Synthesis and Characterization of C, SnO_2, and C+SnO_2 Materials through Resistance Measurement, UV-Visible Spectroscopy, and X-Ray Diffraction

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Abstract – The objectives of this study are i) to determine an electrical property, especially resistance, of carbon (C), tin oxide (SnO_2), and C+SnO2 thin films. ii) to determine the optical property of C, SnO_2 and C+SnO_2 thin films based on UV-visible spectroscopy (UV-Vis). and iii) to determine the crystallinity of C, SnO_2 and C+SnO_2 thin films based on X-ray diffraction (XRD). The results show different physical characteristics from the three samples of the thin film layers. The result on the resistance measurement shows that C thin film has the lowest resistance, followed by SnO2, and C+SnO2 thin films with resistance values of 1.0769 mΩ, 1.0774 mΩ, and 3.8875 mΩ, respectively. The UV-Vis results show a peak for each of the thin film at 256 nm, 257 nm, and 258 nm for C, SnO_2, and C+SnO_2, respectively, which is in the UV area. The XRD results show that the C and SnO_2 thin layers are amorphous while C+SnO_2 thin layer is crystal
Key words: thin film, carbon, SnO_2, C+SnO_2, resistance, UV-Vis, XRD

INTRODUCTION

Currently, the issue of energy for the continuity of human life can not be ignored. This is due to the rapid development of the world economy such that most of the countries in the world are increasing the demand for energy. Generally, the most commonly used energy are fossil-derived energy sources, which are non-renewable. The increasing needs of fossil fuel causes a decrease in the supply of these energy sources and may one day run out. Hence, finding or producing alternative energy sources that are environmentally friendly, renewable, and low production prices are one way to overcome the demand of energy in a long term. One of these alternative energies is solar cells. Solar cells are devices that can convert sunlight into electrical energy.

In order to construct a solar cell certain materials which are transparent and conductive are needed, such as transparent-conductive-oxide or better known as TCO materials. TCO itself is an important material to the advancement of technology today because it has a wide application such smartphone screen, LCD screen, and light sensor.

TCO is conductive because it is a semiconductor material and has a thickness of about 100-200 nm. TCO has an energy gap between 2.5 to 4.5 eV (Dengyuan, 2005). TCO is generally present in the form of indium tin oxide (ITO), tin oxide (SnO_2), fluorinated tin oxide (FTO), and aluminum doped zinc oxide ZnO: Al (AZO) (Sharker, 2015: 243).

In this study, we synthesize three materials that may be used as TCO, that is carbon (C), tin oxide (SnO_2), and C+SnO2. SnO_2 is usually synthesized using sputtering method, sol-gel process, and chemical vapor deposition (CVD) [Kurniati, 2016: 3]. However, in this case we synthesize these materials using a simple method of direct heating.

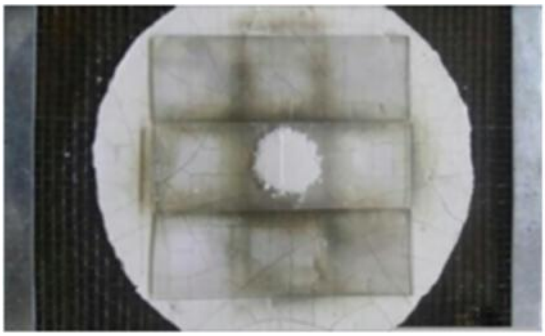
METHODS

This study was conducted from July 2016 until April 2017. Moreover, this study was conducted in various places, that is i) Colloid Laboratory, Physics Education Department, Universitas Negeri Yogyakarta (UNY), ii) Spectroscopy Laboratory, Physics Education Department, UNY, iii) Basic Chemistry Laboratory, UNY, and iv) Integrated Mathematics and Natural Sciences Laboratory, Universitas Sebelas Maret.

The materials used in this study are tin chloride ($SnCl_2$), distilled water, kerosene, and smoke (fume) from an oil lamp. $SnCl_2$ is basic material in order to obtain SnO_2 and the smoke coming from the oil lamp is used to produce the C material. The equipment utilized in this study are i) an oil lamp, ii) glass slides, iii) an electric stove, iv) UV-Vis spectroscope (Shimadzu UV Vis 2450), XRD (Rigaku Miniflex), and v) multimeters (Sanwa Digital Multimeter CD 800a).

The experimental method may be explained as follows. First, C thin layer is created with the following steps: i) clean a glass slide using distilled water, ii) wipe the glass slide to dry using clean tissues, iii) turn on the oil lamp (kerosene as fuel) using a match until smokes come out from the lamp, iv) put the clean glass slide on top of the oil lamp with one of the glass slide surface exposed to the smoke, v) the layer formed on the glass slide is the intended C material which is characterized.

(a)



(b)

Figure 1. Arrangments of the $SnCl_2$ powder and glass slides. The $SnCl_2$ powder is sandwiched between two glass slides (a) and arrangement of two glass slides on each side of the sandwiched $SnCl_2$ powder (b).

Next, SnO_2 thin film is synthesized. This is conducted using the following stages: i) prepare four glass slides which have been cleaned using distilled water, ii) heat the electric stove up to 350 ^oC, iii) weigh $SnCl_2$ powder with a mass of 2 grams, iv) place the $SnCl_2$ powder that has been weighted on top of a clean glass slide and then flattened it, v) put another glass slide on top of the flattened $SnCl_2$ powder such that the powder is sandwiched between two glass slides (Fig. 1a), vi) put the $SnCl_2$ arrangement onto an asbestos sheet, vii) put two clean glass slides on the left and right sides of the $SnCl_2$ arrangement (Fig. 1b). Viii) put the asbestos sheet on top of the electric stove such that the $SnCl_2$ is heated for 10 minutes. Layers of different colors that show on the left and right glass slides of the $SnCl_2$ powder is the SnO_2 thin films.

Finally, the C+SnO_2 thin flm is obtained by combination of the two previous methods. The C layering is conducted first, and then completed by SnO_2 layer on top of the C layer.

After all of the samples are obtained, the next step is to conduct the characterization of the samples. The electrical property of the samples is determined by measuring the resistance of the samples using a prepared electrical circuit in Fig. 2. The resistance is obtained indirectly by increasing the power supply every 1 volt from 5 to 26 volts, and measuring the current on the amperemeter. Assuming an Ohmic (linear) relationship between the voltage and current, the resistance may be calculated. The optical property of the samples is studied via UV-Vis spectroscopy, and the crystallinity is observed using XRD.

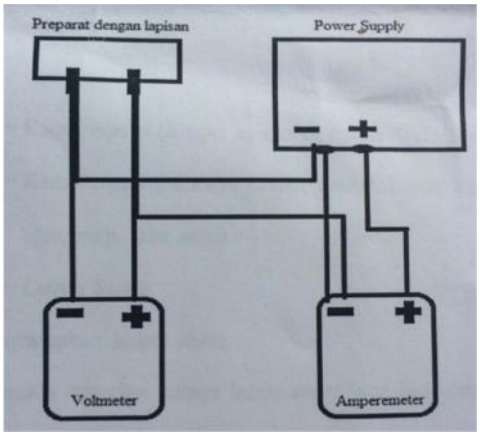


Figure 2. Schematic electrical circuit of resistance measurement Then measure the voltage and current values that listed on the voltmeter and amperemeter by increasing the power supply every 1 volt with range 5 volts up to 26 volts.

RESULTS AND DISCUSSION

As mentioned above, the resistance of the three thin layers is determined by measuring the current and voltage values. Then the value of the resistance may be calculated by assuming Ohmic relationship between the current and voltage.

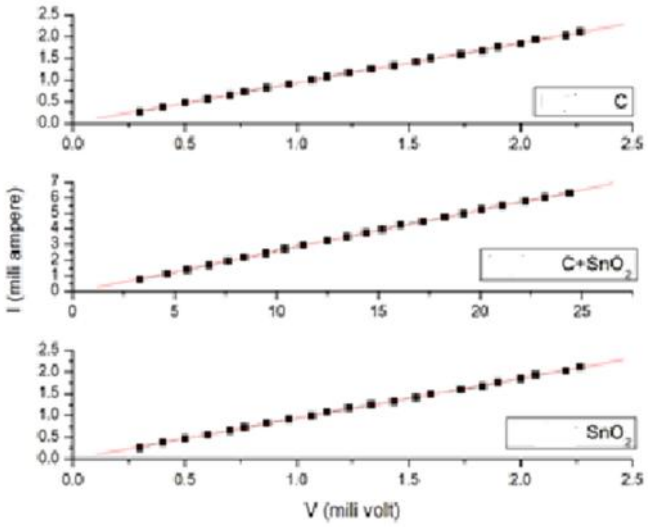


Figure 3. Graphs of the current versus voltage for C, C+SnO_2, and SnO_2 thin layers from the top to bottom, respectively.

Figure 3 shows the graphs of the current versus voltage of the three thin films. It is clearly observed that the graphes are linear (Ohmic), i.e.: increasing the voltage causes the current to increase as well. This is appropriate with Ohm's law. Hence, the resistance of C+SnO_2, C, SnO_2 thin films are 3.8875 mΩ, 1.0769 mΩ, and 1.0774 mΩ, respectively. The C+SnO_2 layer has the greatest resistance value. While C and SnO_2 thin films have resistance values which are almost similar but smaller than C+SnO_2. It seems that the resistance of the combine thin film of C+SnO_2 is obtained as the sum of the invidual thin films of C and SnO_2. This means that combining the layers of C and SnO_2 increases the resistance of the combined layer of C+SnO_2.

We next look at the optical property of the thin films through the UV-Vis results. According to Figure 4 of the absorbances of C, SnO_2, and C+SnO_2 layers, a maximum absorption in the UV region occurs for the three layers. Moreover, noise occurs around the region of 300 nm to 400 nm of the three layers. In the visible region of 400 nm to 800 nm, C+SnO_2 layer forms a bump, while a flat profile is observed for C and SnO_2.

The maximum absorbance value for C is 0.1496 at a wavelength of 256 nm. For SnO_2 the maximum absorbance is about 0.1818 at a wavelength of 257 nm. Finally, for C+SnO_2 the maximum absorbance value is about 0.8163 at a wavelength of 258 nm. This shows that the wavelength at maximum absorbance of the three layers seems to be similar. For the carbon material, a maximum absorance at around 256 nm may show the existence of graphene oxide (GO) material.

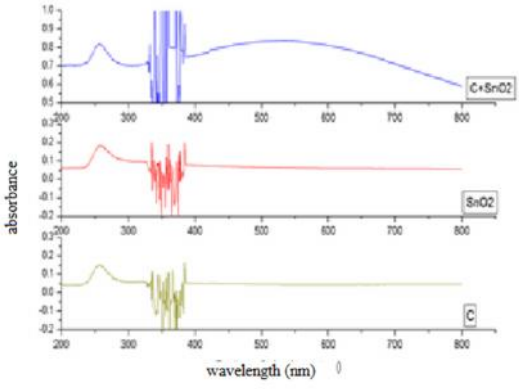


Figure 4. Graphs of UV-Vis results for C+SnO_2, SnO_2, and C thin films from the top to bottom, respectively.

Finally, the crystallinity of the three samples may be determined using XRD results. The XRD results for C and SnO_2 layers show similar pattern on the difractograms (Figure 5). Both do not have distinct diffraction peaks, but form a bump pattern. The patterns show that C and SnO_2 is amorphous. However, C+SnO_2 shows s different difractogram patterns. The C+SnO_2 layer is a combination of the C layer which is coated with SnO_2 layer. The XRD results for the C+SnO_2 layer shows certain peaks on the difractogram, hence making C + SnO_2 layer a crystal.

Only the XRD result of the C+SnO_2 layer is then compared with the JCPDS standard data. The layer has a match with the JCPDS standard tin oxide compound (SnO_2) with number 77-0450 (see Table 1). The XRD result indicates that the structure of SnO_2 is tetragonal rutile (Hermida, et al., 2012). This is supported by JCPDS standard data indicating that SnO_2 has a lattice parameter of a = b ≠ c. SnO_2 is also known as a semiconductor that has low conductivity properties, but this property can be improved by the addition of doping or impurities. Besides, SnO_2 has a porous and stable structure in the acidic state (Adawiyah, 2017: 10).

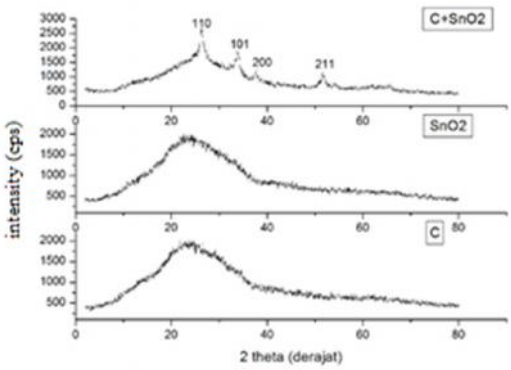


Figure 5. XRD g of C+SnO_2, SnO_2, and C thin film samples from the top to bottom, respectively.

Table 1 shows the JCPDS standard data (second column) compared to the XRD results (third column) for C+SnO_2. From the table it can be seen that the 4 peaks appearing on the difactogram of C+SnO_2 are similar to the peaks of the JCPDS card. The XRD result shows the highest peak at the angle of 26.89˚ while the JCPDS standard data shows 26.542˚. Both angles have an intensity of 100 cps. The fourth peak shows the greatest intensity difference. Such a large intensity difference may be due to the influence of other elements, which in this case is C.

Table 1. Comparison of JCPDS and XRD results.

HKL	JCPDS		XRD	
	2θ	Intensity	2θ	Intensity
110	26.542	100	26.89	100
101	33.808	76.7	33.86	60.72
200	37.887	20.9	37.68	20.43
211	51.675	53.1	51.686	96.97

CONCLUSION

Based on data analysis above, it can be concluded that the resistance values for C, SnO_2 and C+SnO_2 layers are 1.0769 mΩ ,1,0774 mΩ, and 3.8875 mΩ, respectively. The UV-Vis results show an absorbance peak for all three thin films at 256 nm, 257 nm, and 258 nm for C, SnO_2, and C+SnO_2, respectively. Especially for the carbon material, the peak may suggest the existence of GO material. The three maximum absorbance values are in the UV region. Finally, the XRD results indicate that the C and SnO_2 layers are amorphous, while the C + SnO_2 layer is a crystal.

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