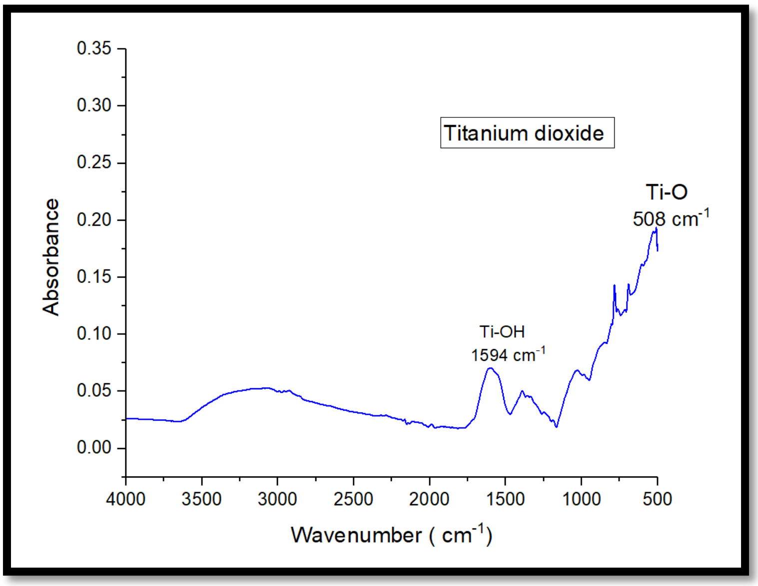

Figure 4 FTIR-ATR Spectrum of TiO_2 nanoparticles

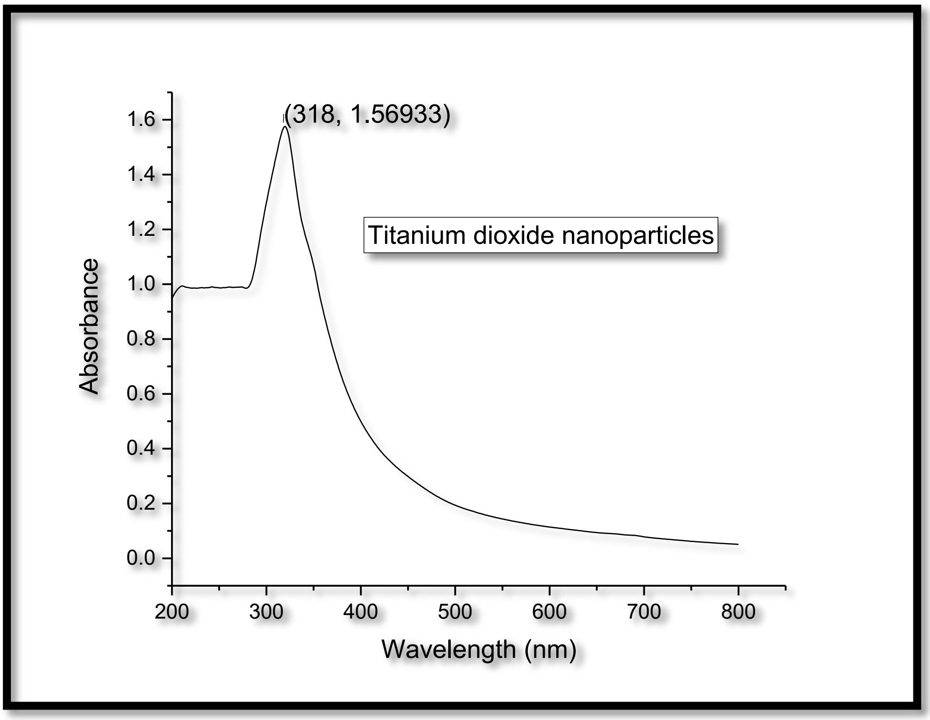

Figure 5 UV-Visible Spectrum of TiO_2 nanoparticles

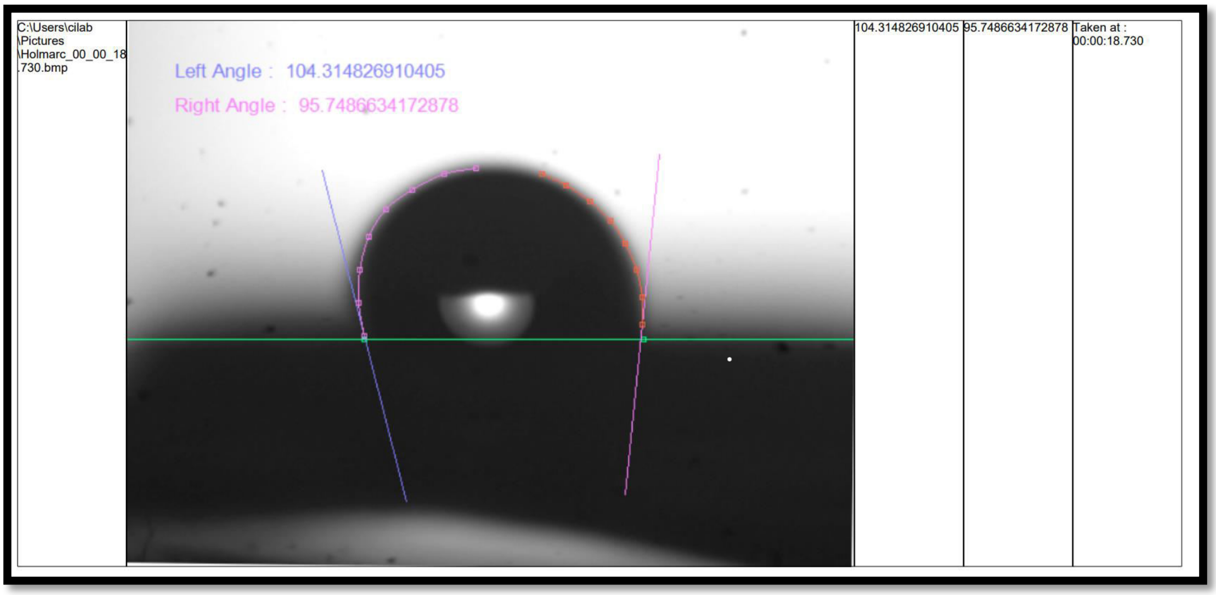

Figure 6 Contact angle analysis of TiO_2 nanoparticles

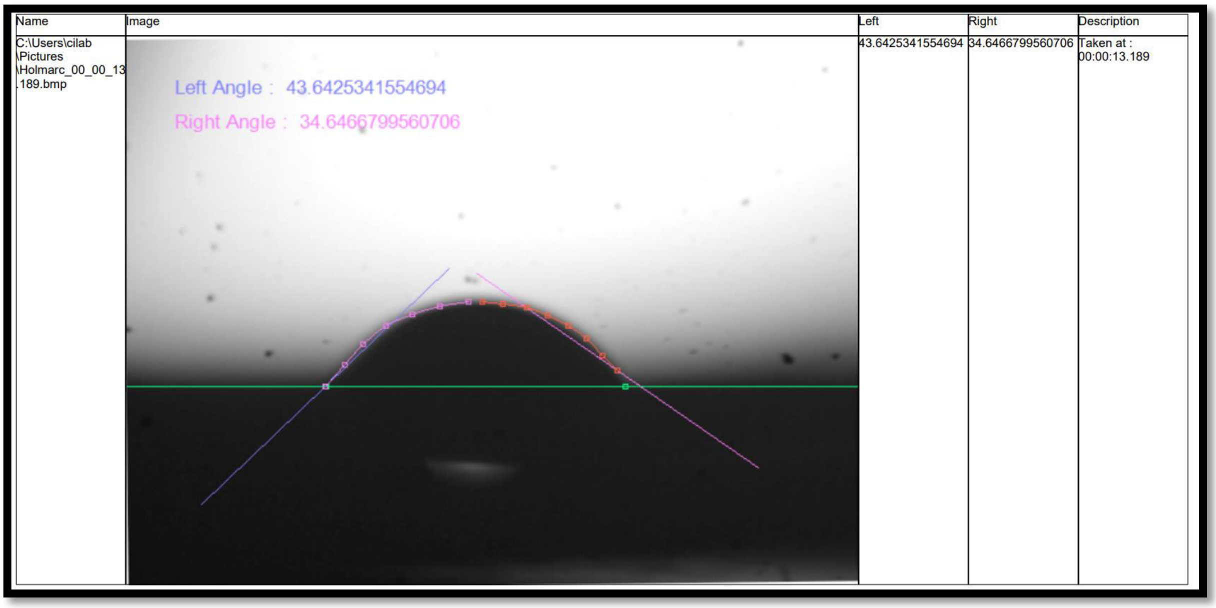

Figure 7 Contact angle analysis of TiO_2 nanoparticles