A Review-Effect of Double Layer Antireflection Coating to Enhance Photovoltaic Transmittance of Silicon Solar

Asnawi[1]*, T N Faiza[1], C Diningsih[1], M Khoiro[1], and R A Firdaus[1]

[1]Physics Department, Universitas Negeri Surabaya

*asnawi@unesa.ac.id

Abstract. The solar cell is an active element that converts light energy into electrical energy into light energy, with a principle known as the photovoltaic effect. Material selection is an important factor in solar cell fabrication, because good material selection will affect the efficiency of solar cells. At this time 95% of solar cells in the world use silicon material, by doping it only with other materials that are positively or negatively charged will produce a p-n junction. In addition to materials, selection factors and manufacturing processes will also affect the performance of the solar cell. This article reviews advances in the use of materials in the manufacture of solar cells. In particular, this article will focus on doped silicon materials and new techniques applied to solar cell fabrication, including titanium, zinc dioxide and magnesium fluoride either monolayer or doublelayer with sol gel spin coating technique to optimize the transmission value of solar cell panels.

1. Introduction

The greater the level of need for electrical power and the scarcity of fossil fuels is needed an alternative for generating electrical energy. One alternative energy that can be used as renewable energy is solar energy. To utilize solar energy properly, a tool is needed that able to changes of light energy sources into other, such as electrical energy. To replace that power a device known as a photovoltaic or solar cell is needed. But the main obstacle faced is related to the capability"of solar cell" systems [1]. Solar cells are renewable energy that is developing quite rapidly in the world, including Indonesia. Our country has a different climate from other countries, where the sunshine throughout the year with existing natural resources (silica sand) is a gift that must be optimized. Although it has a variety of good benefits, solar cell installation systems installed in open spaces also need to be considered. Because it is not impossible if the solar panels are damaged. Therefore, the use of a glass coating on solar cells is very important to prevent solar cells from being damaged by physical shock and corrosion. The refractive index required for the solar cell glass layer to the air index is 1.52. This difference will result in a low solar panel efficiency value of 8%, this is because the panel efficiency is inversely proportional to the intensity of solar radiation [2-5].

For this reason, it is also a major concern by using anti-reflective arrangement materials to minimize the transmission and usability of solar cells. Several methods are used to make anti-reflective coatings, including chemical vapor deposition, aerosol pyrolysis sputtering, laser abrasion, dip coating and sol gel spin coating [6]. The last of the several methods is currently widely used because it is inexpensive, homogeneous, can be carried out at low temperatures, does not use a room with a high level of vacuum, and the thickness of the coating can be controlled [7]. Sol-gel spin coating is a method for making layers of photoresist polymer materials deposited on the surface of silicon and other flat materials. After the solution is dropped on the substrate, the rotational speed is regulated by centrifugal force to produce a homogeneous thin layer [8].

Titanium dioxide (TiO2) at most for solar cells, photocatalysts and sensors. The advantages of titanium dioxide are that it is non-toxic, widely available and the cost of the manufacturing process is quite cheap and can control corrosion using coating methods [9,10], cleaning films [11], solar cells [12], masks [13], anti-bacterial coatings. [14], and optoelectronic storage devices [15]. Titanium dioxide can form an anti-reflective coating because it provides low absorption at short wavelengths and has a high refractive index [16]. Silica material is one of the best basic materials in solar cell fabrication, this material has attracted the attention of researchers. Research on silica has greatly increased because of the ease of the manufacturing process and the wide use of silica in various industries [17,18]. The guidance of silica material with TiO2 material can increase the acidity and hydrophilicity of the surface. In addition, silica is hydrophobic and transparent inert, has high thermal stability, large specific surface area, and low refractive index [19-21]. The higher the SiO2 concentration, the more transparent the resulting photocatalyst. So, it is necessary to determine the right TiO2-SiO2 composition to obtain optimal results [22]. The base-catalyzed silica anti-reflective coating has high transmission but poor abrasion resistance, whereas the acid-catalyzed silica anti-reflective coating has high abrasion resistance but poor transmittance. Antireflective coatings used for coating solar cells must have high transmittance and abrasion resistance.

In several studies, the reflectance value for the Ar SiO2-SiNx layer with a refractive index of 2.2 is 3.3% and the anti-reflective layer SiO2-Al2SO3 produces a reflectance of 10.8% [23]. Likewise, research conducted by Sharma et al. showed that anti-reflective coatings on TiO2-SiO2 materials can produce an efficiency of 14.55% [24]. In addition to TiO2, SiO2 is also combined with magnesium fluoride (MgF2) which has pores of a linear structure with high bonds between particles, so that it can increase the strength of the film layer [25-26]. Likewise, zinc oxide (ZnO) and SiO2 have a low bandgap or energy bandgap equal to 3.2 eV and have very high photosynthetic and stability, making them suitable for anti-reflection coatings [27]. This study aims to compare composite materials of SiO2-TiO2, SiO2-ZnO, SiO2-MgF2 which were analyzed for their anti-reflection properties as applications in solar cells/photovoltaic.

2. Method

This study uses literature methods from various journals and research articles related to the use of SiO2-TiO2, SiO2-ZnO, SiO2-MgF2 materials. Article searches were carried out using keywords from the journal database indexed through google scholar or research gate (55 articles). After obtaining the full text journals, which were executed for various reasons (40 articles), then the selection of journals with good completeness and in accordance with the research objectives (32 articles) was carried out and finally a review of articles was carried out after being eliminated and in accordance with the research topic as many as 29 article. The results of this article review are then reviewed according to the research objectives, which include analyzed various SiO2-TiO2, SiO2-ZnO, SiO2-MgF2 composite materials using the sol gel spin coating method for photovoltaic applications.

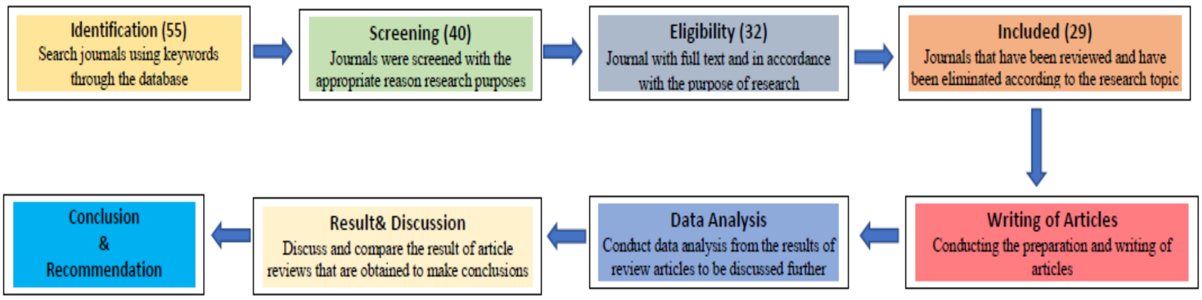
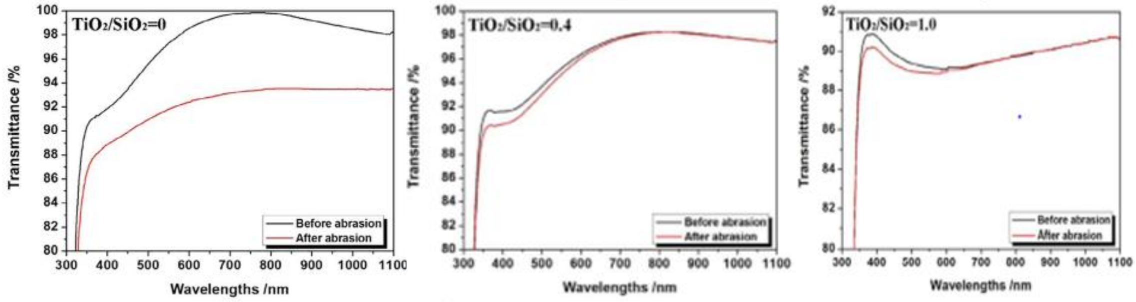


Figure 1. Design of Article Review Research Flow

3. Results and Discussion

3.1. Transmitansi layer of SiO2-TiO2

Abrasion resistance becomes very important for antireflective coatings used outdoors such as PV installations that are resistant to abrasion due to atmospheric conditions and cleaning processes. The transmittance spectrum of the hybrid thin film before and after the abrasion test (Figure 2). The decrease in the maximum transmission value decreased significantly as the weight ratio of titanium dioxide to Silicon dioxide increased which indicated an increase in the abrasion of the hybrid thin film. The maximum transmission is almost unchanged at the titanium dioxide weight ratio of 0.4. This means that the abrasion resistance of material is quite good if the titanium dioxide weight ratio is greater than 0.4. Photocatalytic activity composit material has good oxidation properties, this is because titanium dioxide has the ability to decompose organic substances under UV light. titanium dioxide was combined with Silicon dioxide to prepare the materials hybrid thin film and to keep the surface of the hybrid thin film free from organic contamination.

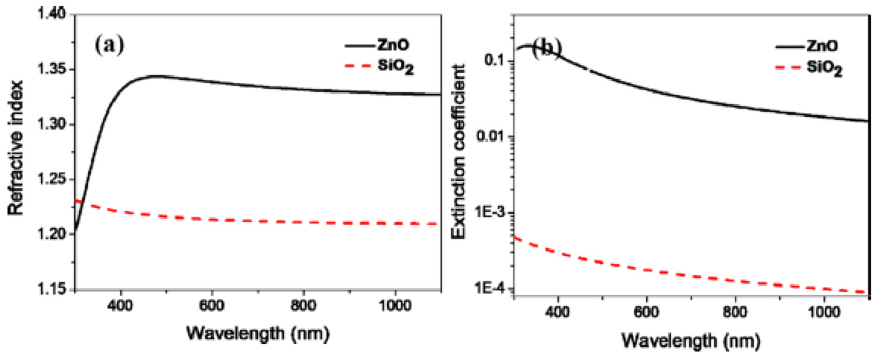


(a) (b) (c)

Figure 2. Transmission Spectrum of SiO2-TiO2 Hybrid Thin Film with Ratios of (a) 0, (b) 0.4 and (c) 1.0 Before and After Abrasion Aesistance Test [25]

3.2. Transmitansi of SiO2-ZnO

The refractive indexes of the"ZnO and SiO2 layers were 1.34 and 1.21 at 550 nm, respectively (Fig. 3 a). In the visible light region, the extinction coefficients of the ZnO and SiO2 layers are less than 0.16 and 0.0005, respectively (Fig. 3b), indicating weak absorption of the layers. The thickness of the ZnO and SiO2 layers can be measured with an ellipsometer and is estimated at 119±4 nm and 91±4 nm, respectively.



(a) (b)

Figure 3. (a) The Refractive Index and (b) the Extinction Coefficient of the SiO2-ZnO Layer [27]

The single layer solar transmission of ZnO in the range of 300-1200 nm and 1200-2500 nm increased by 3.4% and 2.4% compared to glass substrates (SiO2: 5.3% and 3.1%). Maximum transmission appears at around 550 nm. The solar transmittance of the SiO2-ZnO bilayer structure in the 300-1200 nm region was 96.1%, an increase of 6.5%. There is a very wide and relatively flat antireflection band ranging from 470 nm to 900 nm, which can greatly reduce energy loss and further improve efficiency for solar cell applications. The solar transmission of the SiO2-ZnO bilayer in the range of 1200-2500 nm increased by 6.2%, much higher than that of the single layer SiO2 and ZnO. Compared with the single layer SiO2, the SiO2-ZnO bilayer reveals the advantages and importance of capturing solar energy, especially in the infrared region for photovoltaic and thermoelectric solar energy conversion.

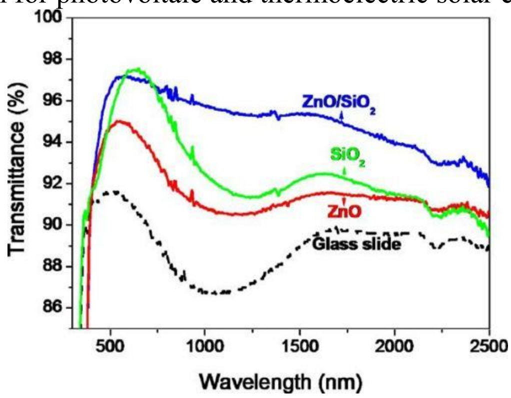


Figure 4. The Transmission Spectra of the Glass Substrate of ZnO, SiO2, and SiO2-ZnO [27]

The reflectance spectra of the glass substrate and the glass substrate coated with ZnO, SiO2 and SiO2-ZnO are shown in Figure 4. “The peak at 360 nm is from the absorption of the glass substrate and at 380 nm is from the intrinsic optical absorption of the ZnO layer. The solar reflectance of the SiO2-ZnO layer in the 300-1200 nm and 1200-2500 nm regions decreased by 6.1% and 4.4%, respectively (ZnO: 2.4% and 0.8%; SiO2: 6.2% and 3.4%)”. The suppression of reflection by the SiO2-ZnO bilayer is enhanced in the solar spectrum compared to the SiO2 single layer.

3.3. Transmittance layer of SiO_2-MgF_2

Based on Figure 5, the spectrophotometric test results for the SiO2-MgF2 layer show excellent optical performance. The average transmission produced by the SiO2-MgF2 layer in the 400-800 nm range is 98.89%. The transmission relative measurement error is known to be within 0.3%. Where the bottom layer is an MgF2 layer with a refractive index of 1.38 and a thickness of 100 nm. The top layer is a nano porous SiO2 layer with a refractive index of 1.12 and a thickness of 123nm. The SiO2-MgF2 bilayer layer exhibits excellent optical properties. Therefore, SiO2-MgF2 films can be used in many fields, such as: as optical devices and solar glass covers [28]. In outdoor applications such as solar cell glass enclosures, high transmission alone is not sufficient. Because many environmental factors significantly affect the performance of the coating such as high temperature, high humidity, wind and sand, and various object collisions. The number of nanopores between the constituent particles for antireflective coating prepared by the sol-gel method can make the optical properties of the film unstable because the antireflective coating”surface is easily damaged. For pure MgF2 sol, a porous network structure will be formed in the layer deposition process, which can make the coating have high porosity and low refractive index.

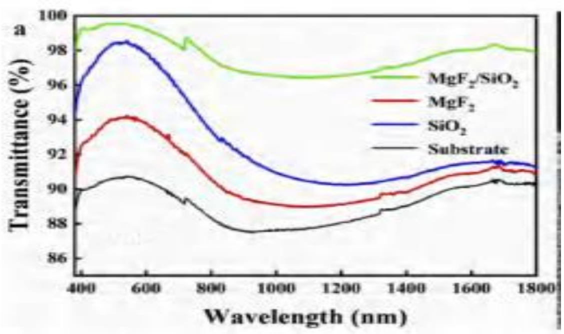


Figure 5. The Transmittance Layer of SiO_2-MgF_2 [2]

However, high porosity can also result in reduced abrasion resistance properties of the film.SiO2-MgF2 composite layer was formed due to the addition of an acid catalyst solution of SiO2 [28]. The SiO2-MgF2 composite layer has lower porosity and denser structure than pure MgF2. Although the top layer of the layer has a loose porous structure due to the low refractive index, the mechanical properties of the top layer layer cannot meet the requirements. However, the hardness level of the undercoat was increased by using a SiO2-MgF2 mixture. When the coating is rubbed, the top layer is easily removed due to its weak mechanical properties. But the undercoat has good mechanical properties, which can make anti reflektive have abrasion resistance [29]. The comparison of transmittance values from the review results regarding the transmittance values of SiO2-MgF2, SiO2-ZnO, SiO2-MgF2 materials, as shown in Table 1.

Table 1. Comparison of Substance Transmittance Value of SiO_2-MgF_2, SiO_2-ZnO, SiO_2-MgF_2

Reference	Material	Methods	Transmitance (%)
[27]	SiO_2-ZnO	Dip Coating Sol Gel	96,1
[28]	SiO_2-MgF_2	Dip Coating	98,9
[25]	SiO_2-TiO_2	Sol Gel	99,7

4. Conclusions and Recommendations

The results of the literature study on the double layer antireflective composite material of silica material with doping is generally quite good in photovoltaics cells, the SiO2-TiO2 composite material has a high transmittance value (97%). Thus, it can be said that these materials can be used as candidates for coatings on solar cells.

Acknowledgments

The author would like to thank the Department of Physics Faculty of Science Universitas Negeri Surabaya for research facilities support so that this research can be carried out well.

References

[1]. Sharma R, Amit G, and Ajit V 2017 *J. Nano Electronic Phys.* **9(1)** 02001
[2]. Zhou G, He J, Gao L, Ren T, and Li T 2013 *RSC Advances* **3(44)** 21789
[3]. Zhang X X, Cai S, You D, Yan L H, Lv H B, Yuan X D, and Jiang B 2013 *Advanced Functional Mater.* **23(35)** 4361-4365
[4]. Prene P, Priotton J J, Beaurain L, and Belleville P 2000 *J. Sol-Gel Scie. Techno.* **19(1)** 533-537
[5]. Zhang L, Qiao Z A, Zheng M, Huo Q, and Sun J 2010 *J. Mater. Chemistry* **20(29)** 6125-6130
[6]. Liang Z, Li W, Dong B, Sun Y, Tang H, Zhao L, and Wang S 2019 *Chemical Phys. Letters* **716** 211-214
[7]. Widodo S 2010 *Seminar Rekayasa Kimia dan Proses* 201-208
[8]. Fitriani F dan Handayani S 2017 *J. Fis. Unand* **6(2)** 156-161
[9]. Linsebigler A L, Lu G and Yates J J T 1995 *Chemical Reviews* **95(3)** 735-758
[10]. Fujishima A, Zhang X, and Tryk D A 2008 *Surf. Sci. Rep.* **63(12)** 515-582
[11]. Pakdel E and Daoud W 2013 *J. Colloid Interface Sci.* **401** 1-7
[12]. Son S, Hwang S H, Kim C, Yun J Y and Jang J 2013 *ACS Appl. Mater. Interfaces* **5(11)** 15-20
[13]. Li Y, Leung P, Yao L, Song Q W, dan Newton E 2006 *J. Hosp. Infect* **62(1)** 58-63
[14]. Evans P and Sheel D W 2007 *Surf. Coatings Technol.* **201(22-23)** 9319-9324
[15]. Saravanan K, Ananthanarayanan K, and Balaya P 2010 *Energy Environ. Sci.* **3(7)** 939-948
[16]. Sali S, Kermadi S, Zougar L, Benzaoui B, Saoula N, Mahdid K, Aitameur F, and Boumaour M 2017 *J. Electr. Engineering.* **68(7)** 24-30
[17]. Li W and Zhao D 2012 *Adv. Mater.* **25(1)** 142-149

[18]. Jankiewicz B J, Jamolia D, Choma J, and Jaroniec M 2012 *Adv. Colloid Interface Sci.* **170(1-2)** 28-47

[19]. Chen Y, Zhong S, Tan M, and Shen W 2017 *Frontiers Energy* **11(1)** 52-59

[20]. Huang H, et al 2018 *Sol. Energy Mater. Sol. Cells* **186** 356-364.

[21]. Preissler N et al 2018 *Physica Status Solidi* (a) **215(14)** 1800239

[22]. Huang C H, Bai H, Liu S L, and Tseng Y H 2011 *Micro Nano Letters* 6**(8)** 646-649

[23]. Diop M M, Diaw A, Mbengue N, Ba O, Diagne M, Niasse O A, Ba B, and Sarr J 2018 *Mater. Scie. Apl.* **9(8)** 205-722

[24]. Sharma R, Amit G, and Ajit V 2017 *J. Nano Electronic Phys.* **9(2)** 02001

[25]. Lin W, Zheng J, Yan L, and Zhan X 2017 *Result Phys.* **8** 532-536

[26]. E. Hecht 2001 *Optics 4th Edition* (Addiso-Wesley Publishing Company- New York)

[27]. Li D, Huang F, and Ding S 2011 *Applied Surface Sci.* **257(23)** 9752-9756

[28]. Sun X, Tu J, Li.L, Zhang W, and Hua K 2020 *Colloids Surfaces A: Physicochemical and Engineering Aspects* **602** 125106

[29]. Sun X, Xu X, Song G, Tu J, Li L, Yan P, Zheng W, and Hu K 2020 *Optical Materials* **101** 109739