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Synthesis of TiO_2 Thin Film with Cobalt Doping Using Sol-Gel Spin-Coating Technique as a Solar Cell Material

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Abstract: Research has been done on thin films by mixing TiO_2 with cobalt doping and adding HCI as a solar cell material. The aim of this research is to produce a thin layer that is good for use in solar cells. This research has several stages, namely: 1) weighing cobalt and titanium; 2) glass substrate preparation; 3) making a sol-gel solution; 4) thin layer deposition; and 5) heating the sample. From these several stages, the result was that a pure TiO_2 solution without doping obtained a thick white solution, whereas the more doping used, the fainter the color of the solution obtained. The thin-layer synthesis process uses a spin-coating method assisted by a modified centrifuge to evenly distribute the sol-gel solution on the surface of the glass substrate.

Keywords: TiO_2 : Cobalt +HCI; solar cells; spin-coating method

Introduction

The ever-increasing human need for energy causes humans to need to look for or process alternative energy to replace the conventional energy that is currently used. Solar energy is an unlimited energy source and will never run out and is used as alternative energy which will be converted into electrical energy (Purwoto, et al., 2018). Sunlight is one of the energy sources used by humans to support various life activities (Amalia & Tamami, 2019; Setiawan et al., 2018). In addition, the sun is the main energy source that emits enormous energy to the earth's surface. In sunny weather, the earth's surface receives around 1000 watts of solar energy per square meter (Manan, 2009).

One of the interesting studies in finding and developing a technology that can make human activities easier is research on thin layers. one type of thin layer is Titanium dioxide. Titanium dioxide (TiO_2) is a semiconductor that is activated using ultraviolet (UV) light because titanium dioxide has a band gap energy of 3.2 eV which corresponds to the wavelength of ultraviolet light (Fujishima *et. al.*, 1997, Linsebigler *et. al.*, 1995). The resulting technology is expected to have good quality and be able to reduce costs in its development. To develop a thin layer, you can basically use organic or inorganic compounds that are semiconducting in nature. Thin layers are usually made by depositing a compound on a medium called a substrate (Abegunde et al., 2019). One area of concern related to research on thin films is the energy sector in the development aspect of solar cell technology (Al-Hossainy et al., 2018; Doyan et al., 2022; Rizaldi et al., 2021).

Thin Film Solar Cell (TFSC) is a type of solar cell developed through the process of adding a thin layer as the basic component of a solar cell (Carron et al. 2019). The development of thin films based on solar cells can

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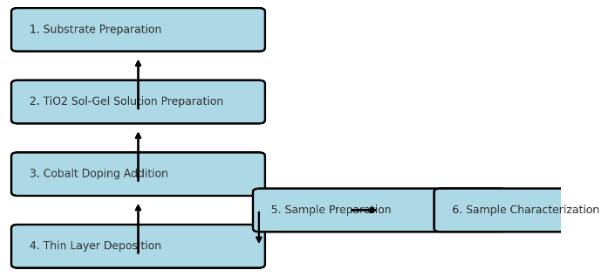
be synthesized using various compounds. Complex compounds are compounds composed of a central metal ion with one or more ligands that donate their free electron pairs to the central metal ion (Fa'izzah & Sugiyarto, 2016).

Based on research conducted by Kalsum U. (2019), when a thin layer of TiO_2 doped with iron (Fe) was synthesized, an increase in the Fe doping concentration increased the photocatalytic ability of the thin layer. The most optimum photocalistic ability was produced by a 3% Fe-TiO_2 thin layer with a reduction in ALB and PV of 45% and 29%, respectively. Therefore, in this research, researchers used a variation of doping in the form of cobalt in the synthesis of TiO_2 in order to make it a solar cell material. Doping is the process of adding impurities to pure semiconductor materials to change their electrical properties (Doyan et al., 2021). Doping adds impurities to semiconductor materials intentionally (Doyan et al. 2018).

A thin layer of TiO_2 precursor material with cobalt doping will be made using the sol-gel spin-coating technique. The use of this technique in the thin film synthesis process is due to several factors, including the fact that the chemical components can be controlled easily, do not require a lot of money, and can be applied to various types of substrates. Of the various types of metal doping such as (Ni, Mg, Co, Fe, Ca and Zn) Co is one that is considered a suitable candidate for inclusion in the TiO2 structure because it is considered capable of reducing the band gap energy of TiO2, thereby causing increased absorption light (Nguyen & Bark, 2020). Based on the description of the problem, researchers are interested in conducting research on "Synthesis and Characterization of TiO_2 Thin Films with Cobalt Doping Using the Sol-Gel Spin-Coating Technique as a Solar Cell Material" as one way to overcome problems arising from the reduction in solar material used as a source of electrical energy.

Method

The process of synthesizing TiO_2 thin films with cobalt doping will be carried out at the Basic Chemistry Laboratory, FMIPA, Mataram University. The tools that will be used include dropper pipettes, beakers, test tubes, digital balances, measuring cups, porcelain cups, double tape, magnetic stirrers, modified centrifuges, ovens, X-ray Diffraction (XRD) brand Shimadzu type 7000 Maxima, Scanning Electron Microscope (SEM) JEOL brand type JSM 6510 LA, Transmission Electron Microscope (TEM) brand HR TEM H9500, and UV-Vis Spectrophotometer type UV Mini 1240. The basic material or precursor that will be used in making the thin layer is Titanium (IV) oxide (TiO_2). The solvent used is ethanol (C_2H_5OH). The material used as doping is Cobalt. The glass substrate measures (10 x 10 x 3) mm. Meanwhile, other materials used to clean the substrate are distilled water, alcohol, and detergent.



Substrate Preparation

The substrate used to make thin layers of TiO_2 is glass. Before being used to make a thin layer of TiO_2, the glass substrate is washed with detergent, then washed with alcohol to remove dust and grease, which can inhibit the attachment of colloidal particles to the substrate. After that, the substrate is dried using tissue. The dry substrate is then stored in a plastic clip to keep it clean; no air should enter the plastic.

Making Thin Layer Samples

The process of synthesizing a thin layer of TiO_2 with cobalt doping on a glass substrate measuring (10 x 10 x 3) mm. The basic TiO_2 material is dissolved in ethanol (C_2H_5OH), which is placed on a magnetic stirrer for ± 30 minutes to obtain a pure TiO_2 sol-gel solution, and cobalt doping is added to produce a TiO_2:cobalt sol-gel solution at varying concentrations (0, 3, 6, 9, and 12%). Then the sol-gel solution was left at room temperature for ± 24 hours before the deposition process was carried out on the glass substrate using a modified centrifuge. The deposition process uses a rotation speed of 100 rpm over a time interval of ± 1.5 minutes. The solution sample that has been deposited is then heated in an oven at 80°C for 30 minutes, and the same treatment is carried out for varying concentrations until a sample of pure TiO_2 and one with cobalt doping is produced.

Characterization of Thin Layer Samples

The next process was to characterize the crystal structure using X-Rays Difraction (XRD), morphology using Scanning Electron Microscopic (SEM) at BRIN Bandung, and optical properties using a UV-Vis Spectrophotometer at the UIN Mataram Laboratory.

Result and Discussion

This research was carried out to produce solar cell materials using glass substrate samples. This research was carried out using a spin-coating technique using a modified centrifuge. According to Doyan et al. (2017), this method can be used to grow (synthesize) thin layers on various shapes of substrates but has drawbacks related to the resulting thickness, which cannot be controlled optimally.

In the research, there are several processes, namely glass substrate preparation and making thin layer samples. Before entering this stage, prepare the tools and materials used. The materials used, such as titanium and cobalt, will be weighed based on concentration. In this study, 5 concentrations were used, namely (0, 3, 6, 9, and 12)%, with varying masses.

Table 1. Quantity of Materials Forming TiO_2 Thin Films

Concentration (%)	Titanium (gr)	Kobalt (gr)	HCl (ml)	Etanol (ml)
0	2	0	20	20
3	1.94	0.06	20	20
6	1.88	0.12	20	20
9	1.82	0.18	20	20
12	1.76	0.24	20	20

The following is a picture of the preparation process for the materials used to make the sol-gel solution.

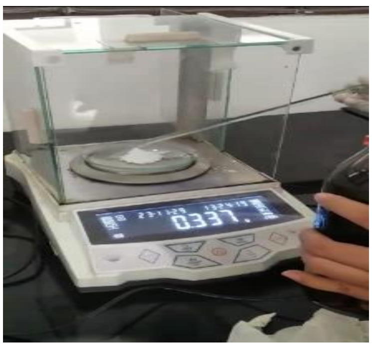


Figure 1. Process of Weighing Titanium and Cobalt

The initial stage in this research is glass substrate preparation. Prepare glass measuring (10 x 10 x 3) mm. then the glass substrate is cleaned using detergent, then distilled water, and dried using tissue before storing. The process of cleaning the glass substrate aims to ensure that the glass being cleaned is not dirty or dusty, which could affect the sticking of the sol-gel solution unevenly if influenced by other particles. The process of drying the glass substrate before storing aims to obtain a good sample because the drier the glass substrate, the better the thin layer sample obtained. The glass produced is a container for the sol-gel solution, which will be used in the deposition process using a modified centrifuge. The purpose of glass preparation is to clean the glass from adhering dirt so that the resulting glass is clean. The function of using distilled water is to clean the glass from dirt so that it does not interfere with the glass surface coating process. Apart from distilled water, washing glass also uses an ethanol solution, which functions to remove impurities such as dirt from cutting glass and to sterilize the glass surface from bacteria that can interfere with the coating process (Putri & Kartika, 2020).

The next stage is to make a sol-gel solution by dissolving all the ingredients in ethanol (C_2H_5OH). Making the solution begins by mixing cobalt with HCl, which is added with a stirrer so that the ingredients are mixed and heated using an MSH-300 magnetic stirrer for 20 minutes. The heated solution was added to ethanol and titanium for 30 minutes to obtain a homogeneous solution. The aim of stirring the solution in a glass using a magnetic stirrer is so that all the ingredients mixed can become a homogeneous mixture and do not settle (Tebriani, Syukri, & Dahyunir., 2013). The following is a picture of pure titanium with added cobalt doping resulting from the solution-making process.

Figure 2. Process for Making Sol-Gel Solution

Figure 3. TiO_2 Solution with Concentrations of (0, 3, 6, 9, 12)%

From this image, it can be seen that there is a color difference between the solution with cobalt doping and the solution without doping. The pure TiO_2 solution without cobalt doping has a white color, while the solution added with cobalt doping has a darker color. It was found that the higher the amount of doping used, the clearer the resulting solution, and conversely, the lower the doping used, the darker the resulting color. Cobalt is a hard but brittle metal, bluish white in color, not very reactive, and dissolves in dilute mineral acids very slowly (Considine, 1981).

After obtaining the sol-gel solution, deposition will be carried out on the glass substrate using a modified centrifuge. This process uses double-sided tape as a glass adhesive, and the glass is rotated based on the same concentration so that the solution on the glass surface does not mix. The glass that has been attached to the modified centrifuge will be dripped with ±10 drops of sol-gel solution until it covers the entire surface of the glass, then rotated at a rotational speed of 100 rpm for 1.5–2.0 minutes. The use of a modified centrifuge tool ensures that the sol-gel solution is evenly distributed on the surface of the glass substrate (Chandramohan et al., 2017). The following is a picture of the deposition process using a modified centrifuge.

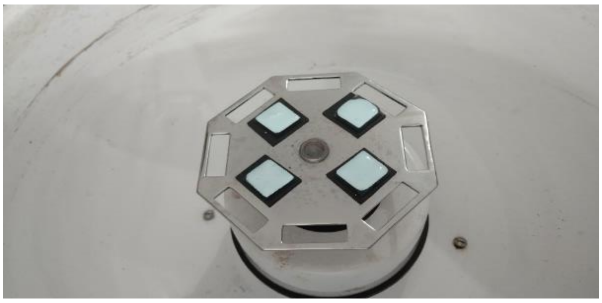


Figure 4. TiO_2 Thin Layer Deposition Process

The next stage is the process of heating the sample using an oven at a temperature of 80° for ± 30 minutes. The aim of the sample heating process is so that the liquid in the solvent after deposition on the glass substrate can evaporate and only leave a layer with relatively the same thickness, as well as maximizing the formation of crystals on the substrate used (Maddu et al., 2018). The following is a picture of the glass substart oven process to obtain a thin layer sample.

Figure 5. Heating the Glass Substrate

Figure 6. Thin Layer Samples with Concentrations of (0, 3, 6, 9, 12)%.

After the oven process, let the glass sit for ± 1 minute before removing it from the porcelain cup. The glass substrate has different colors before and after the deposition and heating process. The appearance of the sample obtained from the heating process is that when using a pure TiO_2 solution, the color of the glass becomes dark white and thicker than when using a solution with cobalt doping added. The following displays a sample obtained from the heating process.

Conclusion

The higher the amount of doping used, the fainter the color of the sol-gel solution obtained. Titanium dioxide is used as a basic material for the synthesis of doped thin films by mixing cobalt and HCI as a solar cell material. Hopefully, the samples obtained from TiO_2 mixed with cobalt and HCI can absorb sunlight energy well.

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