Reducing The Light Reflected by Silicon Surface Using ZnO/TS Antireflection Coating

Andi Suhandi1, Yuyu R. Tayubi2, Firmanul C. Wibowo3, Pepen Ariffin4 and Supriyatman5

1,2Department of Physics Education, Universitas Pendidikan Indonesia, Indonesia
3Department of Physics, Institut Teknologi Bandung, Indonesia
4Department of Physics Education, Universitas Sultan Ageng Tirtayasa, Indonesia
5Department of Physics Education, Universitas Tadulako, Indonesia

E-mail: andi_sh@upi.edu

Abstract. Zinc Oxide (ZnO) thin films was coated on a texturized silicon (TS) surface using a spincoating technique. The TS layer was prepared by a wet etching method using 20% KOH solution at temperature of 80°C for 5 minutes. To prepare precursor solution for ZnO layer, zinc acetate dehydrate, 2-methoxyethanol and monoethanolamine are used as a starting material, solvent and stabilizer, respectively. The XRD and SEM measurements confirmed that the thin films grown by spincoating technique have a single oriented crystal plane and homogeneous surfaces. From photoluminescence measurement found that the optical band gap of grown films to be 3.44 eV. The optical reflectance of the grown films is characterized by UV-VIS spectrometry show that the presence of anti-reflection coating ZnO/TS is proven to reduce the reflection of solar radiation by silicon surface significantly.

1. Introduction

Until now solar cells are widely used and marketed for the purposes at the terrestrial are made of silicon material. There are five reason why silicon today is the material that has been chosen as the material for solar cells, namely: 1) Silicon has the potential for high efficiency, 2) Silicon is available limited, second most element of the earth’s crust, 3) The involved materials and processes are non-toxic and do not harm the environment, 4) The silicon technology already exists and is reliable, and 5) Already exists a broad knowledge of the materials and the devices [1]

One of the problems encountered in the development of silicon solar cells is the high reflection of solar radiation by the surface of the silicon, which reached 35% of the incoming solar radiation. The high reflection of sunlight results in the conversion efficiency of silicon solar cells is limited [2]. To overcome these problems, on the surface of solar cells usually added anti-reflections coating (ARC), that is a thin film of semiconductor material that has a different refractive index to silicon materials. Zinc oxide (ZnO) is very potential for anti-reflections coating of silicon solar cells because it has a refractive index of about 2, has a large optical bandgap in the range of 3.3 to 3.7 eV, are transparent in the visible region and has a good adhesion properties and hardness. [3]
Texturing a silicon (TS) surface that acts as a light trapping thereby forming system ZnO/TS is believed to be much longer reduce the percent of reflection light by the surface of the silicon. Some advantages of texturized silicon surface, diantarany: 1) At least second reflection, 2) The effective absorption length of the silicon layer will be reduced, the light way through the layer increases , 3)The area of the surface becomes bigger, 4) Total internal reflection on the inside of the front layer possible, and 5) Reflection can be reduced about 9/10 of the former reflection [1]. TS are an excellent antireflection coating (ARC) for solar cells. The ARC can enhance the efficiency of solar cells by increasing light trapping in the active region [4,5]. In the last couple of years, many researchers have increasingly focused on zinc oxide (ZnO) because of its multiple applications, such as laser diodes [6], transparent conductive contacts [7], and solar cells [8,9]. ZnO has a direct band gap (3.37 eV), a high exciton binding energy (60 meV) at room temperature (RT), and a wurtzite crystal structure [10]. Recently, ZnO has attracted attention as one of the materials for the ARC of solar cells because it has good transparency and an appropriate refractive index [11,12,13].

ZnO thin films are currently fabricated by chemical vapor deposition [14], pulsed laser deposition [15], Molecular beam epitaxy [16], chemical spray hydrolysis [17], or other high-temperature and in some cases capital and equipment intensive methods. Amongst the different available techniques, the sol-gel technique has the advantage of coating on large areas with easy control of the doping level, solution concentration and homogeneity, without using expensive and complicated equipment compared with other methods.

The results on the thin films of ZnO grown by sol-gel method have been presented. This technique of film preparation is a low-cost process and is attractive as the film properties can be tailored conveniently for a given application. This process, thus, becomes a preferred option for exploratory studies where a large number of candidate materials require screening for their compositions and properties prior to their applications in devices.

In the present work, we report the structural, morphology, and optical properties of ZnO/TS thin films prepared by sol-gel method using spin coating technique. Recently, few studies had reported on the growth of the ZnO thin film on texturized silicon substrate.

2. Experiment
Texturized silicon (TS) surface was prepared by a wet etching method using 20 % KOH solution at temperature of 80°C for 5 minutes. To prepared the precursor solution for ZnO layer, first, zinc acetate dehydrate is first dissolved in mixture of 2-methoxy ethanol and monoethanolamine at room temperature. The sol is prepared by dissolving 8.23 grams (0.75 moles) of zinc acetate and the molar ratio of monoethanolamine to zinc acetate is kept at 1:1. The resultant solution is stirred for 1hr at 60°C to yield a homogeneous, clear and transparent solution using a magnetic stirred. The seed layers are spin coated a day after the solution is prepared. Precursor solution is dropped onto silicon substrate, which are then spinne at 1500 rpm for 30 sec. After processing, the substrate is baked at 350°C for 10 min to evaporate the solvent and remove the organic component in the film. And then the film is heating at 700°C on the furnace to form the ZnO thin solid film on the silicon surface.

The crystal structur of ZnO/TS layer was characterized by X-Ray Diffraction (XRD), the surface morphology and the cross section of ZnO/TS layer were investigated by Scanning Electron Microscopy (SEM), and optical properties of ZnO/TS layer were determined from Photoluminescence (PL) Spectroscopy and UV-Vis Spectroscopy data.

3. Result and Discussion

3.1. Texture of silicon surface and surface morphology of ZnO layer on the silicon surface
Figure 1 show the cross section SEM image of Texturized Silicon.
Figure 1. Cross section SEM image of Texturized Silicon

From the cross section SEM image appears that although not perfect, but it seemed to have been formed a texture on the silicon surface as a result of the wet etching process. The desired texture is pyramidal shape, but the obtained texture in this study have not been entirely pyramid shaped. This indicated that it is necessary to optimization in the etching process, both in percent of KOH solution, etching temperature, and duration of etching.

Figure 2 shows the SEM image of as grown ZnO film deposited on TS substrate. The film deposited in the optimized condition is smooth, dark gray in colour and uniformly covering the substrate with good adherence. The overall surface structure shows grains of spherical shape uniformly covering the substrate without any cracks.

Figure 2. Surface morphology of ZnO/TS layer

3.2. Crystal structure of ZnO layer on the Texturized Silicon Surface

Figure 3 shows the X-Ray diffraction peak intensity for ZnO/TS thin film. ZnO thin films were deposited on a silicon surface both textured and non-textured have single orientation crystal planes. ZnO diffraction peaks occur at $2\theta = 34.40^\circ$ corresponding to the orientation of the crystal planes (002) that is oriented along the c-axis vertical to the surface of the silicon.
3.3. Optical Properties of ZnO layer on the Texturized Silicon Surface

Figure 4 shows the percent of light reflectance versus wavelength obtained from UV-Vis spectroscopy measurement.

It showed that the addition of ZnO antireflecting coating can degrade percent of light reflection by the silicon surface. Texturing a silicon surface making the system ZnO/TS can be further reduce percent of light reflection by the silicon surface. Presence of the texturized silicon surface can be caused the effective absorption length of the silicon layer will be reduced, the light way through the layer increases as shown in fig. 5.
Figure 5. The increases of light way through the silicon substrate as effect of the presence of texturized silicon surface

Light trapped in the silicon material can be generate the hole-electron pair which can be produce photocurrent in the silicon solar cells. Hence the conversion efficiency of silicon solar cell can be increase.

4. Conclusion

The structural, surface morphology and optical properties of solgel spin coated ZnO/TS thin film have been investigated. The XRD spectra indicate that the film is of single crystalline structure. The SEM image showed that the film have a homogenous surface morphology. The values of the optical band gap of ZnO/TS film of about 3.44 eV. The optical reflectance of the grown films are characterized by UV-VIS spectrometry shows that the presence of anti-reflection coating ZnO/TS is proven to reduce the reflection of solar radiation by silicon surface significantly. It is thought that because of these properties, ZnO thin films can be used as an antireflection material in photovoltaic applications.

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