Optical Properties Of As-Deposited Amorphous Carbon Film Fromvarious Substrate Temperaturesvia Custom-Made-CVD

A. Ishak, Ahmad Nurrizal Muhamad, M. Rusop

Abstract: We were deposited the as-deposited amorphous carbon via a modified custom-made-CVD in the range of 350°C to 550°C at atmospheric pressure with constant of negative bias -40V, and argon gas for 1 hour deposition. We used vaporized of palm oil as a carbon source into the chamber. It was observed, above 90% of light were transmitted to the samples instead of sample 500°C (80%). The as-deposited thin film grown on glass and p-type silicon we found uniform, smooth, dark grey colored and thickness in the range of 155 to 190nm. It was found, thickness less than 170nm brought less significant impact to the reduction of transmission percentage. In relationship with structural image in FESEM, the absorption coefficient was found high as the size of particles were big, rough, and agglomerated. The result showed the optical band gaps for 550°C to 350°C were 0.5eV, 1.3eV, 0.1eV 0.7eV, and 1.4eV respectively. The optical band gaps of 400°C and 350°C were suitable for solar cell applications.

Keywords: Modified-CVD; As-deposited; DC bias; Non-doping

I. INTRODUCTION

Amorphous carbons were exhibited the most interesting optical properties in the carbon-based films by ability to tuning wide optical band gap of 5.5 to 0.25 eV range. The amorphous carbon structure has a large variety of forms and the diversity of physical properties depending on the deposition conditions. In the consequence, different optical properties can be obtained by different deposition method and starting material [1-3]. It was reported that, undoped amorphous carbon is weakly p-typed in nature with complex structure and high density of intrinsic defects [4-6], thereby restricts to get maximum efficiency. In this paper, we studied the effect of temperature on optical properties of deposited thin films from palm oil precursor grown on two difference types of substrates; insulator glass and semiconductor pi-type silicon. Here we used bias assisted pyrolysis-CVD. To our knowledge, preparation and study on the optical properties of thin films using vaporized palm oil by using this technique at substrate temperature at 350°C to 550°C has been rarely reported by any research group.

- *Ishak, Ahmad Nurrizal Muhamad, M. Rusop*
- *NANO-ElecTronic Centre, Faculty of Electrical Engineering, Universiti TeknologiMARA, 40450 Shah Alam, Selangor, Malaysia*
- *NANO-SciTech Centre, Institute of Science, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia*
- *Facuty of Electrical Engineering, UiTM Sarawak Kampus Kota Samarahan Jalan Meranek, Sarawa*

II. EXPERIMENTAL

Two types of substrates were used for deposition process; Insulator glass and semiconductor p-type silicon. Each of substrate was cleaned with acetone (C_5H_6O), followed by methanol (CH_3OH) and finally with deionized water for 10 min in Ultrasonic Cleaner (power Sonic 405) respectively.

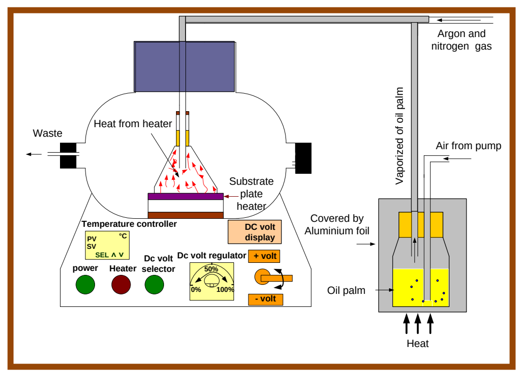

Fig. 1. *A schematic diagram of bias assisted pyrolysis-CVD*

Additionally process was done for removing resistive elements of p-type silicon; they were immersed for around 1 min in a mixture of hydro fluoride acid and water in the ratio of 10:1 before they were cleaned again with deionized water in Ultrasonic cleaner for 10 min. Both substrates were then blown with nitrogen gas. A starting material from palm oil was heated at around 180°C with the hot platter (Stuart CB162) where the vapored of palm oil were flowed into the chamber with a contant flowrate of 115ml/min as shown in Fig. 1.The chamber was heated with difference temperatures ranging from 300°C to 550°C and setup with a constant dc bias of -40V, 222 ml/min,186 ml/min argon gas at atmosperic pressure for 1 h deposition. The argon gas was used for carrier the particle charge onto the substrate and also contaminated particles outside the chamber.The tube and bottle of palm oil were wrapped with aluminium foil.The samples were then characterized by using UV-VIS Spectrophotometer (JASCO/V-670 EX), surface profiler (Veeco Dektak 150), field emission scanning electron microscopic (FESEM, ZEISS Supra 40VP), and I-V measurement (Bukuh Keiki CEP-2000).

III. RESULT AND DISCUSSIONS

The UV/VIS/NIR spectrometer is used for characterized the optical properties carbon thin films in the range of 200-2000 nm wavelength. The UV-VIS transmittance spectrum for carbon thin films is shown in Fig. 2. The deposited thin film grown on glass and p-type silicon we found uniform, smooth, dark grey colored. We predict optical properties of amorphous carbon films vary with the composition and thickness of the films as shown in Fig. 2. It can be observed all samples have high transmittance (T>90%) except for the sample 550^{o}C. We have seen that most spectrum of photon energy are transmitted to the samples rather than reflected. All the average thickness of thin films indicates lower thickness as compared to the sample 500^{o}C as shown in Table 1. By comparing with the transmittance spectrum of sample 500^{o}C in Fig. 2, the reduction of its spectra might be due to the additional thickness of the thin film. The effect of thickness of thin film was also demonstrated by other groups [7,8]. Meanwhile, the high transmittance thin film was reported as a good criterion for solar cell application. A. Ishaket al and others [8-10] demonstrated the important of high transmittance in visible wavelength for solar cell application since they believe it could suppress the reflection at the surface thereby minimize the losses due to thin film properties. We found that in visible light, about 80 % of light are transmitted to the thin film and therefore samples could be action with the visible wavelength.

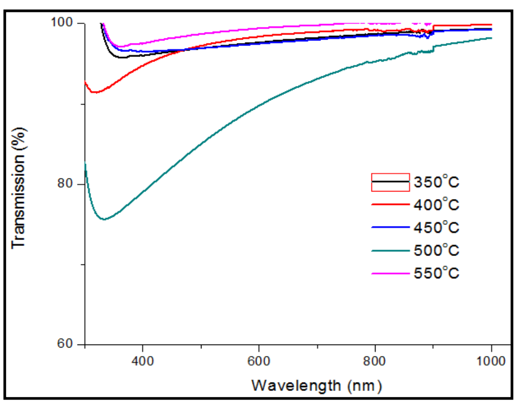

Fig. 2 *Transmittance spectra of as-deposited amorphous carbon films deposited at various temperatures for 1h with negative bias of -40V.*

Table 1 shows the average thickness of thin films characterized by using surface profiler. The average thicknesses of samples for each thin film from 350^{o}C to 550^{o}C are 182nm, 168nm, 190 nm and 160nm and 155nm respectively.

Substrate Temperature^{o}C	350	400	450	500	550
Average of thickness (nm)	182	168	190	160	155

Table 1 Thickness of a-C films deposited at different temperatures

The result show from 350^{o}C to 400^{o}C, the average thickness is in a trend of increased until 450$_{o}$C and decreased thereafter after 500^{o}C and We found, the sample 450^{o}C had the highest average thickness as compared to other samples as indicated in Fig. 2. By comparing with transmittance spectra for the same temperature in Fig. 2, we observe the transmittance spectrum are influenced by the changing of the thickness as reported by other literatures [11,12]. We have also seen that, thin films thicknesses below 170 nm are less contribution on the reduction of transmittance spectrum as can be seen in Fig. 2. The absorption coefficient describes how far the energy of photon can penetrate into the thin film before absorbing process occurred. Fig. 3 shows the absorption coefficient of thin films at various temperatures. It can be seen that, thin films at 350^{o}C is the highest absorption coefficient followed by thin films 500^{o}C and 450^{o}C respectively. It was observed that, at those temperatures, the absorption coefficient ranges are obtained by other groups but with different methods [13,14]. They were noticed that, those ranges are suitable for solar cell application [14,15]. We observe the low absorption coefficients representative by the sample 450^{o}C and 550^{o}C respectively. By comparing with value from other literature [16,17], we observed the range value of absorption coefficient for 450^{o}C and 550^{o}C are less suitable for solar cell application as compared with those three samples as discussed before since they had less absorbing of photon energy.

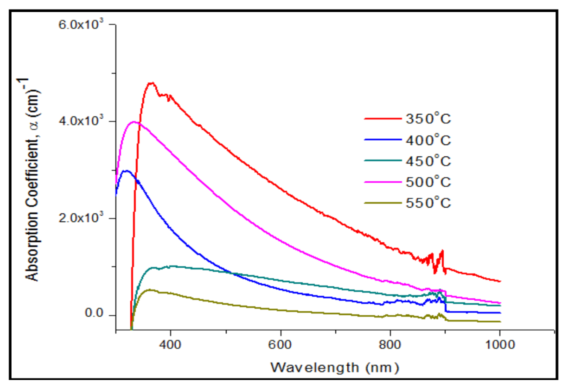

Fig. 3 *Absorption coefficient of non-doped amorphous carbon thin films deposited at various temperatures for 1h with negative bias of -40V.*

Fig. 4 shows the plot of $(\alpha h\nu)^{1/2}$ as a function of photon energy. The Tauc relationship [18] was practically used to evaluate the energy gap. The optical gap is obtained from extrapolation of the linear part of the curve at the absorption coefficient α=0 using the Tauc relation [18]. The optical band gap of thin films for 350^{o}C, 400^{o}C, 450^{o}C, 500^{o}C and 550^{o}C are 0.5eV, 1.3eV, 0.2eV, 0.7eV, and 1.4eV respectively. In our experiment results, the energy band gap gradually increase from 0.20 to 1.4eV as the temperatures is increased from 450^{o}C to 550^{o}C. However, the optical band gap is fluctuated in the range of 350^{o}C to 450^{o}C. The gradually increase of the optical band gap might be due to the higher decomposition of vaporized palm oil thus leading to increase of sp^{3} content as well as dangling bonds, It was agreed that the determination of band gap was not accurate using Tauc's formulation because of the extent of the valence and conduction-band tails in the gap, especially in the case of the films where nanocrystallites are embedded in the amorphous matrix [19,20]. However, it is expected to give an approximate estimate of the band gap. It is predicted that, the optical band gap for the sample of 400°C and 550°C are considered suitable for solar cell application since their band gap are in the range of 1eV to 2eV which that range were reported as the optimum range for obtain high efficiency solar cell [21].

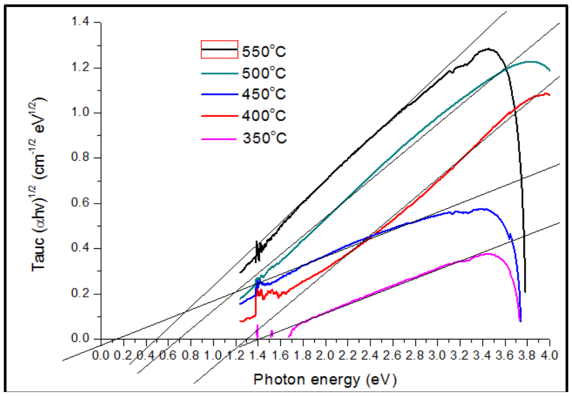

Fig. 4 *Optical band gap of as-deposited amorphous carbon films at various temperatures for 1h with negative bias of -40V.*

Fig. 5 shows FESEM images of amorphous carbon thin films on p-type silicon at various temperatures in the range of 350°C-550°C.The images were taken in the size of 1μm with magnification of 5k and 5.0kV voltage. Surface morphology images showed a uniform deposited thin film but in different size, form and sharp of particles. At 350°C the particles are bigger and agglomerate as compared to other samples. At temperatures 400°C and 500°C, the particles are finer and less agglomerate as compared with 350°C and 450°C. Although it is known that π state determines the gap, but the relationship between the structure and the optical band gap is quite complicated [22]. We observe that structure types did not significantly effect on the transmission as compared with the thickness although there is some number of different forms of structure exists in different sample as shown in Fig 5 (a)-(e). However, there is some relationship in between the absorption coefficient and structural of the film. The absorption coefficient is high as agglomerated particles existed. These can be compared with four of the samples as shown in Fig 5. Furthermore, sample 350°C (the highest absorption coefficient) was rougher and bigger than other three samples (400°C, 450°C and 500°C). We predict, those properties of particles might be contributed for high absorption coefficient. As previously discussed, decomposition of vaporized of precursor and dangling bond were one of the factor for contribution in altering the optical band gap. We found that the optical band gap for these form of structures give low optical band gap (below 2.0eV). The form and sharp of structures might be slightly affected on the changing of optical band gap. We conclude the changing of structures, transmission, absorption coefficient, and band gap are mainly caused by the changing of temperature. The effect of temperature were discussed, agreed and supported in the literatures [23-26].

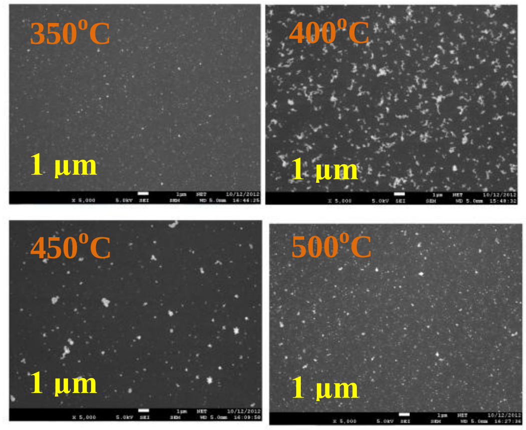

Fig. 5 *FESEM images for 1μm a-C thin film grown on p-type silicon at different temperatures: (a) 350°C, (b) 400°C, (c) 450°C, (d) 500°C by magnification 5k using 5.0kV*

IV. CONCLUSIONS

In this paper, we mainly utilized UV/VIS, Surface profiler, and FESEM spectroscopy to analyze the relationship on the optical properties and the structural of as deposited amorphous carbon thin films. The amorphous carbon thin films were derived from vaporized of palm oil precursor heated of about 180°C. The deposited thin film grown on glass and p-type silicon we found uniform, smooth, dark grey colored and thickness in the range of 155 to 190nm. It was found, thickness gave significant impact to the transmission percentage. Samples with the thickness below 100nm were transmitted above 90% of light while the sample with thickness 160nm gave 80% of light. The films thickness is found gradually increase until 160nm at 500°C and drastically decreased to 155nm at 550°C. The optical bang gap for 400°C and 550°C were in the range of 1eV and 2eV which were suitable for achieves relatively high efficiency solar cell application. However, absorption coefficients for both temperatures at visible wavelength were lower as compared with 350°C, 450°C and 500°C. The results demonstrate, temperature 350°C has the highest absorption coefficient while 550°C the lowest absorption coefficient. The result showed the optical band gaps for 350°C to 550°C were 0.5eV, 1.3eV, 0.1eV 0.7eV, and 1.4eV respectively. FESEM images showed deformation of physical and structural thin films caused by changing temperatures at others constant setting parameters. The results showed that amorphous carbon thin films were dependence with temperature and others setting constant parameters by deformation its structure and physical properties. The FESEM results showed that surface morphology of amorphous carbon thin film changed significantly by increasing temperature. By correlated with FESEM image, we found the bigger and rougher size together with agglomerated particles give higher absorption coefficient as compared to smaller size of non-agglomerated particles.

ACKNOWLEDGEMENT
Theauthors thankto Ministry of Higher Education (MOHE) Malaysia for the scholarship, Universiti Teknologi MARA, Kota Samarahan Sarawak and Research ManagementInstitute(RMI) Universiti Teknologi MARA (UiTM)for thefacilities.

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