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Antibacterial and Radiant Heat Absorbing Effects on TiO2 Based Resins

Azamataufiq Budiprasojo[1], Feby Erawantini[2] and Lizam Mauquta[3]

[1] Engineering Department, Politeknik Negeri Jember, Jember, 68121, Indonesia

[2] Health Department, Politeknik Negeri Jember, Jember, 68121, Indonesia

[3] Engineering Department, Politeknik Negeri Jember, Jember, 68121, Indonesia

Abstract. TiO2 (Titanium dioxide) is widely used as a nanomaterial for bacterial decontamination processes. TiO2 can provide a more decontamination effect when exposed to UV light. Ultraviolet light can be a trigger for Tio2 nanoparticles to inhibit bacterial growth. The specimen we tested was a mixture of clear resin with TiO2 0.01gr - 0.06gr (0% -10% of specimen weight) with an increase of 0.01gr each. From the results of research conducted by our research team it was found that the decontamination effect of Escherichia coli bacteria persists even after exposure to ultraviolet light is eliminated. The specimen is also capable of absorbing sunlight and radiant heat with a consistent increasing trend for each increasing variation of the mixture.

1. Introduction

In the construction industry, nanomaterials are widely used because of their characteristics such as thermal requirements, humidity, energy efficiency, air quality enhancement effects, self-cleaning, and antibacterial effects. Nanomaterials are used on a variety of surfaces such as walls, doors and roofs. On a fiberglass roof, for example, a transparent material with other particles, such as titanium dioxide (TiO2 nanoparticles is inserted2). TiO2 nanoparticles have photocatalyst and hydrophilic properties so they can be anti-UV and anti-fogging [1].

In the automotive sector, transparent materials have begun to be used as vehicle exteriors such as car windshields or helmet glasses. The material used is a mixture of resin with TiO2. With this mixture, the windshield of the vehicle is able to absorb ultraviolet light and self-cleaning antibacterial so that it has a better effect on the health of the driver's body.

Ultraviolet (UV) radiation from the sun for a long time can cause sunburn and skin cancer **[2]**. Therefore, to engineer a material that can scatter UV rays and transmit visible light is necessary. This can be done by inserting / coating a transparent material with other particles, such as Titanium Dioxide (TiO2) nanoparticles.

TiO2 nanoparticles have an energy gap of 3.2 eV so that they can scatter most of the UV and absorb some of the other and very little is transmitted. In terms of its toxicity, TiO2 is classified as safe or non-toxic with a chemical bond that is quite stable against UV rays **[3]**.

Photocatalyst is a process that is assisted by the presence of light on the catalyst material (in this case TiO2). The photocatalytic properties of TiO2 have the advantage that organic pollutants can be degraded into harmless compounds such as water and carbon dioxide, and are more efficient in their use of chemicals and energy **[4]**.

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Besides having photocatalytic properties, TiO2 also has hydrophilic properties. The hydrophilic properties of the TiO2 coated material were discovered in the 1990s, various types of functional materials began to be developed **[5]**.

The hydrophilic nature of TiO2 causes the surface of the material coated with TiO2 to be anti-fogging and self-cleaning because the contact angle of water droplets on the surface is only about 100 and will continue to decrease until it reaches 0 when exposed to ultraviolet light. This property is used to coat glass, so that the glass will be anti-fogging and self-cleaning.

The specimens produced can be developed into automotive glass mica or clear coatings in the paint industry which are useful as heat absorbers, antibacterial, scratch resistant and hardened layers. The food and plastic packaging sector can also take advantage of this material because of its self-cleaning antibacterial and heat absorptive properties.

Currently, the manufacture and use of biomaterials with antibacterial effects in medical treatment planning is rapidly developing. Manufactured products that contain antibacterial agents or coatings with antibacterial properties have become an interesting topic for research in the medical field. Various types of materials with antibacterial properties, and analyzed in the laboratory; some have even been marketed.

There are antibacterial agents that involve nanotechnology or what can be called nanotechnology. Nanotechnology in the medical field is proving to be a promising concept. Nanotechnology is a technology that involves materials in nano size **[6]**. In this study, researchers focused on the use of a nanomaterial known as TiO2 (titanium dioxide).

Titanium dioxide will be one of the ingredients in the resin in an effort to produce resin-based composites with antibacterial properties by adding titanium dioxide which is capable of having the short-term effect of an antibacterial agent.

In this study, the researchers aimed to review the effect of nanomaterials added to titanium dioxide resin-based composites for their antibacterial properties. Observations will be made by comparing the number of bacteria present in two different specimens through SEM tests to obtain images of the number of bacterial colonies present in the specimen. The specimens to be used in this study are resin specimens without a mixture of titanium dioxide and resin specimens with a mixture of 0.06gr titanium dioxide with several variations of treatment.

In this study, researchers made a specimen using a mixture of resin and titanium dioxide (TiO2). This specimen will be analyzed for its heat absorption ability using a digital thermometer, the ability to transmit light with a lumens meter, and the ability to inhibit bacterial life. The addition of 0.01gr, 0.02gr, 0.03gr, 0.04gr, 0.05gr, 0.06gr TiO2 in a resin will be the variety of this research. This study tries to develop a transparent anti-UV material and self-cleaning material, using resin as a transparent material. If the energy is greater than the material gap energy, absorption will occur and if it is smaller than the gap energy, it will be transmitted.

The addition of TiO2 nanoparticles to the resin is expected to increase the absorption of the material against UV radiation and is hydrophilic in nature so that the ability of transparent materials as UV protection and self-cleaning can be maximized, which can be seen from the absorption value of the material and the decrease in the value of the contact angle.

This study aims to modify the transparent material so that it provides protection against UV radiation and self-cleaning, namely by optimizing the ratio of TiO2 nanoparticle concentrations with polyester resin so that the anti-UV and self-cleaning capabilities of transparent materials can be maximized.

2. Methods

2.1. This research can be summarized briefly in the following stages:

2.2. Preparation: Covers the activities of studying the literature and formulating formulas for the composition of the mixture of resin and TiO2. Solid material specimens were made with a fixed volume of resin and varying the mass of TiO2.

2.3. Specimen Making: This study used 5 material samples where each material has the same shape but different TiOcontent2. Making specimens by printing on the molding provided.

ISBN : 978-623-96220-1-5

2.4. Testing: In this process, a measurement of heat absorption is carried out using a digital thermometer. Then tested the ability to transmit light using a lumens meter. After that, antibacterial testing is carried out by inserting the specimens that have been exposed to bacteria into a box that is exposed to sunlight and tested under a microscope to see how many bacterial colonies are still there.

Figure 1. Setting Apparatus

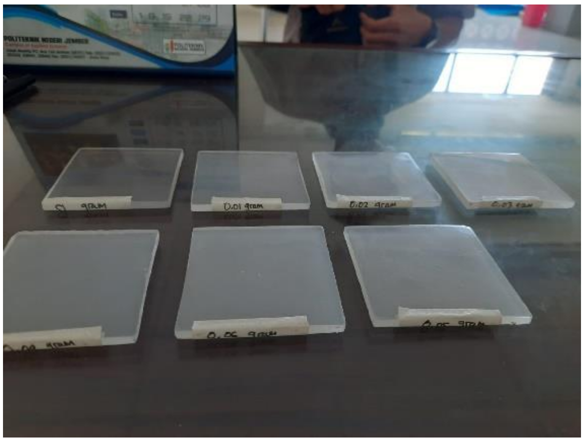

Figure 2. Specimens

Figure 3. SEM (Scanning Electron Microscope) Hitachi TM3030Plus

Figure 4. SEM (Scanning Electron Microscope) Hitachi Specimens Fitting Place.

ISBN : 978-623-96220-1-5

3. Result and Discussion

Table 1. Average Sun Light Intensity

TiO2 Weight (gram)	Average Sun Light Intensity Outside the Box (Lux)	Average Sun Light Intensity Inside the Box (Lux)
0	97300	88700
0,01	97400	70500
0,02	95700	55700
0,03	97500	54400
0,04	96000	47600
0,05	98000	42700
0,06	99300	40900

Table 2. Average Temperature (Sun)

TiO2 Weight (gram)	Average Temperature Outside the Box (°C)	Average Temperature Inside the Box (°C)
0	34,7	42,1
0,01	32,9	41,7
0,02	37,2	44,6
0,03	40,7	49,3
0,04	38,4	48,3
0,05	36,3	44
0,06	33,9	39,9

Table 3. Average Bulb Light Intensity (100W Bulb)

TiO2 Weight (gram)	Average Bulb Light Intensity Outside the Box (Lux)	Average Sun Bulb Intensity Inside the Box (Lux)
0	54700	49040
0,01	49700	41780
0,02	49900	39300
0,03	50600	37520
0,04	49900	36400
0,05	50700	35460
0,06	50300	33480

ISBN : 978-623-96220-1-5

Table 4. Average Temperature (100W Bulb)

TiO2 Weight (gram)	Average Temperature Outside the Box (°C)	Average Temperature Inside the Box (°C)
0	55,3	45,8
0,01	54,5	44,8
0,02	56,7	46,7
0,03	54,4	43,9
0,04	55,1	44
0,05	52,8	44,1
0,06	54,2	44,3

Table 5. Average Specimen Surface Temperature (Sun)

TiO2 Weight (gram)	Average Surface Temperature of Outer Specimens (°C)	Average Surface Temperature of Inner Specimens (°C)
0	36,8	35,5
0,01	38,2	37,5
0,02	37,7	36,5
0,03	37,1	35,6
0,04	39,1	36,2
0,05	38,8	37,4
0,06	38,3	36,7

Table 6. Average Specimen Surface Temperature (100W Bulb)

TiO2 Weight (gram)	Average Surface Temperature of Outer Specimens (°C)	Average Surface Temperature of Inner Specimens (°C)
0	54,8	41,1
0,01	55,1	43,1
0,02	53,7	41,7
0,03	56,9	42,7
0,04	55,8	42,3
0,05	56,2	44,5
0,06	57,9	43,7

ISBN : 978-623-96220-1-5

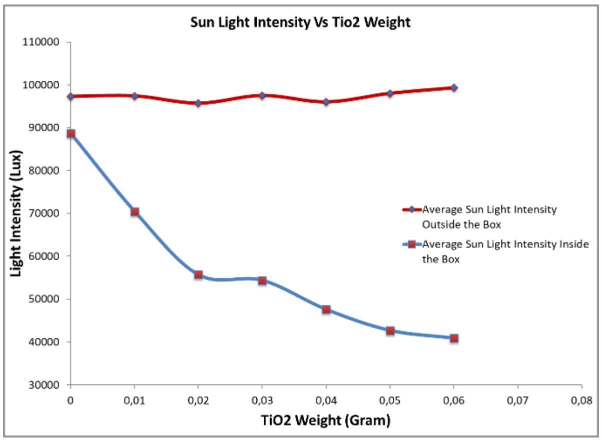

Figure 5. Average Sun Light Intensity

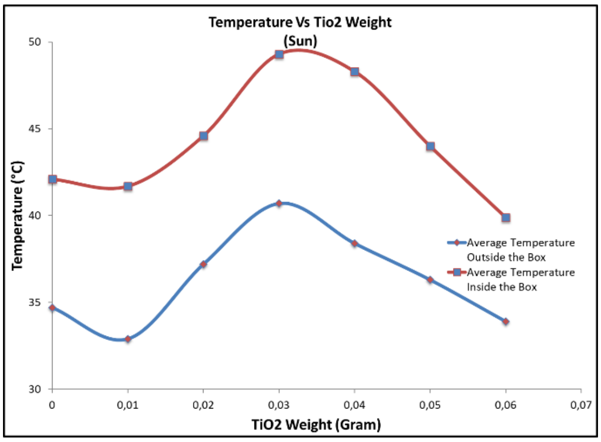

Figure 6. Average Temperature (Sun)

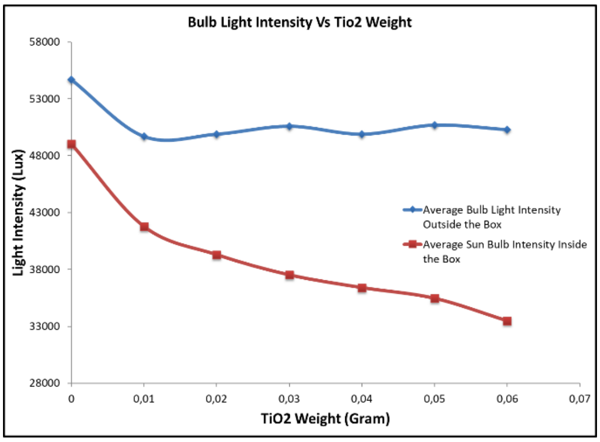

Figure 7. Average Bulb Light Intensity (100W Bulb)

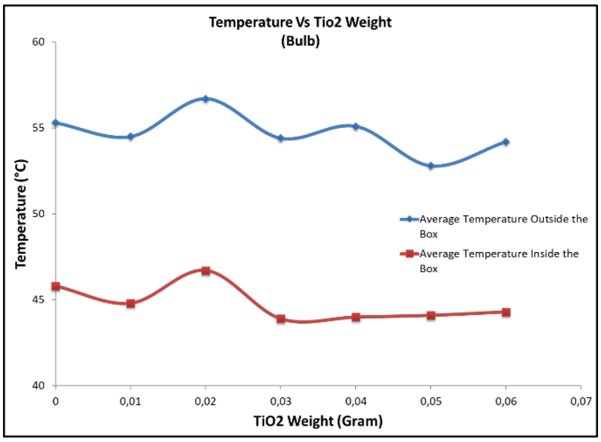

Figure 8. Average Temperature (100W Bulb)

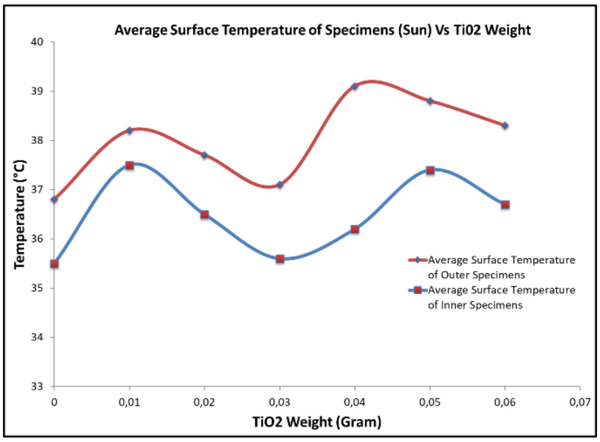

Figure 9. Average Specimen Surface Temperature (Sun)

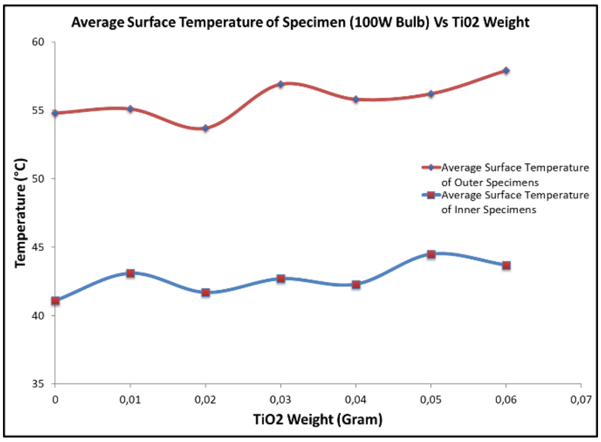

Figure 10. Average Specimen Surface Temperature (100W Bulb)

Based on the intensity data in Table 1,3 it can be seen that samples with a mass of 0.06 grams of TiO2 nanoparticles have a smaller intensity than other samples. This happens because sunlight is

ISBN : 978-623-96220-1-5

partially absorbed by the TiO2 nanoparticles. Besides, the reduction in light intensity after passing through the sample is also influenced by the attenuation coefficient (attenuation) of sunlight.

The smaller the sun intensity after passing the sample, the greater the attenuation coefficient. The amount of sunlight energy absorbed when light travels in a medium can be estimated from the total attenuation coefficient which is the sum of the absorption coefficient and the scattering coefficient by each particle in the material as the propagation medium.

A good lighting standard for a room ranges from 170 to 350 lux **[7]**, while some researcher say it ranges from 200 to 300 lux **[8]**. This light range is for normal conditions without normal activities or activities that do not require a degree of accuracy. If this material is applied as glass, the room will get sufficient lighting during the day without using lights as additional lighting.

Pure anatase phase TiO2 nanoparticles generally have an energy gap of 3.2 eV **[9]**, and they have a maximum UV absorption at a wavelength of 388 nm **[10]**. UV absorption of TiO2 nanoparticles increases with the amount of TiO2 content in the sample.

The inequality of the maximum UV absorption of TiO2 in the sample is because the size of the TiO2 nanoparticles used is not homogeneous, so that the energy gap is also not homogeneous, consequently affecting the absorption wavelength. Besides that, it can also be influenced by the level of purity of the TiO2 nanoparticles themselves, in other words the TiO2 nanoparticles used contain impurities.

Generally, in Figure 5 and 7, the higher the TiO2 content, the lower the transmission. So, it can be assumed that there is a bond between the Ti atoms of the TiO2 nanoparticles and the O atoms of the resin which have an effect on increasing the value of protection against UV radiation.

Based on the results of the research that has been done, the decrease in contact angle before and after the sample is exposed to sunlight is not too significant, this is because TiO2 nanoparticles do not work optimally on the sample. The absorption of TiO2 nanoparticle samples to UV light increases with the amount of TiO2 content in the sample. Meanwhile, the absorption of visible light is getting closer to zero as the TiO2 content is reduced, which means that most of the visible light is transmitted.

The addition of titanium dioxide to the epoxy resin can also increase the absorption of the material at short wavelengths. This indicates that the shortwave light transmission decreases. This epoxy resin and titanium dioxide nanocomposite material is transparent to wavelength or visible light, which means that the absorption of visible light is less.

Table 2 and Figure 6, it is found that the indoor temperature protected by titanium dioxide shows a higher temperature rise compared to the ambient temperature outside the box. Researchers assume this happens because of the accumulation of heat that occurs in the room due to exposure to sunlight and there is no ventilation to circulate heat outside the room.

From this assumption, the researcher then tries to make a data comparison by making a test using a 100 watt incandescent lamp (Bulb) as a heat source in the hope of getting a softer heat. This test data is presented in Table 3 and Figure 8. From the table and figure 8, it is found that the titanium dioxide mixture is able to reduce indoor heat by the heat emitted by incandescent lamps. The best heat dissipation recorded was given by the 0.06gr TiO2 mixture.

Data collection to determine the effect of using titanium dioxide in the room has been carried out by researchers, but how the performance of titanium dioxide to retain micro heat is not known. For this reason, the researchers took surface temperature data from the inner and outer specimens.

This test can show exactly how the conduction heat transfer process occurs in the specimen. the data from this experiment are presented in table 5,6 and figure 9,10. From the tables and figures, it is found that the specimens with a titanium dioxide mixture are able to absorb the penetrating heat. This is evidenced by the lower temperature on the inside of the specimen (the side that is not in contact with heat resource).

This indicates that the heat radiant transmission decreases. This epoxy resin and titanium dioxide nanocomposite material is transparent to heat radiant transmission, which means that the absorption of heat radiant is high.

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Table 6. E.Coli Bacteria Visualizations on the resin specimens with 2000x magnifying

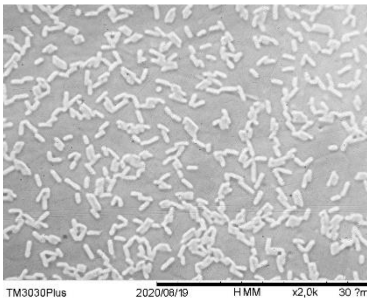
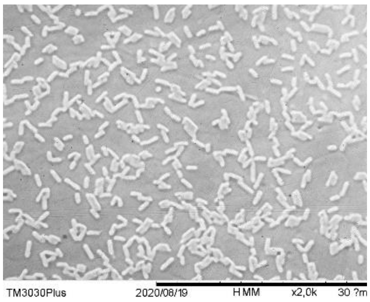
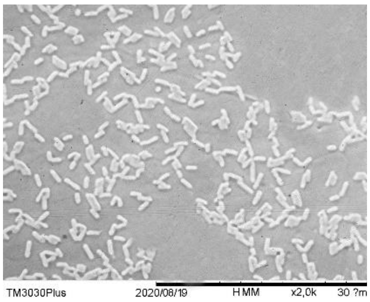
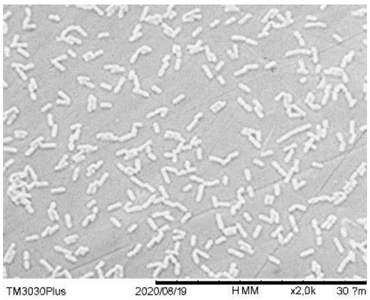
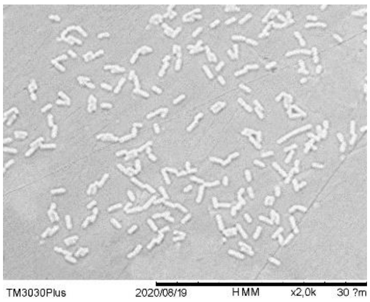
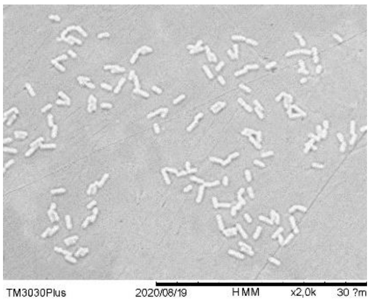
Specimens	Visualizations of E.Coli on the resin specimens		
	Without UV 0 Sec. In Room Temp.	**Without UV 3600 Sec. In Room Temp.**	**After UV 600 Sec.**
TiO2 0 gr			
Specimens	**Visualizations of E.Coli on the resin specimens**		
	Without UV 0 Sec. In Room Temp.	**Without UV 3600 Sec. In Room Temp.**	**After UV 600 Sec.**
TiO2 0.06 gr			

Table 6 is the visualization of bacteria with various treatments. White colour with a capsule shape is a visual of E. Coli bacteria.

By observing directly from the photo, it can be seen that the number of E. Coli bacteria attached to the specimen is reduced in specimens exposed to ultraviolet light and specimens mixed with titanium dioxide. This can be seen from the decrease in white colour.

In the resin specimens that were not mixed with titanium dioxide or in table 6, the Tio2 0gr specimen was written, the lowest number of E. Coli bacteria was visualized in the Tio2 0gr specimen that was exposed to ultraviolet light for 10 minutes. For Tio2 0gr specimens that received treatment, they were left at room temperature for 0 minutes and 60 minutes, recording the same values of E. Coli bacteria.

It was concluded that by using a resin without a mixture of titanium dioxide and left at room temperature, the E. Coli bacteria could survive. In contrast, resin without titanium dioxide mixture but exposed to ultraviolet light showed a reduction in the number of E. Coli bacteria that survived. In the resin specimens mixed with 0.06 g of titanium dioxide or in table 6, the 0.06 gr Tio2 specimen was written, the lowest number of E. Coli bacteria was visualized on the 0.06 g Tio2 specimen that was exposed to ultraviolet light for 10 minutes.

For the 0.06gr Tio2 specimen that received treatment, it was left at room temperature for 60 minutes, recording a lower value of E. Coli bacteria when compared to the 0.06gr Tio2 specimen that received treatment and was left at room temperature for 0 minutes. Although the 0.06gr Tio2 specimen left at room temperature for 60 minutes recorded a decrease in the number of bacteria, it was still unable to

ISBN : 978-623-96220-1-5

beat the decrease in the number of bacteria in the 0.06gr Tio2 specimen with ultraviolet irradiation for 10 minutes.

It was found that by using a resin with a mixture of titanium dioxide and exposed to ultraviolet light, showed a reduction in the number of E. coli bacteria that survived. The final conclusion that can be drawn is resin with a mixture of titanium dioxide is able to kill bacteria even without being exposed to ultraviolet light. If you want to get a better antibacterial effect, you can combine the method of mixing resin with titanium dioxide and the method of irradiating ultraviolet light.

4. Conclusions

The addition of titanium dioxide to the epoxy resin can also increase the absorption of the material at short wavelengths. This indicates that the shortwave light transmission decreases. This epoxy resin and titanium dioxide nanocomposite material is transparent to wavelength or visible light, which means that the absorption of visible light is less.

The heat radiant transmission decreases. This epoxy resin and titanium dioxide nanocomposite material is transparent to heat radiant transmission, which means that the absorption of heat radiant is high.

Resin with a mixture of titanium dioxide is able to act as an antibacterial agent, especially E. Coli bacteria and Ultraviolet light can act as a light capable of killing E. Coli bacteria.

Using a resin with a mixture of titanium dioxide and exposed to ultraviolet light, showed a reduction in the number of E. coli bacteria that survived. The final conclusion that can be drawn is resin with a mixture of titanium dioxide is able to kill bacteria even without being exposed to ultraviolet light. If you want to get a better antibacterial effect, you can combine the method of mixing resin with titanium dioxide and the method of irradiating ultraviolet light.

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