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Study of the Optical Property and Applications of TIO_2–SIO_2 Nano Composites in Textile

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Abstract: Nanocomposite consisting of Titanium dioxide (TiO_2) and silicon dioxide (SiO_2) was prepared by the wet chemical method. and their use in the photocatalytic process has been proposed as an alternative to the conventional TiO_2 catalysts(unique textural and structural properties). The prepared samples then characterized by X-ray diffraction, UV–Vis spectroscopy, Fourier transform infrared spectroscopy. TiO2 nanoparticles acquire complete crystalline anatase phase on thermal treatment of as-prepared anatase TiO2 at 450°C. The crystallite size of the as-synthesized samples was calculated by Scherrer's formula. And the nanocomposite used in the textile due to its unique and valuable properties. TiO_2 –SiO_2 nanocomposites makes textile to become anti bacterial and wrinkle resistance.

***Keywords*: Nanocomposites, Binary oxides, characterization, Co-precipitation**

I. INTRODUCTION

Nano crystalline TiO_2 has solicits continuous consideration due to its versatile applications in optical devices, sensors, catalysis and photocatalysis etc. Titania based materials are of great concequence for a wide variety of applications because of the interest in their specific physical and chemical properties. The nanocomposite materials (binary mixed oxides) has been widely prepared by coprecipitation method and recognized as one of the promising research area. The chemical properties of the titanium dioxide, in addition to its morphology, are intimately related to the crystallo graphic structure of the solid(e.g. rutile, anatase,brookite) TiO_2 nanoparticles acquire complete crystalline anatase phase on thermal treatment of as-prepared anatase TiO_2 at 450°C. Anatase-rutile mixed phase and rutile phase are achieved by annealing anatase TiO_2 at 700°C and 950°C respectively. [1,2]. By its nature ,crystal domain of nanometric size can be capture for the anatase peculiar, although crystal transition from anatase to rutile results in a enormous increase in crystal domain size [3], and consequently into an important decrease in accessible specific surface area(SSA).Thus, the physical properties of the rutile form of titania become hardly compatible with a use as catalyst support [4]. The use of the anatase form of titania is then most often reported in academic studies as catalyst support [5–7] although that the use o ftitania, either anatase or rutile form, remains limited for high temperature reactions. TiO_2 nanoparticles have large specific surface areas and high catalytic performance in which reactions take place on the TiO_2 surface. However, their effective monetary applications are counteracted by two serious disadvantages. Firstly, ultrafine powders will cluster into larger particles, appear in an adverse issue on catalyst performance. Secondly, the separation and recovery of TiO_2 powders from wastewater are difficult [8]. Thirdly, TiO_2 photocatalysis requires ultraviolet (UV) radiation whose energy exceeds the band gap of 3.2 eV (λ —380 nm) of the anatase crystalline phase, utilizing only a very small fraction of sunlight. Titania (TiO_2) based materials are of great interest for a wide variety of applications as air purification[10], self-cleaning surfaces[91 Therefore, several groups have investigated titania coating on high surface area supports such as silica or alumina [10]. Incorporation of SiO_2 into the TiO_2 would reduce the particle size, increase the specific surface area, and suppress the TiO_2 phase transformation from anatase to rutile [11]. The chemical properties of titanium dioxide with silica, are intimately related to the crystallographic structure (e.g. rutile, anatase, brookite) [12-13]. The anatase form of titania/silica (TiO_2-SiO_2) composite have received considerable attention due to their unique properties, such as stability, low thermal expansion coefficient, and high refractive index, which lead to their uses in a wide variety of applications as X-ray imaging, display monitors, laser, amplifiers for fiber–optic communication [14], non-toxicity, photocatalytic property [15], catalyst support [16-20], and optoelectronic devices etc. Many synthetic approaches have been employed to prepare TiO_2/SiO_2 binary oxides as Coprecipitation process has been proved to be an efficient method to prepare ultra-fine particles dispersed in different matrices.

II. EXPERIMENTAL

A. Synthesis of TiO_2 Nanoparticles

The solution of titanium (IV) isopropoxide $Ti(OC_3H_7)_4$ was added dropwise in isopropyl alcohol and stirred for 45 min. The metal oxide was produced by increasing the pH by dropwise addition of 1 N NH_3 solution. The resultant solution was stirred for 36 h and kept for 2 day aging. The solution was filtered after 2 days of aging in order to remove any particulates. The precipitate was washed several times with distilled water and dried in oven for 30 h to remove the solvent. Removal of residual and the stabilization of the materials were carried out by calcination for 4 h at 450°C .

B. Synthesis of SiO2 Nanoparticles

The solution of tetra-ethylorthosilicate Si(OC2H5)4 was added dropwise in isopropyl alcohol and stirred for 45 min. The metal oxide was produced by increasing the pH by dropwise addition of 1 N NH3 solution. The resultant solution was stirred for 36 h and kept for 2 day aging. The solution was filtered after 2 day of aging in order to remove any particulates. The precipitate was washed several times with distilled water and dried in oven for 30 h to remove the solvent. Removal of residual and the stabilization of the materials were carried out by calcination for 4 h at 450°C

C. Synthesis of TiO2/SiO2 Nanocomposites

The solution of titanium (IV) isopropoxide Ti(OC3H7)4 should be added dropwise in isopropyl alcohol and stirred. A solution of tetra-ethylorthosilicate Si(OC2H5)4 in isopropyl alcohol was added to the reaction medium and stirred for 45 min. The resultant solution was stirred for 36 h and kept for 2days aging. The solution was filtered after 2 days of aging in order to remove any particulates. The precipitate was washed several times with distilled water and dried in oven for 30 h to remove the solvent. Removal of residual organics and the stabilization of the materials were carried out by calcination for 4 h at 450°C.

III. CHARACTERIZATION

A. Xrd

The crystal structure of the powder was studied by powder X-ray diffraction In order to determine the crystallite size and lattice constant, XRD patterns of samples were recorded by using a Philips X-ray powder diffractometer PW/1710 having GIXRD geometry; with Ni filter, using monochromatic CuK radiation of wavelength 1.5418Å at 50KV and 40mA.. The average crystallite sizes of TiO2, SiO2 nanoparticles and TiO2/SiO2 nanocomposites were determined according to Scherrer's equation $D = 0.94\lambda/\beta \cos\theta$, where D is crystallite size, λ is wavelength, β is full width half maximum, and θ is angle of diffraction. The Fourier transform infrared spectra of the samples can be studied using Perkin–Elmer infrared spectrophotometer. The spectrum is recorded in the range of wavenumber 500–4,000 cm^{-1}. The UV–Vis spectra were obtained using UV–Vis–NIR spectrophotometer. The spectra were recorded at room temperature in the range 200–1,000 nm. In fig.1 XRD pattern of the as-synthesized (a) TiO2 nanoparticles, (b) SiO2 nanoparticles. While in Figure 2 XRD pattern of the TiO2/SiO2 nano composite has been shown.

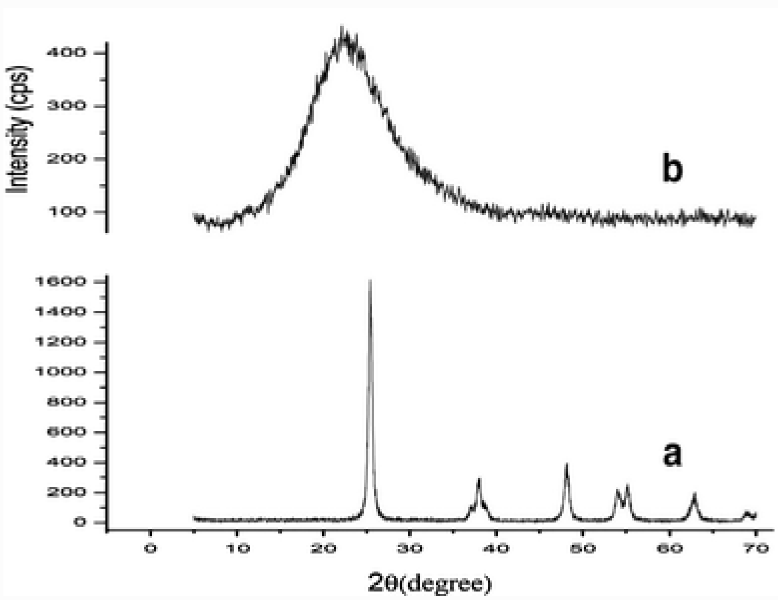

Figure 1 XRD pattern of the as-synthesized **(a)** TiO_2 nanoparticles, **(b)** SiO_2 nanoparticles.

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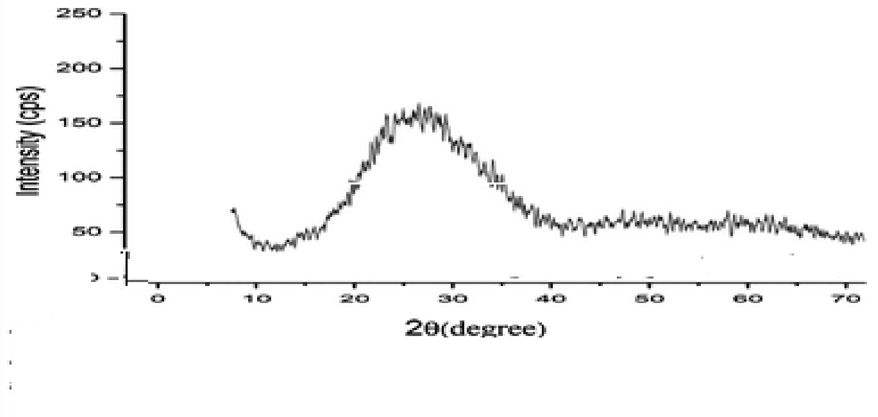

Figure 2 XRD pattern of the TiO_2/SiO_2 nano composite

Table 1 particle size and optical band gap of the as-synthesized samples

Sample	2θ (degree)	β (rad)	Crystallite size (nm)	E_g (eV)
TiO_2	25.38	0.029655	4.63	3.54
SiO_2	22.42	0.22239	0.64	3.85
TiO_2/SiO_2	25.48	0.281549	0.51	3.35

In table 1 B *is* Full width half maximum, θ angle of diffraction, E_g optical band gap

B. UV-Vis Spectrum

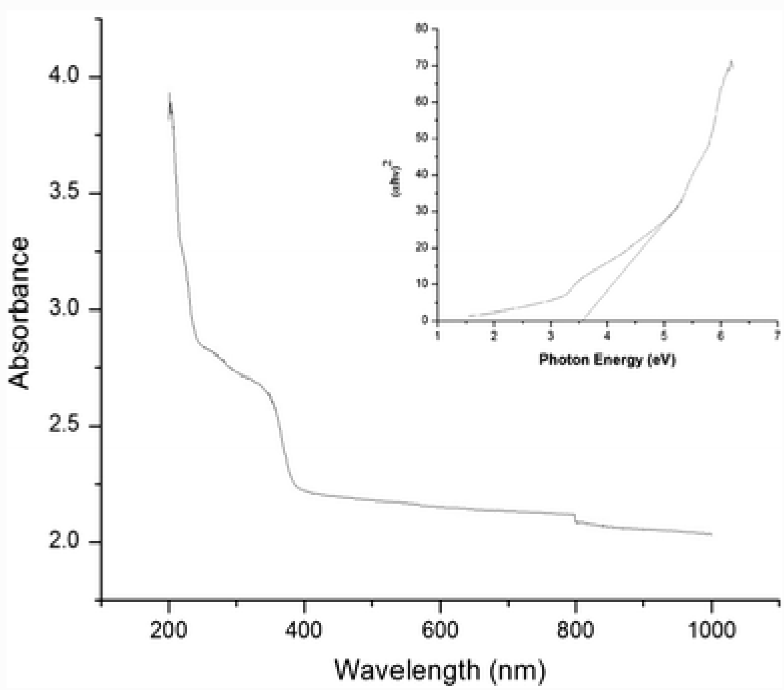

Figure 3. UV-Vis spectrum of the as-synthesized TiO_2 nanoparticles *inset* shows the corresponding plot of photon energy versus $(\alpha h\nu)^2$

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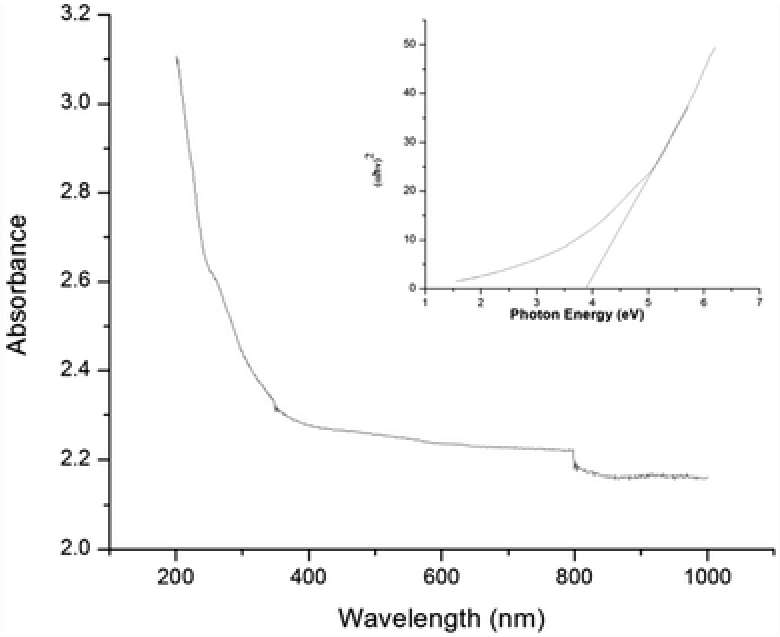

Figure 4 UV-Vis spectrum of the as-synthesized SiO_2 nanoparticles *inset* shows the corresponding plot of photon energy versus $(\alpha h\nu)^2$

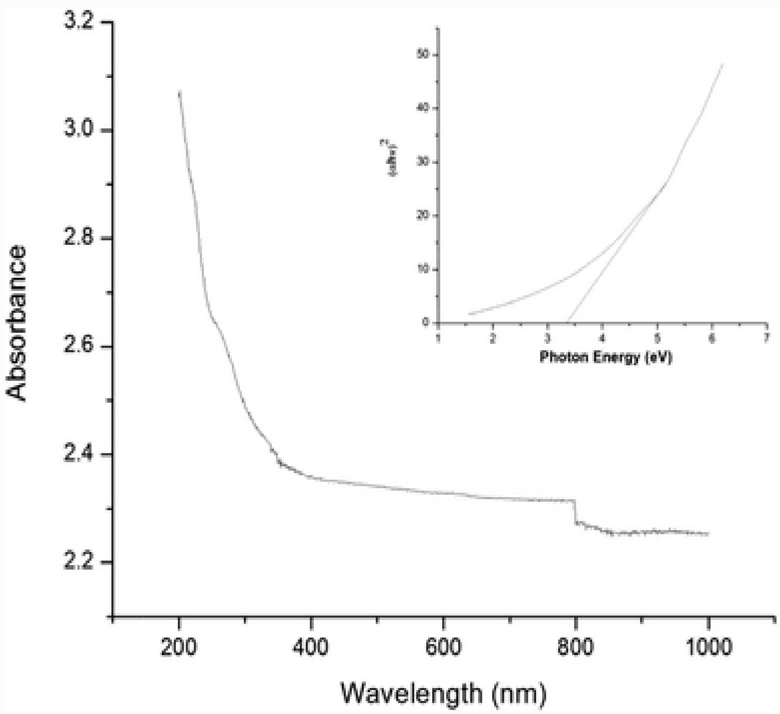

Figure 5 shows the UV-Vis spectrum of the as-prepared TiO_2/SiO_2 nanocompositeand while *inset* shows the corresponding plot of photon energy versus $(\alpha h\nu)^2$

UV–Vis absorption study should be carried out in order to characterize the optical absorbance of the sample. The absorption spectra of the as-synthesized titanium dioxide, silica dioxide(nanoparticles) and TiO2/SiO2 nanocomposite has been shown in Figs 3, 4, and fig. 5. The optical band gap may be calculated by plotting (αhν)2 versus photon energy (hν) based on the relation

$$\alpha h\nu = A(h\nu - E_g)^{n/2} \quad (1)$$

given in equation(1), where α is the absorption coefficient, A denotes a constant parameter, Eg is the band gap and n is the exponent, which is depending on quantum selection rule for a particular material. For a direct transition, n = 1. From the above relation, the intercept of the tangent on the photon energy axis reciprocate to optical band gap From the (αhν)2 versus photon energy (hν) plots, the optical band gaps Eg for all the three synthesized samples were estimated and tabulated in Table 1. Figure 6.shows the UV–Vis spectrum of the as-synthesized samples. All the three as-synthesized samples show similar absorption pattern in which the TiO2/SiO2 nanocomposite shows better absorbance in visible range compared to TiO2 and SiO2 nanoparticles

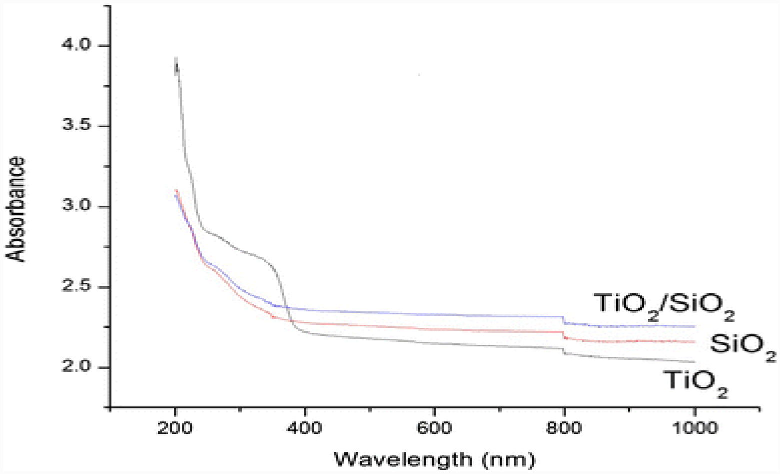

Figure 6 UV-Vis spectrum of the as-synthesized TiO_2, SiO_2 nanoparticles and TiO_2/SiO_2nanocomposite

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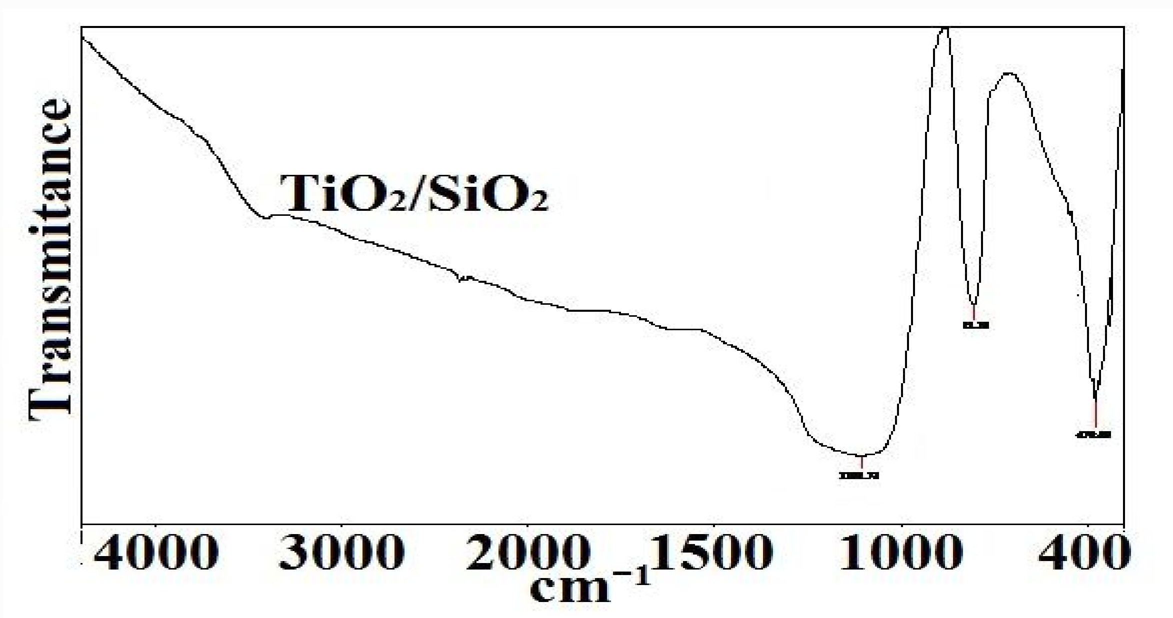

Figure 7. Shows FTIR for TiO2 and SiO2 nano composites.

Fig. 7 shows the FTIR spectrum of samples. Fourier transform infrared spectroscopy is a technique which enables us to identify the organic, inorganic materials and especially the presence of impurity phase in natural or synthesized materials. In Fig. 5 peak at 1647.45cm-1 corresponds to the bending vibration of the O-H of absorbed water. The peaks near 1098.87 cm-1 & 797.74 cm-1 correspond to asymmetric and symmetric vibrations of Si-O-Si linkage. The band at 470.09 cm-1 assigned to the Si-O-Si bending mode. The band at around 476.53 cm-1 can be attributed to the Ti-O and Si-O vibrations, implying the formation of TiO2 and SiO2

[16]. The peaks at 1103.73 cm-1 and 805.16 cm-1 attributes to the asymmetric and symmetric Si-O-Si stretching vibrations. A small peak related to Ti—O—Si linkages appeared at 960 cm−1 affirming the bonding betweenTi and Si.

IV. APPLICATIONS IN TEXTILES

A. *Anti-Bacterial And Wrinkle Resistance*

The antibacterial activity of titanium dioxide nanoparticles in textiles has been shown based on degrading organic materials by photocatalytic reaction. For imparting anti-bacterial properties, titanium dioxide is used.

Metallic ions and compounds can display a certain degree of sterilizing effect. It has been investigated that part of the oxygen in the air or water turned into active oxygen by process of catalysis with the metallic ion, thereby dissolving the organic substance, able to create a sterilizing effect [21]. By applying nano-sized particles, we can increase the particles density(per unit area), and by doing so anti-bacterial effects will be maximized. TiO_2 also acts as a photocatalyst, once it is illuminated by light having energy higher than its band gaps, the electrons in TiO_2 will jump from the valence band to the conduction band, and the electron (e-) and electric hole (h+) pairs will form on the surface of the photocatalyst. The electrons and oxygen combine into O2-, the holes and water will generate hydroxyl radicals. When the organic compound falls on the surface of the photocatalyst it will combine with O2$^-$ and OH- respectively(because of unstable chemical), and turn into carbon dioxide (CO_2) and water (H_2O). Such type of reaction is known as 'oxidation-reduction',[22]. The photocatalyst may become able to decompose common organic matters in the air such as odor molecules, bacteria, and viruses. We know that Resin is commonly used, to impart wrinkle resistance to a fabric in conventional methods. But this will transport a pratfall in the tensile strength of the fiber, abrasion resistance, water absorbency and dyeability, as well as breathability. To obtain better result TiO_2 [23, 24] and SiO_2 [25] nanoparticle can be used to improving the wrinkle resistance of cotton and silk respectively, in place of resin. TiO_2 can be antiquated with carboxylic acid concealed by UV irradiation, which is used to catalyze the cross-linking reaction between the cellulose molecule and the acid.

V. CONCLUSION

Nanocomposite Fig. 7 shows the FTIR spectrum of samples. Fourier transform infrared spectroscopy is a technique which enables us to identify the organic, inorganic materials and especially the presence of impurity phase in natural or synthesized materials. In Fig. 5 peak at 1647.45cm-1 corresponds to the bending vibration of the O-H of absorbed water. The peaks near 1098.87 cm-1 & 797.74 cm-1 correspond to asymmetric and symmetric vibrations of Si-O-Si linkage. The band at 470.09 cm-1 assigned to the Si-O-Si bending mode. The band at around 476.53 cm-1 can be attributed to the Ti-O and Si-O vibrations, implying the formation of TiO2 and SiO2 [16]. The peaks at 1103.73 cm-1 and 805.16 cm-1 attributes to the asymmetric and symmetric Si-O-Si stretching vibrations. A small peak related to Ti—O—Si linkages appeared at 960 cm−1 affirming the bonding betweenTi and Si.

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VII.CONCLUSION

Nanocomposite consisting of Titanium dioxide (TiO2) and silicon dioxide (SiO2) was prepared by the wet chemical method. From the XRD pattern and FTIR data, we are able to find that TiO2 nanoparticles gain complete crystalline anatase phase on thermal analysis at 450°C. Anatase-rutile mixed phase and rutile phase are achieved by annealing anatase TiO2 at 700°C and 950°C respectively. At angle (2 thetas) 25.38 the particle size is 4.63 while at an angle (2 thetas)25.48 the particle size becomes .51nm. TiO2 nano-particles also shows anti-bacterial activity in textiles. And also shows the wrinkle resistance activity in cotton and silk respectively. When TiO2 consolidate with silica matrix the band gap gets enhanced. Which makes it able to used in textile industries for strengthening the textile properties like the antibacterial and anti wrinkle.

VIII. ACKNOWLEDGEMENTS

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IX. ACKNOWLEDGEMENTS

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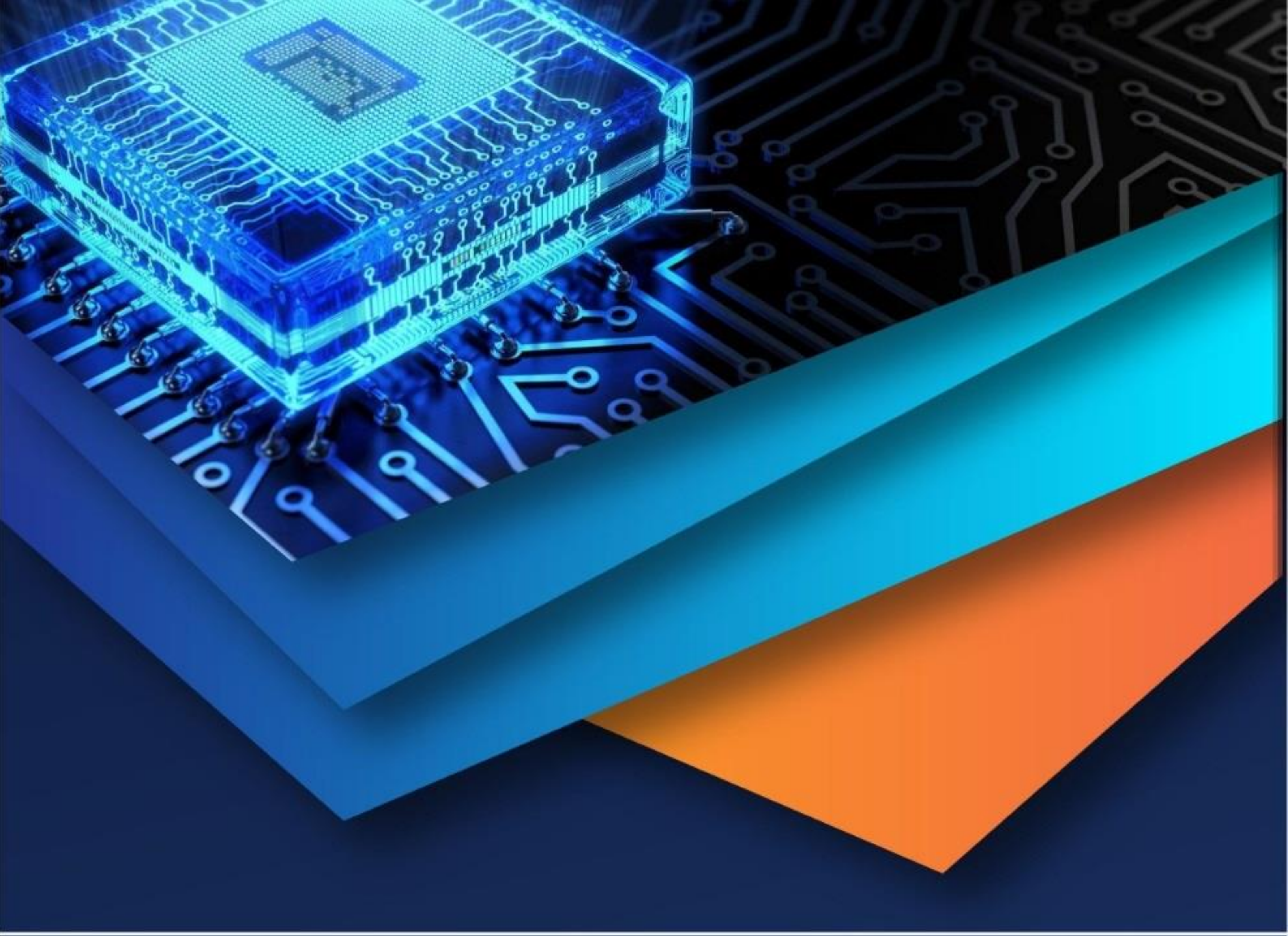

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