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Research Article

STUDIES ON PROPERTIES OF TITANIUM DIOXIDE BIOMATERIAL

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A B S T R A C T

Pure titanium dioxide (TiO_2) is a semiconductor, which means its electrical conductivity is very low. The properties of titanium dioxide such as electrical conductivity, absorption coefficient, refractive index, concentration, temperature and pH-values were measured based on diffusion techniques. Absorption coefficient decreases with increasing the thickness of the titanium dioxide. As increasing the thickness of titanium dioxide decreases the intensity of gamma radiation. The absorption coefficient depend upon the absorbing material and the intensity of the radiation. Higher the absorption coefficient was enviable where the material covers soft tissue. A small absorption coefficient specify that the material was relatively transparent. The pH-values of sample does not depend on concentration of the titanium dioxide. It indicate that antacid potential present, which will be caused by biological infective resistance to human beings. The temperature of the samples increases conductivity also increases gradually. The concentration of the sample increases conductivity also decreases. The diffusion technique enables the measurement of the electrical properties of liquids. This biological effect was more significant for pharmacitical applications. By varying the film deposition and annealing conditions titanium dioxide refractive index changes with wavelength. The variations in refractive index that reduces the refractive of a surface treated with an anti-reflective coating.

INTRODUCTION

Titanium dioxide (TiO_2) is the most abundant element in the earth's crust. It is the most important white pigment currently produced commercially. Pure titanium dioxide is a colourless crystalline solid. As with other d-block elements in its group of the Periodic Table, TiO_2 is stable, non-volatile and largely insoluble [1]. Titanium dioxide pigments have extremely high refractive indices, whiteness and high reflectance in the visible region of light. Titanium dioxide is the most stable white pigment due to its stability, titanium dioxide is non-toxic and considered to be a very safe material. The most essential property of white pigment is its ability to opacify and whiten the medium in which it is dispersed. The opacifying potential is controlled by two properties, refractive index and particle size. Refractive index is not a fixed property but varies with the wavelength of light.

The electrical conductivity of a water solution is a measure of how much material is dissolved in the water. Electrical conductivity is an important for electrochemical water quality parameter.

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The electrical conductivity can be expressed as Siemens per centimeter (S/cm) measured between the opposing faces of 1cm cube of liquid at a specific temperature. The charge on ions in solution facilitates the conductance of electrical current and the conductivity of the solution is proportional to its on concentration. The conductivity depends on the value of the pH, concentration of ions and the temperature. Chemical composition of the sample water determines its conductivity [2].

A Biomaterial is any substance that has been engineered to interact with biological systems for a medical purpose either a therapeutic (treat, augment, repair or replace a tissue function of the body) or a diagnostic one. As a science, biomaterials are about fifty years old. The study of biomaterials is called biomaterials science (or) biomaterials engineering. It has experienced steady and strong growth over its history with many companies investing large amounts of money into the development of new products. Biomaterials science encompasses elements of medicine, biology, chemistry, tissue engineering and materials science. A restoration is a material which substitutes the missing tooth structure and restores the form and function of the tooth. Temporary restorations are often required before the placement of a permanent restoration. Materials used for temporary restorations are expected to last for only a short period of time. They serve as an interim restoration, till the permanent restoration can be fabricated and inserted. Materials that are used for biomedical or clinical applications are known as biomaterials. Biomaterial can be derived either from nature or synthesized in the laboratory using a variety of chemical approaches utilizing metalic components, polymers, ceramics or composite materials. They are often used and adapted for a medical application and thus comprises whole or part of a living, structure or medical or biomedical device which performs replace a natural function. Such functions may be relatively passive, like being used for bioactive with a more interactive functionality such as hydroxyl-apatite coated hip implants. Biomaterials are also used every day in dental applications surgery and drug delivery. The study of absorption coefficient of biomaterials has been an important part of research work in science. Hubbell has compiled an extensive data on absorption coefficients of gamma rays in some compound in the energy range of 1 keV to 20 MeV [3][4].

Titanium dioxide biomaterial exists in three primary phase anatase, rutile, and brookite with different sizes of crystal cells in each case [5]. The popularity of titanium dioxide in materials sciences began with the first photo catalytic splitting of water in 1972 [6]. In recent years TiO_2 has been used widely for the preparation of different types of nanomaterials, including nanoparticles, nanorods, nanowires, nanotubes, and mesoporous. Nano - anatase TiO_2 which is smaller than 20 nm, has surface corner defects that alter the size of the crystal cell [7]. Due to its unique properties, nanosized titanium dioxide represents a promising research subject for various modern fields of science and technology, including microbiology, nanobiotechnology and fundamental medicine. Thus the most popular directions include the design of a new generation of drugs based on synthetic nanobioconstructs containing TiO_2 nanoparticles and aimed at curing cancer and viral or genetic diseases. The necessity of developing new approaches to fight against these diseases is associated with the limitations inherent in conventional methods of therapy and profilaxis. Thus for viral infections, the therapy efficacy tends to decrease due to permanent mutation of viruses.

The calculated intensity *I* of transmitted through a layer of material with thickness *x* and the incident intensity I_0 according to the inverse exponential power law that is usually referred to as Beer-Lambert's law: $I(x) = I_0 \, e^{-\mu x}$

Where, μ denoted absorption coefficient, *x* is the thickness of the material. The absorption factor of a material is obtained by the ratio of the emergent and incident radiation intensities $\frac{I}{I_0}$

In this investigation authors offered diffusion technique that can be employed for the dimensions of the electrical conductivity, absorption coefficient, concentration, refractive index and pH-values of titanium dioxide.

MATERIALS AND METHODS

Collection of sample

Titanium dioxide was collected from company: MOLYCHEM, BATCH NO. MCR-13643. Titanium dioxide particle size about 0.13nm.

Preparation of Sample

The TiO_2 biomaterial was mixed and handled according to manufacturers' directions. Three cylindrical specimens 13mm diameter and 1.6 mm thick of each material were prepared in a mold and pressed between two microscope glass slides. The titanium dioxide material was made in the form of pellet. Pellets of TiO_2 were shown in Figure 1.

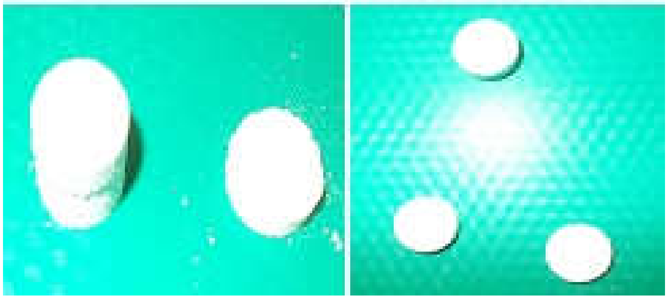

Fig 1 Pellets of titanium dioxide (TiO_2)

Experimental methods

Resistance and current is measured by using Kithely-2700 Model. Conductivity is measured with a probe and a meter. A voltage is applied between the two electrodes in the probe immersed in the sample water. The drop in voltage caused by the resistance of the water is used to calculate the conductivity per centimetre. The conductivity (C) is the inverse of resistivity (R) is determined from the voltage (V) and current (I) values according to Ohm's law. The units of conductivity are Siemen per centimeter (S/cm).

$$V = IR \, , C = \frac{1}{R} = \frac{I}{V} \; (mho) \qquad \text{-------------(1)}$$

The standard connections and arrangement was made between Geigur-Muller (G.M) Counting System, detector and source. Experimental arrangement of G.M.counting system was shown in Figure 2. Place a gamma (γ) source cobalt-60 in the source tray at about 2 cm from the end window of the G.M tube. Set the G.M voltage at the operating voltage (625V) of the GM tube. Place the absorber between end window detector and source holder containing absorbers of respective thickness. We took the reading for the period of 60 sec without any absorber and tabulated the experiment by recording the data stored for different thickness in the increasing order for the same period of 60 sec. Repeat the same steps as explained above for next absorber sets of titanium dioxide biomaterial. The intensity of γ-rays passing through a medium is given by

$$I(x) = I_0 \, e^{-\mu x} \qquad \text{----------------(2)}$$

I_0 = original intensity of beam (without an absorber), I = intensity through absorber of thickness x, μ= absorption coefficient of the medium (cm^{-1}). Refractive index was measured based on spectroscopic technique.

Fig 2 Experimental arrangement of G.M.Counting System

RESULTS

Absorption coefficient of titanium dioxide nanocomposites were shown in Table 1. Absorption coefficient decreases with increasing the thickness of the titanium dioxide were shown in Figure 3. As increasing the thickness of titanium dioxide decreases the intensity of gamma radiation were shown in Figure 4 , Figure 5 & Figure 6. Absorption coefficient can be used in sorting the gamma radiation. The absorption coefficientdepend upon the absorbing material and the intensity of the radiation. Higher the absorption coefficient was enviable where the material covers soft tissue. A small absorption coefficient specify that the material was relatively transparent.

The properties of substances like concentration, conductivity, pH-values and temperature are an important in many advanced biological, medical and engineering applications such as heat exchangers. The distilled water hydrogen ion concentration pH 7.0 was neutral. The average pH-value (6.7) of titanium dioxide for different concentration were shown in Figure 7. The pH-values of sample does not depend on concentration of the titanium dioxide. It indicate that antacid potential present, which will be caused by biological infective resistance to human beings.

The resistivity of the TiO_2 decreases with increasing the temperature. The conductivity dimensions are temperature dependent. Conductivity techniques are generally used in industry. The temperature of the samples increases conductivity also increases gradually. The concentration of the sample increases conductivity also decreases. The diffusion technique enables the measurement of the electrical properties of liquids. This biological effect was more significant for pharmacitical applications were shown in Figure 8, Figure 9 & Figure 10. Biological effects is more significant for medical and pharmaceutical applications. Conductivity has been recommended that drinking water quality can be tartan effectively.

By varying the film deposition and annealing conditions titanium dioxide refractive index changes with wavelength. Refractive indices of synthetic rutile crystal and natural anatase crystal as a function of wavelength was shown in Figure 11. The refractive index is a very important property of the components of any optical instrument. The refractive index of refraction of a material is a dimensionless number that describes how light propagates through that medium. The refractive index determines how much the path of light is bent or refracted, then entering the material. The refractive index also determines the amount of light that is reflected when reaching the interface, as well as the critical angle total internal reflection. The refractive index can be seen as the factor by which the speed and the wavelength of the radiation are reduced with respect to their vacuums values. While the refractive index affects wavelength, it depends on photon frequency, color and energy so the resulting difference in the bending angle causes white light to split into it's constituent colors.

The variations in refractive index that reduces the refractive of a surface treated with an anti-reflective coating. Variant refractive index can generate resonant cavity that can enhance phase shift of output light. This is important for design and fabricate a variety of optoelectronic device such as Hologram and lens. Refractive index is used to measure the concentration of a solute in an aqueous solutions. The refractive index is a measure of how light propagates through a material. The higher the refractive index the slower the light travels which causes a lens thickness decreases with correspondingly increased change increasing refractive index in the direction of the light with in the materials.

Composites of TiO_2 will likely be better agents than pure TiO_2 for these applications, and the main obstacles during the course of the therapeutic use of such nanomaterials will be the ability to target the nanomaterials to the cells in matter and to deliver light of the correct wavelength so as to induce cytotoxicity only in the desired cells and tissue locations. TiO_2 induces some signs of cytotoxicity at concentrations above 20 μg ml^{-1}, although more relaxed estimates claim that higher concentrations still pose no risk of cytotoxicity. Any therapeutic or diagnostic treatment with anatase TiO_2 nanoparticles must take these dose limits into consideration in order to protect healthy tissues from such cytotoxic effects.

Table 1 Absorption coefficient of titanium dioxide nanocomposites

S.No	TiO_2 thickness x (cm)	Counts without sample (I_0)	Counts/sec (I)	$\mu = \frac{\ln(\frac{I_0}{I})}{x}$
1	0.2	1342	1147	0.785
2	0.4	1342	1133	0.423
3	0.6	1342	1125	0.293
4	0.8	1342	1112	0.234
5	1.0	1342	1106	0.193

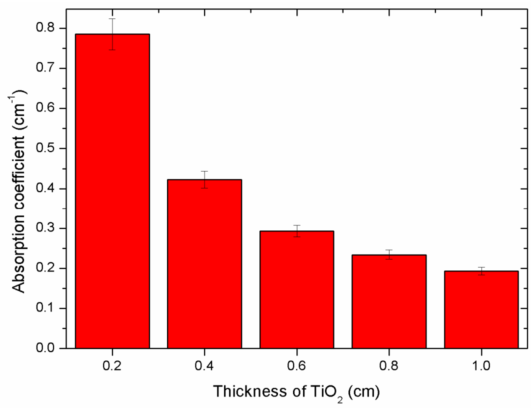

Fig 3 Absorption coefficient versus thickness of TiO_2

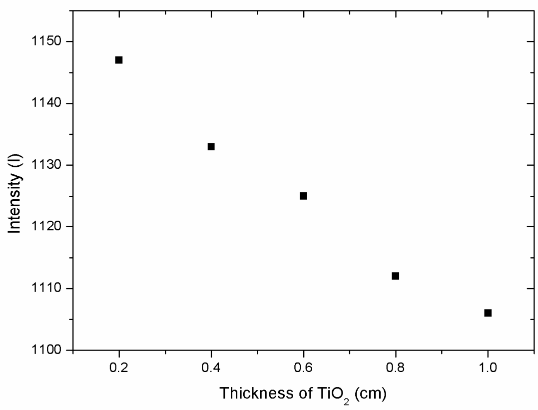

Fig 4 Thickness of TiO_2 versus Intensity

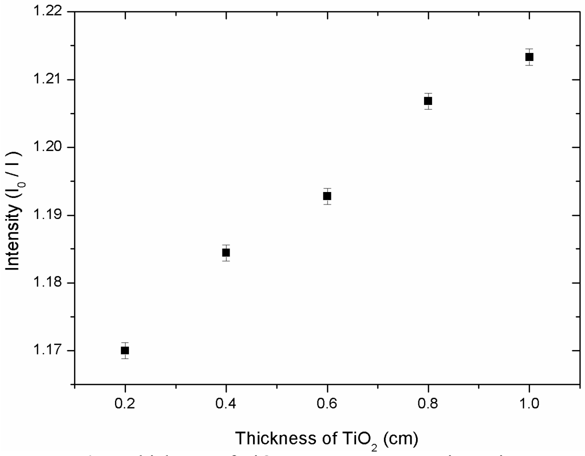

Fig 5 Thickness of TiO_2 versus gamma ray intensity

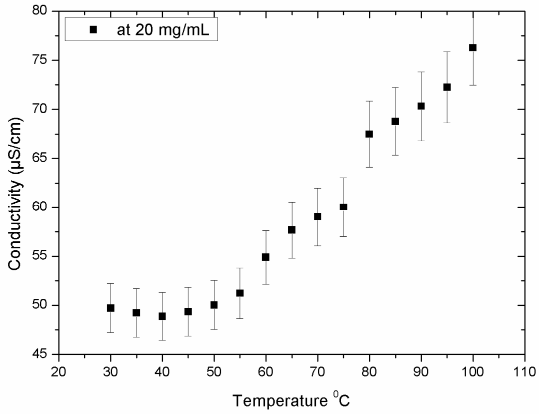

Fig 9 Temperature versus conductivity of the TiO_2

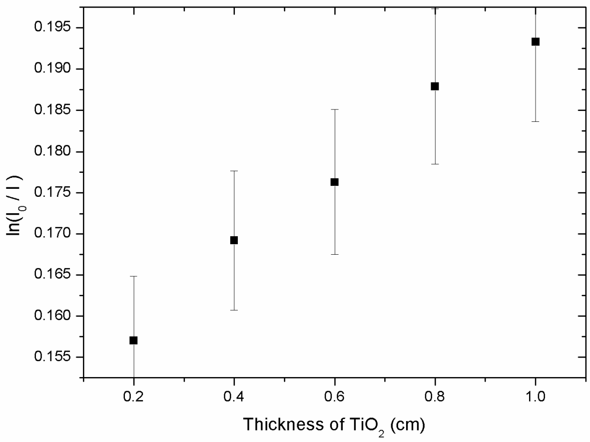

Fig 6 Thickness of TiO_2 versus ln $(\frac{I_0}{I})$

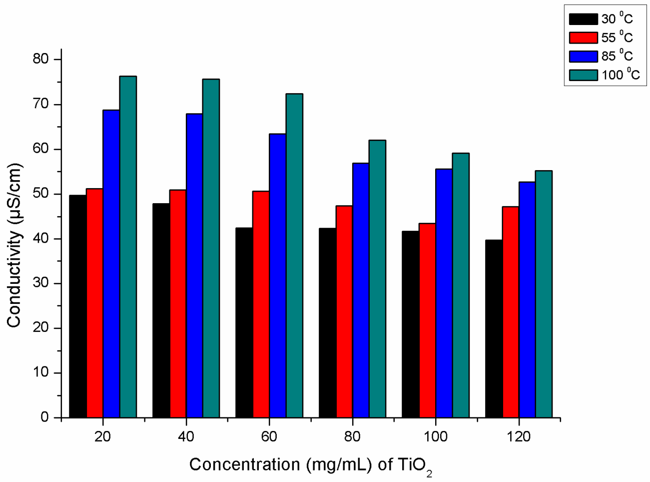

Fig 10 Conductivity versus concentration of the TiO_2

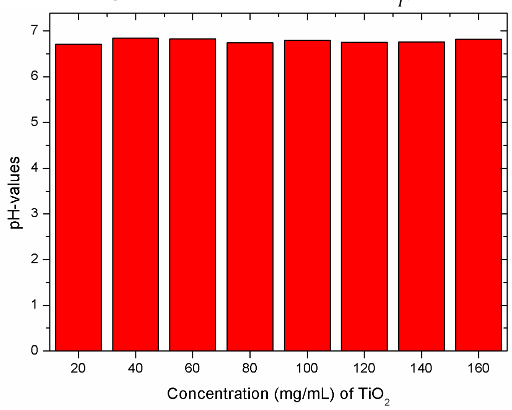

Fig 7 The pH-values of TiO_2

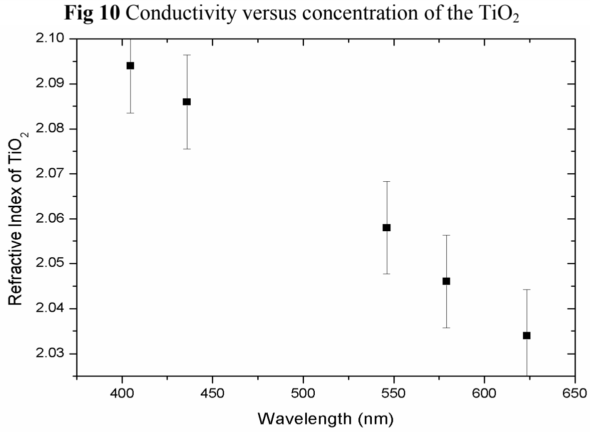

Fig 11 Refractive index as a function of wavelength

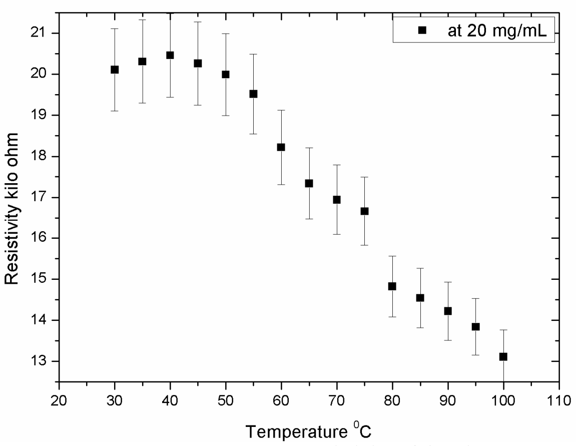

Fig 8 Temperature versus resistivity of the TiO_2

DISCUSSION

Biomaterials were used widely in modern restorative dentistry because of their excellent harmony with natural teeth. Absorption coefficient can best be used in sorting the gamma radiation protective abilities of the restorative materials. One of the most effective photo catalysis reactions with TiO_2 was accomplished by the Gratzel laboratory, when a 10.6% solar light efficiency was achieved by using a dye - sensitized solar cell technology [8]. The coupling of TiO_2 to a narrow - gap semiconductor material can result in an increase in photo catalytic reactivity, as well as an increase in photo response. When a narrow - gap semiconductor coupled to a TiO_2 nanoparticle is exposed to visible light, it produces reactive electrons that can travel through the semiconductor to the nonactivated TiO_2 nanoparticle [9]. This process extends the photo response of the TiO_2 to visible light wavelengths.

Coupling TiO_2 to a semiconductor also decreases charge recombination, because the heterojunction space between the two semiconductors allows for a more efficient separation of reactive electrons and electropositive holes.

The functionalization of TiO_2 nanoparticles with polymers with good conducting properties can be used to direct the charged electrons (e −) and electropositive holes (h +) away from the surface of TiO_2. The addition of polymers that allow for a large internal interface area between the polymer and the TiO_2 particle aids in charge segregation and also prevents charge recombination [10]. Similarly, the addition of clays can aid in charge segregation by providing a large internal interface between the clay and the TiO_2 molecule. In the past, a multitude of polymer/ TiO_2 nanocomposites have been used on the basis of their ability to increase photo catalytic reactivity [11][12].

For many years, titanium and Ti-based alloys have been used extensively in permanent implants for orthopedic, dental and prosthetic applications. More recently, titanium has been used on the nanoscale for implant surface modifications and tissue - engineering applications. With the details of the biological response to an implant placement having been elucidated at the sub cellular level, nanotechnology has been utilized for the surface modification of titanium implants to maximize the natural tissue response to achieve implant integrity and to prevent implant failure. For tissue - engineering applications, TiO_2 has been integrated into bioactive glass composites for use as scaffolds for bone tissue generation. Rajasekhar *et al.* reported that absorption coefficients of few restorative dental materials [13].

TiO_2 is a naturally occurring mineral used as a bright white pigment for paint, in the food industry as a coloring, in sunscreens and cosmetics and in other industrial uses. After processing, it is exist as white, powder solid. According to Poggio *et al.*, cola had the lowest pH (2.55) and might damage the surface integrity of resin composites [14]. Buchalla *et al.* reported that storage in acidic solutions had very little effect on resin based luting cements [15]. Many hydroxyl ions were presented in solutions at neutral pH or low pH. The strong influence of the alkaline medium on the composite properties was attributed to their interactions with OH ions during the hydrolysis process. The charge on ions in solution facilitates the conductance of electrical current and the conductivity of the solution is proportional to its on concentration. The conductivity depends on the value of the pH, concentration of ions and the temperature. Chemical composition of the sample water determines its conductivity. A previous study has been made widely on curry leaves from its stem up to its bark. This review gathers variety of idea from multifarious research which has been done on curry leaves and provides a better cognizance of its therapeutic and non-therapeutic properties [16].

The concept of refractive index apply within the full electromagnetic spectrum from X –rays to radio waves. While the refractive index affects with wavelength, it depends on photon frequency, color and energy. The resulting difference in the bending angle causes white light to split into it's constituent colors. This is called dispersion. It can be observed in prisms and rainbows and chromatics aberration in lenses. By varying the film deposition and annealing conditions titanium dioxide refractive indices in the range of 1.726-2.633 (at λ = 600 nm) could be achieved. Subsequently, a double-layer antireflection (DLAR) coating was designed comprised of low and high TiO_2 refractive index material [17].

CONCLUSION

Titanium dioxide can be found in many products ranging from paint to food and drugs to cosmetics. In the meantime, TiO_2 nanoparticles, nanocomposites and nanoconjugates will continue to be used for different industrial purposes, from water purification to self - sterilizing surgical devices. TiO_2 nanoparticles, nanocomposites and nanoconjugates show variable degrees of photocatalytic reactivity, photoresponse and surface reactivity, all of which influence their interactions with biological systems. Anatase TiO_2 nanoparticles especially those below 20 nm in size, where this crystal phase predominates have the most pronounced surface reactivity.

According to the most conservative estimates, anatase TiO_2 induces some signs of cytotoxicity at concentrations above 20μg ml^{-1}, although more relaxed estimates claim that higher concentrations still pose no risk of cytotoxicity. Any therapeutic or diagnostic treatment with anatase TiO_2 nanoparticles must take these dose limits into consideration in order to protect healthy tissues from such cytotoxic effects. Consequently, modifications of the nanoparticle surface will be essential in order to prevent nanoparticles from aggregating and behaving as macroparticles, which are subject to different *in vivo* clearance mechanisms than nanoparticles. Composites of TiO_2 will likely be better agents than pure TiO_2 for these applications, and the main obstacles during the course of the therapeutic use of such nanomaterials will be the ability to target the nanomaterials to the cells in matter and to deliver light of the correct wavelength so as to induce cytotoxicity only in the desired cells and tissue locations.

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