Recent Progress in Self-Cleaning Materials with Different Suitable Applications

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Abstract: Self-cleaning properties have received significant attention for the importance of their potential. Coatings at Nano-scales offer possibilities of using materials for self-cleaning surfaces. Recent efforts have begun to focus on the kinds of materials including metals, semiconductors and polymers. Such materials can have enormous potential in only a few applications. Moreover, the production of these materials requires high costs with low photo activity. In this regard, TiO\textsubscript{2} and its derived materials have shown acceptable and effective suggestions for this application. Moreover, the mechanism of self-cleaning has been explained by the effect of hydrophilic and hydrophobic. Hydrophilic and hydrophobic can have many applications in different areas like water purification, microfluidics and photovoltaic. In this review, the application of self-cleaning in solar cells and environment as well as TiO\textsubscript{2} derived materials and their applications in water management have been briefly illustrated. In addition, it has been explained that a huge number of self-cleaning materials, applications and improvement in utilities have been essential. In short, we have conducted a comprehensive review of the new approach and to mention numerous materials with hydrophobic and hydrophilic properties would be promising for most environmental concerns.

Keywords: Self-cleaning, TiO\textsubscript{2}, Hydrophobic

Introduction

Self-cleaning materials with different suitable wettability for different applications have been the main concern in solar energy area (Banerjee et al., 2015). Due to numerous applications, various materials have been the center of researchers’ attention (Andrews et al., 2013). Those are materials used in house furniture and glasses, or out of the house like solar panels in roof (Liu et al., 2014a). Surfaces coated with self-cleaning material can be cleaned by rain, for example, even though waxy substances such as insect bodies or leave parts may cling unto the surface (Fillion et al., 2014). Self-cleaning surfaces are either hydrophilic or hydrophobic (Oberli et al., 2014). When the surface is hydrophilic, water spreads over it, washing away the contaminants. When the surface is hydrophobic, water particles roll over into droplets, removing, in the process, dust and washing away the contaminants (Zhang et al., 2012). Some reviewers have mentioned
the photocatalytic activity of titanium dioxide (Nishimoto and Bhushan, 2013). TiO$_2$ has been studied for its potential use in water purification and air and water decontamination. TiO$_2$ is being considered in relation to applications in antireflection materials, biosensors (Bixler et al., 2014), photodegradation (Zhao et al., 2014) and solar cells (Liu et al., 2013a). With regards to photocatalytic properties, TiO$_2$ composites are generally considered the best for their physical and chemical characteristics. TiO$_2$ films can provide UV protection, deodorizing effect (Ragesh et al., 2014), antibacterial and self-cleaning functions (Ueda and Levkin, 2013) when used as coating material. The use of TiO$_2$ maximizes photocatalytic effect; however, TiO$_2$-based materials used as photo catalysts are difficult and costly to recycle (Tian et al., 2013a). We have introduced several hydrophilic and hydrophobic TiO$_2$-based materials and discussed combined self-cleaning and hydrophobic or hydrophilic properties with photocatalytic activity. Self-cleaning coatings for materials such as glass, cement and paint have also been discussed with the iteration that a material used as a self-cleaning coating should have two characteristics; first, not being easily oxidized and second, help remove dust and particles when washed by rain or blown by the wind. There are other considerations, such as reflectivity and transparency. Polysiloxane and organosilicons are suitable candidates for making coating materials when all of these requirements are taken into account. We have also discussed TiO$_2$ compounds with high adhesive strength and high surface effect. The get bigger profits in self-clean coatings contains to their low preservation value, high persistence and great possible usages. So, coatings, for sample, may propose beneficial persistence against fouling, icing, corrosion. Hybrid surfaces containing of a micro pillar discipline of hydrophobic and hydrophilic places were planed and created to realize the effects of their unique surface morphology and chemistry on droplet concentration condensation. Droplet impact tests have disclosed that hybrid surfaces depict high contact angles, which is feature of merely hydrophobic surfaces.

**Hydrophilic Properties**

There is a photocatalytic phenomenon in hydrophilic surfaces, whereby the presence of light will cause the decomposition of dust and other contaminants (Song and Mano, 2013). Currently, TiO$_2$ and its photocatalytic derivatives are considered important substances with a high potential. TiO$_2$ is a chemically and physically stable material that is not only easily available. Furthermore and it has low toxicity, low cost and high photo activity compared to materials currently in use (Lai et al., 2013). When it comes to the use of TiO$_2$ as a self-cleaning material, it is restricted by its limited absorption of UV light. This is because UV light is only 3-5% of the solar range. Hence, for outdoor applications, the use of pure TiO$_2$ during the fabrication of self-cleaning materials, like glass and tiles, is a limiting factor due to the low availability of UV light. Several strategies for increasing the efficacy of utilizing the visible sector of the solar spectrum have been suggested (Kisch, 2013). The hydrophilic characteristic of TiO$_2$ was reported by Wang et al. (2014a). Their research made note of the fact that water would spread on TiO$_2$ surfaces that were irradiated by UV light. It was found that the UV irradiation reduced the contact angle between the surface and the water to 0°. This same thing happened when oily liquids like hexadecane were tested on the surface (Keane et al., 2014). There are several advantages of using TiO$_2$ in self-cleaning coatings. These advantages include high transparency of TiO$_2$ thin films, high photocatalytic activity and hydrophilic properties that occur due to UV-irradiation. Single layers and multiple layers of TiO$_2$ were coated on materials like glass through using a layer-by-layer technique, thus creating self-cleaning materials (Fisher et al., 2013). The ability of these photocatalytic sheets to degrade chemicals was tested on methylene blue. A cost-effective technique for use in photovoltaic cells has been explored recently. The technique was deemed suitable for use in fabricating photocatalytic, hydrophilic and high transparency TiO$_2$ films (Banerjee et al., 2014). Under the microscope, it was observed that UV irradiation caused the change in contact angle. UV irradiation causes changes in the TiO$_2$ solid-liquid boundaries on the surface (Qu and Duan, 2013). Each TiO$_2$ molecule has six positions, five of which are filled with Ti atoms, with the last position occupied by H$_2$O or OH$^-$ group. Irradiation with UV light causes an oxygen bridging area to form on the surface by converting Ti$^{4+}$ ions to Ti$^{5+}$ (Zhao et al., 2013). Microscopic observation of TiO$_2$ crystals revealed that there were hydrophilic and Oleopholic parts on the TiO$_2$ surface that allowed for the formation of microscopic flow channels for oil and water (Sakai et al., 2003). According to previous research, TiO$_2$ coated materials with hydrophilic properties that were stored in the dark for two days showed a decrease in hydrophilic properties. This was due to the slow substitution of oxygen in the air with water. It is possible to recover the hydrophilic properties of the surface by exposing it to UV light again. The experiments showed that TiO$_2$ has convertible hydrophilic properties and that hydrophilic-oleophobic properties can be induced on the surface by UV irradiation (Emeline et al., 2013). Highly interrelated hydrophilic polymers were collected through the polymerization of (paraffin-oil)-in-water emulsion samples using interior phases below 74 vol%. Moisture adsorption, water contact angle, swelling test, water vapor transmission and mechanical tests were executed to appraise the hydrophilicity-hydrophobicity. the Titanium (Ti) surfaces with various construction, combination, crystal Fig. 1 and grain size are disposed by micro arc oxidation and
thermal treatment and then their hydrophilicity and surface roughness are considered. The empirical results show that there is no essential correlation between hydrophilicity and surface roughness.

**Fig. 1:** Bio-inspired surface respond in nature through hydrophobic and hydrophilic properties
Hydrophobic Properties

A hydrophobic surface can be fabricated by controlling chemical combinations and monitoring the structural properties of solid surfaces. Unlike hydrophilic materials, there are not as many examples of hydrophobic surfaces (Emeline et al., 2013). Hydrophobic surfaces have several self-cleaning advantages when compared to hydrophilic surfaces. These advantages include the reduced potential adhesion of bacterial activities (Li et al., 2015a) and extra cleaning activity (Zhang et al., 2015a). Functionalizing TiO$_2$ through the modification of surface morphology has an added benefit of increasing smoothness and lowering free energy on the surface. The aim of creating hydrophobic surface coating is usually to prevent hydrophilic TiO$_2$ conversion through irradiation when it displays photocatalytic and hydrophobic characteristics. The transparency of hydrophobic films were investigated by through calcination of a mixture of titanium acetylacetonate and aluminum acetylacetonate, then coated with fluoroalkylsilane (Zhang et al., 2015a). The films were characterized according to their porous and smooth surface where the roughness was correlated to TiO$_2$ concentration. This particular experiment showed the constant hydrophobicity of the film and photocatalytic properties of stains for up to 1800 h. The photocatalytic potential of TiO$_2$, in addition to its photo induced amphiphilic property can be explained by the self-cleaning action of the hydrophobic film (Liu et al., 2013b; Katsanaki et al., 2013; Pelaez et al., 2012). There was an increase in the Ti/oxygen volume and consequently, the value of hydroxyl group due to exposure to UV light (Hamilton et al., 2014; Weng and Huang, 2013). A group of scientists carried out a survey to test the self-cleaning ability of some materials by using graphite powder on the surface. The results showed that the graphite was adsorbed easily by the surface through the water on the hydrophobic surface. As a result, the graphite slide off the surface (Kitano et al., 2013; Reszczynska et al., 2015). One simple and applicable fabrication method can give the surface the ability to repair and introduce a new generation of hydrophobic surfaces. This phenomenon is important because it causes less mechanical damage. It is also beneficial when used in self-cleaning materials. A hydrophilic surface was successfully created by irradiating the photocatalytic hydrophobic surface with UV light. This was due to the oxygen that was gathered through heating. However, this was only possible provided that the film - a hydrophobic surface - was stored outdoors for 4 weeks in high humidity conditions i.e., >90%. The increased hydrophobicity between the hybrids of inorganic-organic films was attributed to the chains of the hydrocarbon throughout the hybrid film (Wu et al., 2013a). Super hydrophobic surfaces for self-cleaning utilizations often toil mechanical inconsistency and do not work excellent after abrasion/scratching. Coverage of TiO$_2$ nanoparticles to the formulation displays expand addition in water contact angle owing to the structural betterment with hierarchical surface roughness. Mechanical consistency and persistence of the coatings has been attained by using a mercantile sticky to bond the super hydrophobic “paint” to different layers, considering of super hydrophobic materials inspired by nature has drawn major scientific interest in last decades. A main compete of using the superhydrophobic surfaces for the self-cleaning coatings production is their modified proficiency in different atmospheric conditions, e.g., UV light. Tribological and hydrophobic properties of the varied surfaces were associated with their chemical structures. After accelerated UV presentation, no considerable variations in the chemical structure, hydrophobic and tribological features of the modified surfaces were detected. Hydrophobic efficacy was supported in UV light what can be undertaking in efficient self-cleaning coatings receiving. Zinc Oxide (ZnO) Nano rods were combined at room temperature on potassium permanganate operated silicon and glass layer by simple chemical procedure using zinc acetate as pioneer. The surface energy of the as produced pure and coated models was computed by evaluating the contact angle of two several liquids. Also, even after UV irradiation the contact angle stay same unlike the state for the uncoated model where the contact angle gets reduced importantly after UV irradiation. Applying the new hydrophobic sample, the prediction error of contact angle can be less than 3% contrasted with the measured one.

Antibacterial Activities

Recently, materials with photocatalytic properties like TiO$_2$ derivatives have garnered attention from researchers. This is due to the fact that materials like TiO$_2$ have a potential use as self-cleaning antibacterial material (Niu et al., 2013; Feng et al., 2013; Afzal et al., 2013; Wu et al., 2013b; Xiao et al., 2014; Etacheri et al., 2013). Investigated the self-cleaning properties of TiO$_2$ and found films that contained TiO$_2$ had photocatalytic activity with antibacterial effects that were caused by irradiation by UV light (Patrocini et al., 2014). Nanocomposites like Cu$_x$O/TiO$_2$ had been used to aid visible light absorbance in indoor conditions. The Cu$_x$O used in the nanocomposites were a mixture of Cu (II) and Cu (I) (Tian et al., 2013b; Wang, 2014).
The visible light absorption of TiO$_2$ and photocatalytic oxidation of volatile compounds increased when in the presence of Cu (II). In the absence of light, Cu (I) had antimicrobial properties (Fateh et al., 2014). Photocatalysts were used to perform photocatalytic disinfection of Aspergillus niger, Staphylococcus Aureus, Escherichia coli, Candida Albicans and Enterococcus faecalis. The order of inactivation was found to be as follows: E. coli > S. aureus > E. faecalis > C. albicans > A. niger (Karimi et al., 2014a; Zhu et al., 2014; Yao and He, 2014; Xu et al., 2013a). The fabricated surface with TiO$_2$ followed by Ag nanoparticles showed a high antibacterial potential against E. coli (Kapridaki et al., 2014). Antibacterial characteristics can be retrained for a long time by inserting Ag nanoparticles between TiO$_2$ nanotubes and ammonium salt in Table 1. According to previous research, nanocomposites that exist in this combination have a high potential for biocompatibility and can retain antibacterial characteristics for a long time. The ammonium salts in the surface of the coating causes a decrease in the release of Ag from the nanocomposites (Lien et al., 2013; Erdural et al., 2014). Electrochemical anodization was used to test the antibacterial properties of titanium nanotubes on E. coli and S. aureus. The investigation revealed that E. coli (97.5%) and S. aureus (99.9%) were successfully disinfected by the nanotube materials after the application of UV irradiation. Two characteristics of surface structural morphology and also physiochemical properties of titanium materials play a significant duty in anti-bacterial activity (Mokhtarimehr et al., 2015). The structure of Ag/I/TiO$_2$ has shown potential as it has efficient photocatalytic activity with regards to antibacterial cases and organic pollutants (Wang et al., 2014a; Pakdel et al., 2013; Pakdel and Daoud, 2013; Li and He, 2013). The active visible light self-cleaning of cotton fibers coated with AgI and TiO$_2$ shows a more efficient degradation of methyl orange after visible light irradiation, as compared to the self-cleaning activity of cotton fibres coated with TiO$_2$ alone (Nakata et al., 2014). Silver nanoparticles have been applied on the surface of TiO$_2$ nanoarrays in order to combine photocatalytic self-cleaning surfaces with active surface detection (Guldin et al., 2013; Yadav et al., 2014). There is a suggested antibacterial activity mechanism for TiO$_2$ that when the cell wall and cell membrane of bacterial cells are destroyed, it means that TiO$_2$ is irradiated (Li et al., 2013a).

### Photo-Controlled Wetting

There has been a novel application regarding photo-controlled wetting applied for bio-materials and some other materials like ceramic which is called reversible photo-response surface. This technique, because of its different applications, has attracted researchers’ attention that focused on controlled wetting properties (Wang et al., 2014b; Li et al., 2013b; Xu et al., 2013b; Zhang et al., 2013a; Crick et al., 2012). This is a ‘smart coatings’ which has the ability to switch from time to time to hydrophilic and hydrophobic surfaces by light irradiating under specific wavelength (Wooh et al., 2014; Nandan et al., 2015). The specific characteristics of this kind of materials have various applications in different areas that can be such as controlled drug delivery, membranes and sensors and finally surface coatings (Xie et al., 2014; Xu et al., 2013c; Mills et al., 2012; Yang et al., 2002; Sawai et al., 2013). In this regard-, there are some factors with higher importance in case of leading the nature of wetting which includes degree of the surface polarity, morphology and roughness of the surface (Wang and Guo, 2014; Gao et al., 2014a). One researcher called Li, together with his colleagues, worked on providing a new micro-Nano silica/titanium thin-film combination through Nano-spheres of TiO$_2$ and SiO$_2$ and a kind of water-resistant substances i.e., Aquapel. This new micro combination of TiO$_2$–SiO$_2$ has the potential of diverse wettability (Gao et al., 2014b). Moreover, this composite has performed a pattern which angles in

| Table 1: Hydrophilic and hydrophobic characteristics of TiO$_2$ |
|---------------------------------------------------------------|
| Hydrophilic                                                                 | Hydrophobic                                                                 | Reference |
| Potential adhesion of bacterial activities                     | Decrease the potential adhesion of bacterial activities                     | Li et al. (2015a) |
| Cleaning activity Potential                                     | Extra cleaning activity Potential                                           | Zhang et al. (2015a) |
| High quality of hydrophilic due to UV-irradiation                | -                                                                          | Fisher et al. (2013) |
| Water would spread on TiO$_2$ surfaces                          | Water would slide off TiO$_2$ surfaces                                      | Kisch (2013) |
| -                                                              | Graphite adsorption by hydrophobic surface                                 | Kitano et al. (2013; Reszczynska et al., 2015) |
| Contact angle between 0° and 90°                                | Contact angle more than 90°                                               | Kisch (2013) |
| -                                                              | Photocatalytic potential of TiO$_2$ and its photo induced amphiphilic property | Liu et al. (2013b; Katsamaki et al., 2013; Pelaez et al., 2012) |
water significantly and dependent on the microscopic roughness of the surface (Gao et al., 2014b). Since this composite of TiO$_2$-SiO$_2$ has different ratio in size, it has some effects on their properties (Gao et al., 2014b; André et al., 2013; Zang et al., 2014). In another survey, illustrate that reducing of hydrophilicity potential can be due to surface restructuring titanium during the irradiation process (Balachandran et al., 2014).

**Self-Cleaning Materials**

Besides all TiO$_2$ derives for self-cleaning purpose as explained before, there are some metal oxide materials like SnO$_2$ and ZnO, which have the potential of photocatalytic activity (Mills et al., 2013). These n-type metals such as SnO$_2$ show- the characteristics of switchable hydrophobicity and hydrophilicity before and after UV irradiation (Mills et al., 2014a). The hydrophobic and hydrophilic conversion has been credited from surface roughness whereas oxygen and hydroxyl produced due to UV irradiation. SnO$_2$ films fabrication on glass have been achieved by spermine functionalization (Mills et al., 2014b). The SnO$_2$ with cooperation of superoxide radicals and sunlight lead to degradation of pathogens and organic dyes. Photo induced hydrophilicity characteristics of SnO$_2$ films together with photocatalytic properties can be used for coatings with properties of antifouling. Pan and his colleagues surveyed the experiment of fabrication SnO$_2$ hydrophobicity base on morphological surface roughness (Bateman et al., 2012). The microchannel created on the surface led to air entrance into the channels and as a result, prevention from water penetration. This switchable wettability structure with the potential of changing via UV irradiation can be useful for industrial coatings regarding self-cleaning applications. Some researchers with the leadership of Sun found that ZnO films showed a conversion of photo-induced hydrophilic (Radeka et al., 2014). This phenomenon has been credited to surface defects like TiO$_2$ against UV following by adsorption of water. Another researcher called Plasmon surveyed the visible part of light absorbed by the hybrid of Ag–ZnO and increased photocatalytic activity because of specific combined structure (Ke et al., 2014). The UV part persuaded photocatalytic active Nano arrays which potentially could be applied for self-cleaning in Fig. 2. (Midtdal and Jelle, 2013; Lu et al., 2015).

![Fig. 2: Schematic image of metal oxide material (ZnO and SnO$_2$) with photocatalytic properties](image-url)
Large scale commercially TiO$_2$ photo induced hydrophilic conversion for various applications such as cement, glass, paints and tiles were achieved to develop self-cleaning and anti-fogging. The application of TiO$_2$ photo catalysts in the glass of windows and tiles has been used in buildings to present the materials with the potential of photocatalytic self-cleaning in buildings construction (Spasiano et al., 2015; Murugan et al., 2013; Zhang et al., 2013b; Radetić, 2013). This modification in materials can be accomplished by solar irradiation leading to the photo catalysis process. Self-cleaning glass would be practical through Pilkington glass which involves a nanocrystal line film from TiO$_2$ with 15 nm thickness on the surface of glass (Galkina et al., 2014). This active glass is one of the best products in self-cleaning applications and has recently been used in many different buildings in commercial and private all around the world. Have investigated this technique as a suitable choice in case of semiconductor photo catalysis (Pasqui and Barbucci, 2014; Karimi et al., 2014b; Montazer et al., 2012). This potential has been measured in order to confirm the ability of stearic acid degradable. Moreover, there are some beneficial matters in case of active potential applicable in self-cleaning which are optimum absorption of solar radiation, low reflectance visible light (7%) and acceptable transmittance. Nowadays, few self-cleaning window glasses like Bio-clean TM, Sun-clean TM and Radiance TITM have been commercially added to the market. TOTO Ltd., a Japanese producer, introduces a new technology to the market that is super hydrophilicity photo induced glass that through sunlight, breaks down all pollutants in smaller sizes to be washed by rain/water. This technology has been used by TOTO Ltd. in building construction as paint and coat materials, not only indoor but also outdoor usage. These products are produced through spraying TiO$_2$ on the glass then tempered at 600-800°C in order to highly attach to the surfaces (Rehan et al., 2013; Afzal et al., 2014; Kim et al., 2016; Nawaz et al., 2015). Using this high temperature leads to high stability of TiO$_2$ which is possible to develop self-cleaning materials use in building. Recently, scientists by using a suspension from ethanol coated by TiO$_2$ have made a combination i.e., perfluorooctyltrioethoxysilane (fluoroalkylsilane) (C$_{16}$H$_{33}$F$_3$O$_2$Si) which has the potential to be used for hard and soft materials as well. This kind of coatings has the potential to be used on paper, steel, clothes and glass in case of various applications. In this system, drops of water would be gathered without any effect on material (Kim et al., 2016; Sharker et al., 2015; Lee et al., 2014; Nam et al., 2013). An example for self-cleaning glass can be pointed to the National Opera Hall in China (Darmanin and Guittard, 2015). Also, in the case of white cement, can be bolded regarding to Dives in Misericordia Church in Rome (Liu et al., 2014b) and for Roof can be pointed to Cricket Stadium in Dubai Sports City (Murakami et al., 2014). There is a research that shows that by covering with active concrete 15% of ceilings in city of Milan, the pollution would be decreased up to 50% (Miljkovic et al., 2013; Zhang et al., 2015b). Another company named Heidelberg Cement has produced TiOcem(TM), which is another air pollution reducer in case of self-cleaning cement (Hancock et al., 2012; Vorobyev and Guo, 2015; Long et al., 2015). Also, in Japan the tiles made of self-cleaning material for using in windows and roof from company Eco-friendly are used widely. On the other hand, anti-fogging characteristics of self-cleaning coatings have been used in automobile companies to produce clean mirrors and headlights (Yong et al., 2013). TiO$_2$ films have been improved through the application of Ni$^{2+}$ and Fe$^{3+}$ to produce self-cleaning active materials in buildings (George et al., 2014; Yong et al., 2014; 2015). Antimicrobial activity of TiO$_2$ has a huge potential in the construction of building materials for both indoor and outdoor applications (Lu et al., 2015; Li et al., 2015b; Dunderdale et al., 2015). Antimicrobial activity of TiO$_2$ is very critical due to their applications in food industries and medical science to preserve food and drug from contamination by microbes. There are few companies that use this technique in their products which are Biocera TOTO and Karperey. They have produced films on ceramics that function as an antimicrobial agent (Shi et al., 2015). In this case, the thing which is important is the product with the characteristics of antimicrobial activity and deodorizing property in Table 2. Also, another product is cotton textile plus TiO$_2$ nanoparticles (Shi et al., 2014a; Lochovsky et al., 2012; Dai et al., 2015; Kamei et al., 2014; Lv et al., 2014). In this case, the mechanical properties of cotton textile have been improved through TiO$_2$ coating (Shi et al., 2014b) and antibacterial properties besides stain removal (Zhou et al., 2015; Lei et al., 2014). The effects of self-cleaning and Photocatalytic of textile were developed through soaking the fibers in multi-wall carbon nanotubes and TiO$_2$ composition and using succinic acid as a parameter to link them (Wang et al., 2013; Yao et al., 2011; Li et al., 2015c). Antimicrobial, self-cleaning and UV protection characteristics were achieved through the combination of polyester with TiO$_2$ and Ag nanoparticles (Cheng et al., 2014). Also, Polyester which is coated with a combination of AgI/AgCl/TiO$_2$ has increased antimicrobial properties against E. coli and the efficiency of methylene blue (Lei et al., 2014; Gurav et al., 2014). Materials with keratin base have been applied a lot in substances such as tires and textiles because of biodegraddability (Raza et al., 2015; Wang et al., 2015; Manabe et al., 2014; Gurav et al., 2015; Shang and Zhou, 2015).
Table 2: TiO$_2$ photo-induced hydrophilic conversion for various applications

| Substrate Formulation | Application | Reference |
|-----------------------|-------------|-----------|
| Glass + TiO$_2$ with 600-800°C | Windows, tunnel, road lights and vehicles | Sharker et al. (2015); Lee et al., 2014; Nam et al., 2013 |
| Polyester coated with gI/AgCl/TiO$_2$ | Buildings and Automotive Industries | Cheng et al. (2014) |
| Cement + TiO$_2$ | Building roof, Floor and walls | Liu et al. (2014b) |
| MWCNT+TiO$_2$ | Medical devices, furniture and household appliances | Wang et al. (2013); Yao et al., 2011; Li et al., 2015c |

Conclusion

This article focused on giving an overview based on photocatalytic self-cleaning materials from TiO$_2$ and derives and considering wettability characteristics. All of the materials, which have been explained in detail, have a specific importance in environmental pollution that can be used in various solutions, such as antireflective coatings, antifogging and antibacterial. Some models, such as cement, cotton and automotive cases, have been presented in detail to realize the mechanism of hydrophilicity activity upon UV irradiation. This part of light produces changes in TiO$_2$ surface. Photo-controlled convertible wetting characteristics recently have attracted scientist’s attention. Moreover, morphology and surface roughness have been reported as the most important factors of the wetting. Several techniques, like condensation using Nano- hetero-junctions, composites and metals have been illustrated through the photocatalytic activity which could improve self-cleaning. Although, it is important to note that comparing the self-cleaning activity from different materials and sources, because of different intensities, time of irradiation etc., is quite challenging. However, any adaptations that increase the surface roughness would be recommended in case of self-cleaning activity. The application of hetero structure materials to increase self-cleaning activity looks to be an effective trend in this case.

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Conflict of interest

The authors confirm that there are no conflicts of interest.

Authors Contributions

All authors contributed to design the study, write and revise the manuscript.

Ethics

This study was approved by Mechanical Engineering Department, Universiti Teknologi PETRONAS (UTP), DarulRizvan, Bandar Seri Iskandar, 32610 Perak, Malaysia.

Recommendation

However, a few more studies need to be performed to realize the structural relationships between materials used and the structure-wettability design of them. Common competes faced in feasible usages and the propensity of future progress are introduced and considered to simplify a global comprehension of self-cleaning coatings.

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