THE USE OF NANO-SIZED NATURAL SILICA TO VISIBLE LIGHT PHOTOCATALYST AS A MASK COATING FOR INACTIVATION OF SARS-CoV-2: A REVIEW

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ABSTRACT
Research on antiviral agents to inactivate SARS-CoV-2 is still a concern of researchers. Many innovations have been made, one of which is coating the surface of cloth masks using photocatalyst materials. Visible light photocatalysts have been shown to have antimicrobial properties in sunlight. The study of material modification becomes important to select and optimize the supporting materials used. We observed that modifications with nano-silica particles (SiO$_2$) have good transmission capabilities and can be produced from natural sources (biological and non-biological). Therefore, this utilization is carried out to apply the principle of zero waste, namely renewable natural sources as a source/precursor of nano-silica. In this study, we focus on renewable research related to the use of natural nano-silica as supporting material for visible light photocatalysts will be explored to be coated on polyester mask fabrics as an effort to inactivate SARS-CoV-2 on the surface of the mask.

Keywords: Coating, Visible Light Photocatalyst, Mask, Nano-silica, SARS-CoV-2.

INTRODUCTION
The COVID-19 pandemic is still a major problem affecting the world. This disease causes a respiratory illness with flu-like symptoms including cough, fever, and difficulty breathing. Finding an antiviral agent that can inhibit SARS-CoV-2 activity on the surface of masks is still a challenge for researchers to be able to coexist with COVID-19. In this case, coating the surface of a cloth mask with a photocatalyst becomes very important because it can create a self-cleaning effect with the help of visible or ultraviolet light. Photocatalysts have been shown to have antimicrobial properties. One of the most appropriate solutions is the use of natural sunlight in the form of visible light. Visible light photocatalyst needs to be modified so that its use as a surface coating material for reusable polyester cloth masks can inhibit virus activity properly. Nano-silica (SiO$_2$) particles have good light absorption and transmission capabilities. Therefore, coating nano-silica to the surface of a visible light photocatalyst agent can increase its photocatalytic activity by maximizing light absorption. The more optimal the absorption of visible light rays by the photocatalyst agent, the better the application as an antiviral for COVID-19 due to SARS-CoV-2. The choice of SiO$_2$ as a supporting material is because this material can be produced from natural sources (biological and non-biological). Sources of SiO$_2$ can be produced from agricultural waste (biological sources) and beach sand (non-biological) which both have high abundance, especially in Indonesia. Reviews of SiO$_2$ from nature and its use to degrade viruses we have described in our previous work. Comprehensively, we want to continue the review by exploring the latest research related to the use of nano-silica from nature as a support material for visible light photocatalysts for coating on polyester mask fabrics as an effort to inactivate SARS-CoV-2 on the surface of the mask.

Nano-silica
Silica is the mineral that has the most abundance in the earth's crust, and over time it is widely used for human purposes, silica is found in the human body and is widely used as a biomaterial in dentistry, bone surgery, and dermatology. Silica (SiO$_2$) is mostly found in the form of sand or quartz on earth. Silica is one of the constituent structures for various natural and artificial structures and the development of nanotechnology raises interesting research topics for researchers to explore the new capabilities of nano-silica.
silica.\textsuperscript{6} Silica at the nanoscale has interesting properties when compared to its bulky structure which brings nano-silica applications in various fields. This is due to its low toxicity, high chemical and physical stability, large surface area to volume ratio, and direct surface chemical properties so that it can be combined or functionalized with various functional species and molecules.\textsuperscript{7} Recently, silica nanoparticles have attracted the attention of researchers because of their unique properties such as large surface area, large and adjustable pore volume, good biocompatibility, hydrophobic ability, and availability of scalable synthesis.\textsuperscript{8} Silica nanoparticles are very stable and non-toxic.\textsuperscript{9} Nano-silica is also transparent to light so it can be a suitable matrix for luminescent materials.\textsuperscript{10} As silica decreases in size to nano-silica, many unique features emerge that can be effective additives to increase the durability, strength, and flexibility of polymers.\textsuperscript{11} Silica particles with a size below 100 nm, especially those with a size of tens of nanometers tend not to crumble easily because of their large atomic surface to atomic mass ratio.\textsuperscript{12} The presence of nano-silica in various forms such as mesoporous silica,\textsuperscript{13} solid silica, hollow silica,\textsuperscript{14} silica gel, and rod-shaped nano-silica.\textsuperscript{15} Silica in the form of a virus bringing nano-silica has benefits in various fields. silica-based nanoparticles have been widely used in cancer therapy and diagnostics in particular to deliver drugs, genes, and contrast agents.\textsuperscript{16} The oil industry also gains many benefits from nano-silica, nano-silica is widely used for reducing water content in sedimentary rocks, filtration and rheological control of fluids, stability of emulsions, and to obtain oil yields, and attracting reductions in porous media.\textsuperscript{6} Based on research conducted by Foroutan et al., (2020) Nano-silica can also be used as an adsorbent for heavy metals from shipping industry wastewater because it has a porous structure. Nano-silica is also the most widely used in cement and concrete to improve its performance of pozzolanic reactivity and pore-filling effect.\textsuperscript{17} In a corrosive environment, corrosion ions can easily penetrate through the concrete surface to the inside due to the porous surface structure so that the concrete is easily damaged, for that nano-silica is used to modify cement as a Surface Protection Material (SPM). Nano-silica in this case is useful for increasing the penetration resistance of the system\textsuperscript{21}. Nanocomposite polymers usually use silica nanoparticles because of their low production costs and better reinforcement performance when compared to other reinforcing nanofillers such as carbon nanotubes (CNT).\textsuperscript{22} The suspension of silicon dioxide nanoparticles in ethylene glycol is also useful as a nanofluid with good viscosity and thermal and electrical conductivity.\textsuperscript{23}

**Bio and Non-Biological Nano-Silica**

As a non-essential element in biota, silicon is available in the form of silicic acid. The presence of silica is associated with an increase in general plant strength and external stress. Silicon accumulates in plant tissues as amorphous silica with cell walls being the preferred site for silicon accumulation.\textsuperscript{24} Rice husk ash can be used as a precursor of powdered nano-silica by precipitation method.\textsuperscript{25} Silica can also be extracted from red sorghum husks by the calcination process.\textsuperscript{26} Silica can be extracted from other natural sources such as bamboo leaves, bagasse fiber, and peanut shells which are waste materials that can be an environmental problem if present in large quantities.\textsuperscript{27} Corn cob ash, cassava peel, and tea pulp fiber are agricultural wastes that have great potential for silica production.\textsuperscript{28} In addition to biological materials, silica can also be extracted from non-biological materials such as beach sand by the alkaline fusion method\textsuperscript{29} or two-step extraction, namely the formation of potassium silicate and the formation of silica gel.\textsuperscript{30} Another non-biological source of silica is lapindo mud and coal fly ash, which is a cheap and abundant waste of the coal industry and is rich in silicon.\textsuperscript{31}

**Visible Light Photocatalyst**

The use of visible light photocatalysts is a promising alternative in degrading unwanted substances, such as dyes, organic pollutants, and microbes. The underlying reason for this is that the use of sunlight as an energy source makes this technology safer and greener. The sun is the most abundant, clean, and safe sustainable energy source and about $3 \times 10^{24}$ J of energy is provided by the sun to the earth per year\textsuperscript{32}. In addition, the application of visible light photocatalysts has advantages, such as low cost and simplicity.\textsuperscript{38}

**Coating Material**

The application of this technology is very broad, including in the textile sector. Textiles are used in everyday life and are used to protect the surface of the skin. The application of photocatalysts in textiles can be done
by modifying the textiles through coatings. Many studies have been carried out on textile coatings with various functions. The material is coated on the textile material to perform functions such as degrading harmful organic matter and unwanted contaminants such as bacteria and viruses on the textile surface.39

Table 1: SiO$_2$ Nanoparticles and Their Uses

| No | Size          | Form                                      | Utility                                           | Ref. |
|----|---------------|-------------------------------------------|--------------------------------------------------|------|
| 1. | 135 nm        | Functionalized SiO$_2$ nanoparticles      | The heavy metal adsorbent in waste                | 32   |
| 2. | 20 - 420 nm   | Silica nanoparticles with functionalized surface 3-aminopropyl triethoxysilane (APTES) | Effective additive to obtain weathering-resistant asphalt adhesive | 22   |
| 3. | 190 nm        | Antibody functionalized mesoporous silica nanoparticles | Murine leukemia stem cell (LSC) therapy           | 33   |
| 4. | 24.9 nm and 30.1 nm | Sulphobetain siloxane zwitterion functionalized silica nanoparticles | Antifouling coating system                        | 34   |
| 5. | ~60 nm        | Functionalized mesoporous silica nanoparticles | Prostate cancer therapy                           | 35   |
| 6. | 13 nm         | Silver nanoparticles immobilized silica    | Antibacterial fiber                               | 36   |

Photocatalyst Coating without Modification

TiO$_2$ (Titanium dioxide)

Photocatalytic nanomaterials such as TiO$_2$ are receiving a lot of attention due to their potential applications in environmental remediation.40 This material is a semiconductor photocatalyst that has been widely used because it is relatively efficient, inexpensive, non-toxic, chemically and biologically inert, and has high reactivity under UV light irradiation (< 390 nm).41 However, due to the wide band gap of TiO$_2$ (~3.2 eV), it can only be applied in UV irradiation which is ~5% of solar energy, while visible light contains about 45% of solar energy.38 TiO$_2$ photocatalyst without being able to work on susceptible UV irradiation. Many researches on this have been carried out, one of which is as an antibacterial agent in cellulose fabrics. The results showed that this photocatalyst was able to be active with UV irradiation for 1 hour with 100% degradation percent. However, this photocatalyst is not active in visible light irradiation.42 The development of the research was carried out by adding and modifying TiO$_2$ so that it could be active in visible light irradiation. Modifications made include the addition of organic and inorganic substances.

GO (Graphene oxide)

Graphene oxide (GO) has an -conjugated system due to the presence of a functional group composed of hydroxyl, epoxide, and carboxyl groups. This system allows GO to absorb visible light. This causes GO to be used as a visible light photocatalyst material. Graphene oxide also has several advantages, namely having a large surface area, good electron-carrying ability, and thermal stability. Many studies have been carried out on graphene oxide as a photocatalyst for coatings in textiles. Graphene oxide (GON) nanosheets were coated on the surface of the nonwoven fabric using the elevated temperature padding method (ETPM). With this coating, the coated fabric can effectively degrade the dye compound by 93% in 30 minutes in water.43

ZnO (Zinc Oxide)

ZnO as a photocatalyst has several advantages such as having an appropriate band gap, easy to obtain, functioning as a good UV-protector, biocompatibility, and being cheap. Research using ZnO photocatalyst as a coating on cotton fabrics has been carried out. In this study, methylene blue was used to assess the self-cleaning properties. The degradation efficiency of methylene blue of ZnO-coated cloth under solar irradiation at different times to determine the self-cleaning properties of ZnO-coated cloth. At this stage, ZnO was still active in the UV range and showed good degradation of methylene blue but experienced a slight decrease in activity after washing 10 times with light irradiation.44

Modified TiO$_2$ (Titanium dioxide)

It is necessary to make some modifications to TiO$_2$ to reduce the band gap in the photocatalyst. Modifications are carried out in many ways, including doping or composite of TiO$_2$ with other materials,

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including the use of SiO$_2$. Many studies on this subject have been carried out and will be described in this subsection. Research by modifying TiO$_2$ photocatalyst with inorganic compounds in the form of elements has been carried out. Research conducted by Barmeh et al. succeeded in doping Ni on TiO$_2$ thin film TiO$_2$ under visible light. TiO$_2$ thin films were prepared using the spray coating method. The results show that TiO$_2$ thin film has visible light photocatalytic activity and hydrophobic properties of TiO$_2$ thin film of olive oil and water contact angle.$^{45}$

In Fig.-1 Ni$^{2+}$ ions enter and fill the interstitial into the TiO$_2$ lattice. Dopants Ni succeeded in reducing the absorption spectrum from TiO$_2$ to 2.48 eV so that it has photocatalytic properties of visible light. Thus the photocatalytic activity and hydrophilicity under visible light were successfully carried out.$^{45}$ In another study, TiO$_2$ was modified with chloride ions using neoprene as a binder and coated on a layered cloth. The added chloride ion can able to replace the oxygen atom in TiO$_2$. This modification was able to increase the absorption of visible light and the photocatalytic activity of the composite-coated fabric against RhB and MB dyes for 50 minutes were 95.2% and 96.0% respectively and could be recycled for 8 cycles.$^{46}$

![Fig-1: Water Droplets on a Thin Layer of TiO$_2$ Contaminated with Olive Oil Before (left) and after (right) Visible Irradiation, (a) Undoped, and (b) Ni Doped$^{45}$](image1)

Reactive oxygen produced such as h$^+$, •OH, •O$_2^-$ are involved in photocatalytic oxidation of dyes. The composite-coated fabric showed excellent degradation performance for cationic dyes because Cl-TiO$_2$ electrostatically adsorbed cationic dyes, enhancing photosensitization and promoting dye degradation (Fig-2). Apart from Ni and Cl, elemental Ag has also been modified in TiO$_2$. Ag-TiO$_2$ composites coated on the surface of coated fabrics had an increased degradation of methylene blue stains compared to untreated fabrics. In this study, the element Au was also used to modify TiO$_2$ in coated fibers. The results showed that the layered fabric had better degradation activity against Congo red dye than without treatment.$^{47}$ Photocatalytic TiO$_2$ coated with fluorescent carbon nanoparticles (NPs) also provides organic pollutant decomposition activity on various substrates. Protection of visible light photocatalysts can improve photocatalytic efficiency and capability.$^{48}$ Nitrogen-doped Degussa P25 TiO$_2$ coated carbon was successfully immobilized on a glass plate using epoxidized natural rubber (ENR-50) and polyvinyl chloride.
(PVC) as organic binders. Its photocatalytic activity was studied by means of photocatalytic degradation of 2,4-dichlorophenoxyacetic acid under a fluorescent lamp of 45W visible light with an average percent degradation of 99.18 ± 0.54%.\textsuperscript{49} In this discussion, it can be concluded that the addition of species in the form of elements is proven to be able to make TiO\textsubscript{2} photocatalysts in visible light absorption and can be used in the textile sector.\textsuperscript{25} Modification of TiO\textsubscript{2} with metal oxides provides many promising opportunities due to its abundance. One of them is the synthesis of Cu\textsubscript{x}/TiO\textsubscript{2} photocatalyst as an antiviral.\textsuperscript{51} Research that covers the use of metal oxides is very broad, involving metal oxides with different spatial dimensions. Research by modifying TiO\textsubscript{2} with 1-dimensional metal oxide material, namely ZnO Nanorods (ZnO: 1 NRs/TiO\textsubscript{2}) on the surface of the film has been investigated.\textsuperscript{52} Another study using 1-dimensional materials was conducted by Momeni and Ghayeb (2016) who succeeded in synthesizing modified TiO\textsubscript{2} and WO\textsubscript{3}/TiO\textsubscript{2} nanotubes by the electrochemical anodizing method.\textsuperscript{53} TiO\textsubscript{2} modification is also carried out by using more than one supporting component. Research by Guan \textit{et al.} synthesized Ag/AgCl/ZIF-8/TiO\textsubscript{2} photocatalyst and coated it on the surface of cotton cloth through a simple method to make a visible-light photocatalyst composite.\textsuperscript{54} Photocatalyst modification using organic compounds has also been carried out. Research conducted by Kim \textit{et al.} succeeded in synthesizing visible light photocatalyst TiO\textsubscript{2} modified with porphyrin (TCPP, TCNPP, TPyP) deposited on a hydrophilic self-cleaning cloth. The addition of polyethylene terephthalate (PET) was also carried out to assist the degradation of a Rhodamine dye in the fabric. The results show that PET/TiO\textsubscript{2}/TCPP samples have the best degradation efficiency.\textsuperscript{55} Then amine-covered TiO\textsubscript{2} nanoparticles synthesized using tetra butyl titanate and amino polymers on functional cotton fabrics were also carried out. The antibacterial activity of the modified cotton fabric shows excellent antibacterial properties and good photocatalytic degradation of methylene blue.\textsuperscript{56}

**GO (Graphene Oxide) Modified**

Modifications to graphene oxide have also been investigated. One of them was research by Qi \textit{et al.} which modified GO with the oxide compound SnO\textsubscript{2-x} prepared using the hydrothermal method. In addition, the SnO\textsubscript{2-x}/GO modified cotton fabric exhibits highly efficient and durable self-cleaning activity. In addition, the mechanism for the photocatalytic activity of SnO\textsubscript{2-x}/GO Modification of GO using elements is also done.\textsuperscript{57} Nitrogen-doped graphene quantum Dots (N-GQDs) exhibit good properties as photocatalysts due to their high stability, catalytic activity, and biocompatibility. Nitrogen doping is intended to reduce the bandgap N-GQDs, thus enabling the formation of photocatalysts that are active in visible light to degrade methylene blue dye. The N-GQD photocatalyst showed photocatalytic activity which successfully degraded 93% of the dye within 90 minutes.\textsuperscript{58}

**Table-2: Material for Self-Cleaning on Fabric or Substrate**

| No | Material          | Cloth          | Activity                        | Irradiation         | %Degradation | Ref. |
|----|------------------|----------------|---------------------------------|---------------------|--------------|------|
| 1. | TiO\textsubscript{2} | Cellulose fabric | Antibacterial agent            | UV                  | 100%         | 38   |
| 2. | Ni-TiO\textsubscript{2} | Thin movie     | Photocatalytic activity and hydrophilicity | Visible light      | Significant  | 45   |
| 3. | TiO\textsubscript{2}-Cl | Quilted fabric | RhB and MB dye degradation      | Visible light       | 95.2% and 96.0% | 59   |
| 4. | Ag-TiO\textsubscript{2} | Quilted fabric | Methylene blue stain degradation | Solar Irradiation   | Significant  | 47   |
| 5. | Ag/Au-TiO\textsubscript{2} | Quilted fabric | \textit{Escherichia coli, Staphylococcus aureus, and Pseudomonas aeruginosa} bacteria | Solar Irradiation   | Significant  | 47   |
| 6. | N-TiO\textsubscript{2} | ENR-50         | 2,4-dichlorophenoxyacetic acid degradation | Visible light       | 99.18 ± 0.54% | 49   |
| 7. | Cu\textsubscript{x}/TiO\textsubscript{2} | Coating material | Antivirus                      | Visible light       |              | 51   |
| 8. | ZnO NRs/TiO\textsubscript{2} | Film          | RhB degradation               | Visible light       | 97%          | 52   |
Photocatalyst Modification with SiO₂

Research on the use of SiO₂ in textiles has been carried out for various purposes in increasing photocatalytic efficiency and revealing the characteristics of the SiO₂ coating media. This study aims to improve the photocatalytic efficiency and durability of functional cotton polyester fabric coated with TiO₂/SiO₂ nanoparticles. The coating is done using the sonochemical method. The nanoparticles formed during sonochemical irradiation according to the hydrolysis and polycondensation reactions in Fig-3. In the sonosynthesis of nano-TiO₂/SiO₂ composites, the acoustic cavitation process can produce transient localized heat zones with very high temperatures and pressures. This rapid change can cause sonolysis of water to form OH and H radicals.  

In this study, differences in the hydrophobicity properties of composite-coated fabrics were produced. Figure-4 shows the shorter water droplet absorption time on TiO₂/SiO₂ coated fabrics compared to pure TiO₂ coated fabrics. The results show that the TiO₂/SiO₂-coated cloth has excellent self-cleaning and antibacterial properties even after 30 washings. Apart from that, the coating does not significantly affect the quality of the textile treated such as tensile strength, whiteness index, ventilation property, and surface roughness. Several studies have also compared unmodified TiO₂ with TiO₂-SiO₂ composites to find out whether SiO₂ has a good enough role as a supporting material for TiO₂ for its antibacterial application. TiO₂ samples with an average particle size of about 30 nm were larger than TS10 about 20 nm and A4TS10 about 20 nm. The composite phenomenon can be explained that the SiO₂ network that can inhibit the growth of TiO₂ particle size. The results show that the composite performance is better than TiO₂ alone. Then the results were re-optimized by adding Ag so that the antibacterial activity produced under simulated sunlight
was able to degrade within 30 minutes. Then the addition of SiO$_2$ to the TiO$_2$ photocatalyst was also compared to its performance with commercial TiO$_2$ Degussa P25 TiO$_2$. The results show that the composite has 3 times better activity than Degussa P25 TiO$_2$. The research continued with the addition of other components such as the research conducted by Gao et al. who succeeded in making a self-cleaning substrate coated with a TiO$_2$-modified visible light photocatalyst with SiO$_2$ and GO. This research into composites has great potential for commercialization.

The use of SiO$_2$ and GO compounds as supporting materials for BiVO$_4$ by using reduced GO (RGO). Photocatalyst BiVO$_4$/SiO$_2$/reduced graphene oxide (RGO) was synthesized by hydrothermal method and coated on cotton cloth. The results showed excellent photocatalytic activity in degrading CI Reactive Blue 19 under visible light irradiation. The dimensional shape of the compound has been shown to be able to affect performance. This is explained in the study of Zhao et al. who succeeded in synthesizing a hollow hybrid ball of SiO$_2$/TiO$_2$ inserted with Ag using a two-step hydrothermal method. Recent research that we have done previously regarding the use of SiO$_2$ from nature is used as supporting material for TiO$_2$. Furthermore, modification of TiO$_2$ using SiO$_2$ material to increase photocatalytic activity shows high thermal stability and mechanical strength, and increases the surface active site of the photocatalyst. Another advantage of the mixed TiO$_2$/SiO$_2$ oxide is that it inhibits TiO$_2$ agglomeration and transformation from anatase. This research is devoted to the application of SiO$_2$ from the sand as a substitute for SiO$_2$ synthetic in the field of photocatalyst supporting material.

**Table-3: SiO$_2$ as a Supporting Material for Self-Cleaning on Fabrics Substrates**

| No | Material      | Cloth         | Activity                                                                 | Irradiation      | % Degradation       | Ref |
|----|---------------|---------------|--------------------------------------------------------------------------|------------------|---------------------|-----|
| 1  | TiO$_2$/SiO$_2$ | Cotton/ polyester | Removal of methylene blue dan antibacterial against *E. Coli* and *S. aureus* | UV Before UV, After UV | Significant 97.7% and 96.5% 99.2% and 98.8% | 60  |
| 2  | TiO$_2$-SiO$_2$ | Polymer       | Superhydrophilic properties                                              | -                | Less than a 5° water contact angle | 67  |
| 3  | TiO$_2$-SiO$_2$ | Thin film     | Composition on cell adhesion and antibacterial activity                  | Solar irradiation | Over 92 wt%         | 68  |
| 4  | BC-SiO$_2$-TiO$_2$-Ag | Membranes | Violet dye                                                               | UV               | Degrading 97% of the dye | 69  |
POLYESTER MASK COATING

Polyester fibers are widely used in ready-to-use products because of their excellent performance such as the ability to control the morphology of the fiber (crystalline and non-crystalline distribution and connectivity of the unit load) thus allowing the balance of thermal stability and its dimensional, transport, and mechanical properties to be precisely controlled. Polyester fabric has a porous and corrugated structure making it suitable for use as a substrate. Liu et al. mentioned the dispersion of P(St-MAA) poly(styrene-co-methacrylic acid) can be adsorbed constantly on the fiber surface, and fill the empty space between the fibers, then form an orderly photonic crystal structure on the polyester fabric. Polyester primers can interact chemically with various metal oxides through the formation of carboxylate bonds. Polyester is also used by Xu et al. as a suitable template for the fabrication of TiO$_2$ microtubes (consisting of TiO$_2$ nanowires).

The hydrophilic nature of polyester can be the reason polyester is used for gas separation on an industrial scale by adding graphene oxide suspension to the polyester fabric as a substrate by spray coating technique. The spray coating technique was used to make graphene oxide membranes from dilute graphene oxide dispersions, and this technique has been shown to reduce the extrinsic wrinkles formed. This results in reduced porosity in the inner layer.

Table-4: Types of Masks and Their Properties

| No | Mask                                                                 | Nature                                                                 | Ref. |
|----|----------------------------------------------------------------------|------------------------------------------------------------------------|------|
| 1  | Laser-induced graphene mask on non-woven fabric                      | Hydrophobic, photothermal (>85°C), antibacterial.                       | 79   |
| 2  | Curcumin longa and Alllium Cepa essential oil mask                   | Antivirus, easy to breathe and scented.                                 | 80   |
| 3  | Electrospun ultrafine fiber-based mask                               | Good particle filtration performance and potentially reusable.         | 59   |
| 4  | Laser-induced graphene mask on non-woven fabric                      | Superhydrophobic, photothermal (>80°C), can be recycled directly.      | 81   |
| 5  | TiO$_2$/chlorophyll composite mask                                    | Good photocatalytic bactericidal performance.                          | 82   |
CONCLUSION

Transmission of COVID-19 can be caused by aerosol particles from infected patients through respiratory inhalation or other body fluids. Based on the literature, silica has various advantages as a supporting material to optimize the use of masks. The abundance of natural silica availability and the large influence on the material allows the photocatalyst to have better activity. The inhibition of agglomeration allows the photocatalyst with natural silica as supporting material to enlarge the outer surface of the contact area with the virus on the mask. In addition, it produces high thermal stability and mechanical strength, as well as increasing the surface-active site. Silica has been shown to contribute to microbial degradation. Therefore, further studies on the use of natural silica as a photocatalyst support material for coating cloth masks are needed to increase its functionality.

ACKNOWLEDGEMENT

This work was supported by Riset Data Pustaka dan Daring (RDPD) Universitas Padjadjaran to Diana Rakhmawaty Eddy (ID: 1959/UN6.3.1/PT.00/2021), the Academic Leadership Grant (ALG) to Iman Rahayu (ID: 1959/UN6.3.1/PT.00/2021), and Indonesian Ministry of Research, and by the Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT) to Diana Rakhmawaty Eddy (ID: 1207/UN6.3.1/PT.00/2021).

REFERENCES

1. U. Masashi, K. Yonemitsu, Y. Momose, Y. Ishii, K. Tateda, T. Inoue, et al., *Biocontrol Science*, **26**(2), 119(2021), https://doi.org/10.4265/bio.26.119
2. V. Doremalen, T. Bushmaker, D.H. Morris, M.G. Holbrook, A. Gamble, B.N. Williamson, et al. *The New England Journal of Medicine*, **382**, 1564(2020), https://doi.org/10.1056/nejmc2004973
3. S. Khaiboullina, T. Uppal, N. Dhabarde, V. R. Subramanian, S. C. Verma, *Viruses*, **13**(1), 19(2021), https://doi.org/10.3390/v13010019
4. A. Luthfiah, Y. Deawati, Firdaus, L.M., Rahayu, I., Eddy, D. R. *Science and Technology Indonesia*. **6**(3), 144(2021), https://doi.org/10.26554/sti.2021.6.3.144-155
5. M. C. Gonçalves, *Molecules*, **23**(8), 2021(2018), https://doi.org/10.3390/molecules23082021
6. M. F. Fakoya, S. N. Shah, *Petroleum*, **3**(4), 391(2017), https://doi.org/10.1016/j.petlm.2017.03.001
7. F. D. M. Daud, M. H. Johari, A. H. A. Jamal, N. A. Z. Kahlib, A. L. Hairin, *AIP Conference Proceedings*, **2068**, 1(2019), https://doi.org/10.1063/1.5089301
8. P. Singh, S. Srivastava, S. K. Singh, *ACS Biomaterials Science & Engineering*, **5**(10), 4882(2019), https://doi.org/10.1021/acsbiomaterials.9b00464
9. P. G. Jeelani, P. Mulay, R. Venkat, C. Ramalingam, *Silicon*, **12**(6), 1337(2020), https://doi.org/10.1007/s12633-019-00229-y
10. L. Li, W. Wang, J. Tang, Y. Wang, J. Liu, L. Huang, Y. Wang, F. Guo, J. Wang, W. Shen, L.A. Belfiore, *Nanoscale Research Letters*, **214**, (2019), https://doi.org/10.1186/s11671-019-3006-y
11. N. J. Saleh, R. I. Ibrahim, A. D. Salman, *Advanced Powder Technology*, **26**(4), 1123(2015), https://doi.org/10.1016/j.apt.2015.05.008
12. Y. Tzeng, R. Chen, J. L. He, *Nanomaterials*, **10**(12), 1(2020), https://doi.org/10.3390/nano10122467
13. A., Mehmood, H. Ghafar, S. Yaqoob, U. F. Gohar, B. J. Ahmad, *Journal of Developing Drugs, 6**(2), 174(2017), http://dx.doi.org/10.4172/2329-6631.1000174
14. L. Hosseini, R. Moreno-Atanasio, F. Neville, *Langmuir*, **35**(24), 7896(2019), https://doi.org/10.1021/acs.langmuir.9b00639
15. Y. Zhang, K. Xia, X. Liu, Z. Chen, H. Du, X. J. Zhang, *Journal of the Taiwan Institute of Chemical Engineers*, **102**, 1(2019), https://doi.org/10.1016/j.jtice.2019.05.005
16. F. Hagemans, R.K. Pujala, D.S. Hotie, D.M.E. Thies-Weesie, D.A.M. De Winter, J.D. Meeldijk, A. Van Blaaderen, A. Imhof, *Chemistry of Materials*, **31**(2), 521(2019), https://doi.org/10.1021/acs.chemmater.8b04607
17. W. Wang, P. Wang, X. Tang, A. A. Elzatahry, S. Wang, D. Al-Dahyan, M. Zhao, C. Yao, C. Hung, X. Zhu, T. Zhao, X. Li, F. Zhang, D. Zhao, *ACS Central Science*, 3(8), 839(2017), https://doi.org/10.1021/acscentsci.7b0025
18. V., Shirshahi, M. Soltani, *Contrast Media & Molecular Imaging*, 10(1), 1(2015), https://doi.org/10.1002/cmmi.1611
19. N. Parthasarathi, M. Prakash, and K. S. Satyanarayanan, *Rasayan Journal of Chemistry*, 10(2), 442(2020), https://doi.org/10.1016/j.eti.2020.101031
20. F. D. M. Daud, N. A. M. Azmy, M. S. Mahmud, N. Sarifuddin, H. H. Mohd Zaki, *Materials Science Forum*, 1010, 501(2019), https://doi.org/10.1063/1.5089301
21. G. Żyła, J. Fal, *Thermochimica Acta*, 650, 106(2017), https://doi.org/10.1016/j.tca.2017.02.001
22. V. Vaibhav, U. Vijayalakshmi, S. M. Roopan, *Spectrochimica Acta, Part A: Molecular and Biomolecular Spectroscopy*, 139, 515(2015), https://doi.org/10.1016/j.saa.2014.12.083
23. E. Smiechowicz, B. Niekraszewicz, M. Strzelinska, M. Zielecka, *Autex Research Journal*, 20(4), 441(2020), https://doi.org/10.33369/aut-2020-0036
24. I. Nath, J. Chakraborty, P.M. Heynderickx, F. Verpoort, *Applied Catalysis B: Environmental*, 227, 102(2018), https://doi.org/10.1016/j.apcatb.2018.01.032
25. B. Zhang, H. Tan, W. Shen, G. Xu, B. Ma, X. Ji, *Cement and Concrete Composites*, 92, 7(2018), http://dx.doi.org/10.1016/j.cemconcomp.2018.05.012
26. A. Truppi, P. Petronella, T. Placido, M. Striccoli, A. Agostiano, M.L. Curri, R. Comparelli, *Catalysts*. 7(4), 100 (2017), https://doi.org/10.3390/catal7040100
41. N. T. Hoang, A. Thi, K. Tran, N. Van Suc, T. Nguyen, *Material Research Bulletin*. 3, 339(2015), https://doi.org/10.3934/matersci.2016.2.339
42. N. De Vietro, A. Tursi, A. Beneduci, F. Chidichimo, A. Milella, F. Fracassi, E. Chatzisymeon, G. Chidichimo, *Photochemical and Photobiological Sciences*, 18(9), 2248(2019), https://doi.org/10.1039/C9PP00050J
43. R. Panhwar, I.A. Sahito, A. Khatri, K.C. Sun, *Materials Chemistry and Physics*, 262, 124294 (2021), https://doi.org/10.1016/j.matchemphys.2021.124294
44. C. Zhu, J. Shi, S. Xu, M. Ishimori, J. Sui, H. Morikawa, *Cellulose*, 24(6), 2657(2017), https://doi.org/10.1007/s10570-017-1289-7
45. A. Barmeh, M. R. Nilforoushan, S. Otroj, *Thin Solid Films*, 666, 137(2018), https://doi.org/10.1016/j.tsf.2018.09.007
46. Z. Cao, T. Zhang, P. Ren, D. Cao, Y. Lin, L. Wang, B. Zhang, X. Xiang, *Catalysts*, 10(1), 69(2020), https://doi.org/10.3390/catal10010069
47. J. Jaksik, P. Tran, V. Galvez, I. Martinez, D. Ortiz, A. McEntee, E.M. Durke, S.T.J. Aishee, M. Cua, A. Touhami, H.J. Moore, M.J. Uddin, *Journal of Photochemistry and Photobiology A: Chemistry*, 365, 77(2018), https://doi.org/10.1016/j.jphotochem.2018.07.037
48. Y.K. Kim, S.M. Sharker, I. In, S.Y. Park, *Carbon*, 103, 412(2016), https://doi.org/10.1016/j.carbon.2016.03.036
49. N.A. Sabri, M.A. Nawi, W.I. Nawawi, *Optical Materials*, 48, 258(2015), https://doi.org/10.1016/j.optmat.2015.08.010
50. E. Pakdel, W.A. Daoud, S. Seyedin, J. Wang, J.M. Razal, L. Sun, X. Wang, *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, 552, 130(2018), https://doi.org/10.1016/j.colsurfa.2018.04.070
51. M. Miyauuchi, K. Sunada, K. Hashimoto, *Catalysts*, 10(9), 1093(2020), https://doi.org/10.3390/catal10091093
52. Y. Wang, Y.Z. Zheng, S. Lu, X. Tao, Y. Che, J.F. Chen, *ACS Applied Materials and Interfaces*, 7(11), 6093(2015), https://doi.org/10.1021/acsami.5b00980
53. M.M. Momeni, Y. Ghayeb, *Ceramics International*, 42(6), 7014(2016), https://doi.org/10.1016/j.ceramint.2016.01.089
54. X. Guan, S. Lin, J. Lan, J. Shang, W. Li, Y. Zhan, H. Xiao, Q. Song, *Cellulose*, 26(12), 7437(2019), https://doi.org/10.1007/s10570-019-02621-8
55. H. Kim, R. Manivannan, G. Heo, J.W. Ryu, Y. Son, *Research on Chemical Intermediates*, 45, 3655(2019), https://doi.org/10.1007/s11164-019-03813-4
56. G. Zhang, D. Ji, H. He, S. Ramakrishna, *Materials Science and Engineering R: Reports*, 143, 100594 (2021), https://doi.org/10.1016/j.mser.2020.100594
57. Z. Qi, K. Wang, Y. Jiang, Y. Zhu, X. Chen, Q. Tang, Y. Ren, C. Zheng, D. Gao, C. Wang, *Cellulose*, 26(16), 8919(2019), https://doi.org/10.1007/s10570-019-02662-z
58. R. Riaz, M. Ali, I.A. Sahito, A.A. Arbab, T. Maiyalagan, A.S. Anjum, M.J. Ko, S.H. Jeong, *Applied Surface Science*, 480, 1053(2019), https://doi.org/10.1016/j.apsusc.2019.02.228
59. Z. Zhang, D. Ji, H. He, S. Ramakrishna, *Materials Science and Engineering R: Reports*, 143, 100594 (2021), https://doi.org/10.1016/j.mser.2020.100594
60. W. Di Li, J. Gao, L. Wang, *Journal of Industrial Textiles*, 46(8), 1633(2017), https://doi.org/10.1177%2F1528083716629138
61. H.V. Dang, V. M. Le, H. A. Hoang, *International Conference on Chemical Engineering, Food and Biotechnology*, 020025 (2017), https://doi.org/10.1063/1.5000193
62. C. Anderson, A. J. Bard, *The Journal of Physical Chemistry*, 99(24), 9882(1995), https://doi.org/10.1021/j100024a033
63. J. Gao, W. Li, X. Zhao, L. Wang, N. Pan, *Textile Research Journal*, 89(4), 517(2019), https://doi.org/10.1177%2F0040517517750647
64. B. Liu, L. Lin, D. Yu, J. Sun, Z. Zhu, P. Gao, W. Wang, *Cellulose*, 25(2), 1089(2018), https://doi.org/10.1007/s10570-017-1628-8
65. W. Zhao, L. Feng, R. Yang, J. Zheng, X. Li, *Applied Catalysis B*, 1(3), 181(2011), https://doi.org/10.1016/j.apcatb.2011.01.025
66. D. R. Eddy, S.N. Ishmah, M.D. Permana, M. L. Firdaus, *Catalysts*, 10, 1248(2020), https://doi.org/10.3390/catal10111248
67. A.R. Vázquez-Velázquez, M.A. Velasco-Soto, S.A. Pérez-García, L. Licea-Jiménez, *Nanomaterials*. 8(6), (2018), https://doi.org/10.3390/nano8060369
68. B. Erdural, U. Bolukbasi, G. Karakas, *Journal of Photochemistry and Photobiology A: Chemistry*, 283, 29(2014), http://dx.doi.org/10.1016/j.jphotochem.2014.03.016
69. K.U. Rahman, E.P. Ferreira-Neto, G.U. Rahman, R. Parveen, A.S. Monteiro, G. Rahman, Q. Van Le, R.R. Domenequetti, S.J.L. Ribeiro, S. Ullah, *Journal of Environmental Chemical Engineering*, 104708(2020), https://doi.org/10.1016/j.jece.2020.104708
70. A. Ojstršek, D. Fakin, *Coatings*, 9(9), 4(2019), https://doi.org/10.3390/coatings9090545
71. T. Yuranova, R. Mosteo, J. Bandara, D. Laub, J. Kiwi, *Journal of Molecular Catalysis A: Chemical*. 244(1–2), 160(2006), https://doi.org/10.1016/j.molcata.2005.08.059
72. S., Landi, H. Aziza, S. Chandren, *Journal of Engineering and Technological Sciences*, 7, 113(2016), https://doi.org/10.11113/jt.v7n113.
73. Y. Rilda, F. Syukri, Alif, H. Aziza, S. Chandren, *Journal of Engineering and Technological Sciences*, 7, 113(2016), https://doi.org/10.11113/jt.v7n113.
74. M. Jaffe, A.J. Easts, X. Feng, The Textile Institute Book Series. Woodhead Publishing, 2020, 133(2020), https://doi.org/10.1016/B978-0-08-100572-9.00008-2
75. G. Liu, L. Zhou, Q. Fan, L. Chai, J. Shao, *Journal of Materials Science*, 51(6), 2859(2016), https://doi.org/10.1007/s10853-015-9594-8
76. L.I. Fockaert, S. Pletincx, D. Ganzinga-Jurg, B. Boelen, T. Hauffman, H. Terryn, J.M.C. *Applied Surface Science*, 508, 144771(2020), https://doi.org/10.1016/j.apsusc.2019.144771
77. Y. Xu, W. Wen, J.M. Wu, *Journal of Hazardous Materials*, 343, 285(2018), https://doi.org/10.1016/j.jhazmat.2017.09.044
78. K., Pal, G.Z., Kyzas, S., Kralj, F. Gomes de Souza, *Journal of Molecular Structure*, 1233, 130100(2021), https://dx.doi.org/10.1016%2Fj.molstruc.2021.130100
79. A., Önal, O., Özbek, S. Nached, *Journal of the Turkish Chemical Society, Section A: Chemistry*, 7(3), 821(2020), https://doi.org/10.18596/jotcsa.788410
80. H. Zhong, Z. Zhu, J. Lin, C.F. Cheung, V.L. Lu, F. Yan, C.Y. Chan, G. Li, *ACS Nano*, 14(5), 6213(2020), https://doi.org/10.1021/acs.nanolett.0c02250
81. X., Pan, W., Dong, J., Zhang, Z., Xie, W., Li, H., Zhang, X., Zhang, P., Chen, W., Zhou, B. Lei, *ACS Applied Materials & Interfaces*, 13(33), 39446(2021), https://doi.org/10.1021/acsami.1c10892
82. L., Huang, S., Xu, Z., Wang, K., Xue, J., Su, Y., Song, S., Chen, C., Zhu, B.Z., Tang, R. Ye, *ACS Nano*, 14(9), 12045(2020), https://doi.org/10.1021/acs.nanolett.0c05330
83. A.F.M. Ibrahim, Y.S. Lin, *Chemical Engineering Science*, 190, 312(2018), https://doi.org/10.1016/j.ces.2018.06.031

[RJC-6932/2020]