



REPUBLIK INDONESIA
KEMENTERIAN HUKUM DAN HAK ASASI MANUSIA

SURAT PENCATATAN CIPTAAN

Dalam rangka perlindungan ciptaan di bidang ilmu pengetahuan, seni dan sastra berdasarkan Undang-Undang Nomor 28 Tahun 2014 tentang Hak Cipta, dengan ini menerangkan:

Nomor dan tanggal permohonan : EC00201983902, 26 November 2019

Pencipta

Nama : **Dr. Marjoni Imamora, M.Sc**
Alamat : Perumahan Dobok Indah Blok C No.3 Lima Kaum Batusangkar,
Batusangkar, Sumatera Barat, 27211
Kewarganegaraan : Indonesia

Pemegang Hak Cipta

Nama : **Dr. Marjoni Imamora**
Alamat : Perumahan Dobok Indah Blok C No.3 Lima Kaum Batusangkar,
Batusangkar, Sumatera Barat, 27211
Kewarganegaraan : Indonesia
Jenis Ciptaan : **Karya Tulis (Artikel)**

Judul Ciptaan : **Effect Of Graphite Oxide Solution Concentration On The
Properties Of Multilayer Graphene**

Tanggal dan tempat diumumkan untuk pertama kali di wilayah Indonesia atau di luar wilayah Indonesia : 31 Desember 2013, di Selangor

Jangka waktu perlindungan : Berlaku selama hidup Pencipta dan terus berlangsung selama 70 (tujuh puluh) tahun setelah Pencipta meninggal dunia, terhitung mulai tanggal 1 Januari tahun berikutnya.

Nomor pencatatan : 000171827

adalah benar berdasarkan keterangan yang diberikan oleh Pemohon.

Surat Pencatatan Hak Cipta atau produk Hak terkait ini sesuai dengan Pasal 72 Undang-Undang Nomor 28 Tahun 2014 tentang Hak Cipta.



a.n. MENTERI HUKUM DAN HAK ASASI MANUSIA
DIREKTUR JENDERAL KEKAYAAN INTELEKTUAL

Dr. Freddy Harris, S.H., LL.M., ACCS.
NIP. 196611181994031001

Effect of graphite oxide solution concentration on the properties of multilayer graphene

Cite as: AIP Conference Proceedings **1571**, 115 (2013); <https://doi.org/10.1063/1.4858639>
Published Online: 31 December 2013

Marjoni Imamora Ali Umar, Chi Chin Yap, Rozidawati Awang, Muhamad Mat Salleh, and Muhammad Yahaya



View Online



Export Citation

ARTICLES YOU MAY BE INTERESTED IN

[Preparation of patterned graphene-ZnO hybrid nanoflower and nanorods on ITO surface](#)
AIP Conference Proceedings **1571**, 54 (2013); <https://doi.org/10.1063/1.4858629>

[Ultraviolet-visible spectroscopy of graphene oxides](#)
AIP Advances **2**, 032146 (2012); <https://doi.org/10.1063/1.4747817>

[Facile synthesis of graphene from graphite using ascorbic acid as reducing agent](#)
AIP Conference Proceedings **1725**, 020003 (2016); <https://doi.org/10.1063/1.4945457>

Lock-in Amplifiers up to 600 MHz

starting at
\$6,210



 Zurich
Instruments

Watch the Video 



Effect of Graphite Oxide Solution Concentration on the Properties of Multilayer Graphene

Marjoni Imamora Ali Umar^{a,b}, Chi Chin Yap^a, Rozidawati Awang^a,
Muhamad Mat Salleh^c and Muhammad Yahaya^a

*School of Applied Physics, Faculty of Science and Technology, Universiti Kebangsaan Malaysia,
43600 Bangi, Selangor, Malaysia.*

*Department of Physics Education, Faculty of Tarbiyah, Sekolah Tinggi Agama Islam Negeri (STAIN)
Batusangkar, 27213, West Sumatera, Indonesia*

*Institute of Microengineering and Nanoelectronics (IMEN), Universiti Kebangsaan Malaysia,
43600 Bangi, Selangor, Malaysia*

Abstract. This paper reports the influence of graphite oxide (GO) solution concentration on the optical and electrical properties of multilayer graphene (MLG) films. Graphene oxide (GrO) films were deposited on the glass substrates by spin coating aqueous solutions of GO with different concentrations (7, 8, 9, 10 and 11 mg/ml). The GrO films were then thermally reduced at temperature of 500°C in argon flow for half an hour to form MLG films. Both the transmittance and sheet resistance decreased with the GO concentration from 8 mg/ml to 9 mg/ml, possibly due to thicker and uniform coverage of MLG over the substrate. However, the transmittance and sheet resistance increased rapidly as the GO concentration reached 11 mg/ml, which can be attributed to poor film quality. The MLG film obtained at concentration of 10 mg/ml showed the highest transmittance/sheet resistance ratio with 69 % transmittance and sheet resistance of $292 \pm 63 \text{ k}\Omega/\text{sq}$. The optimum MLG film was utilized as counter electrode in dye sensitized solar cells based on ZnO nanorods.

Keywords: Dye sensitized solar cells; sheet resistance; transmittance.

PACS: 68.65.Pq; 78.67.Wj; 81.05.uf; 81.20.Ka

INTRODUCTION

For the past two decades, graphene has been attracting attention due to its good electrical property and high optical transmission [1-5]. Graphene as a monolayer of carbon in two dimensional honeycomb lattices can be easily prepared by reduction of graphene oxide (GrO) [6-8]. Hummers method is a famous, low cost and simple technique to obtain large quantity of graphite oxide (GO) which can be exfoliated to form GrO film [9].

It is well known that both sheet resistance and transmittance of graphene film decrease with film thickness. Weber et al. reported that the transmittance of 24 nm-thick graphene film at 300 nm is ~55 % which is much lower than that of 8 nm-thick graphene film (~80 %) [10]. Meanwhile, graphene film should be made thicker to minimize the boundaries between individual graphene sheets which normally result in higher sheet resistance [11]. The thickness of the graphene film could be controlled by manipulating the GO solution concentration or coating cycle [12]. This present work reports the effect of GO solution concentration (7, 8, 9, 10 and 11 mg/ml) on the optical and electrical properties of multilayer graphene (MLG) films. The highest transmittance to sheet resistance ratio of MLG film was obtained at GO concentration of 10 mg/ml. The corresponding MLG film has been successfully applied as transparent counter electrode in dye sensitized solar cell (DSSC).

EXPERIMENTAL

The procedures to produce GO flake using modified Hummers method were described elsewhere [13]. The GO flakes were dissolved in deionized water at various concentrations of 7, 8, 9, 10, and 11 mg/ml by sonication for 20 min followed by stirring for 2 hours. Then, the resultant solution was spin-coated on the glass substrates to form GrO films. Next, the GrO films were annealed at 500°C in argon flow for half an hour to form MLG films.

Halo DB-20 UV-Vis spectrophotometer was used to investigate the optical transmission of MLG films. The sheet resistance of MLG films was characterized by four point probe measurement using Keithley 2401 source

meter. Lastly, DSSC consisted of ZnO nanorod arrays as photoanode and optimum MLG as counter electrode with an iodine electrolyte was fabricated as shown in FIGURE 1. The ZnO nanorod arrays were grown on FTO glass substrates following the method described elsewhere [14-15]. The DSSC with active area of 0.23 cm² was characterized by current–voltage measurement under 100 mW/cm² simulated AM 1.5 G sunlight using Keithley 237 source measurement unit.

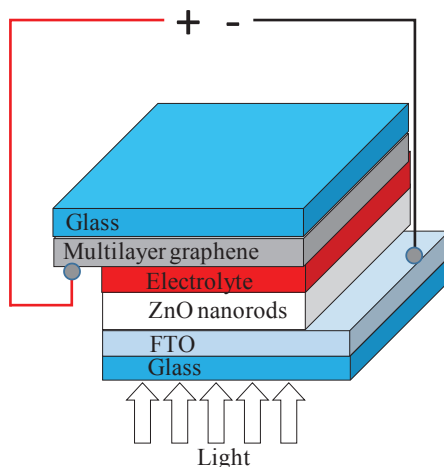


FIGURE 1. The DSSC with ZnO nanorods/electrolyte/MLG structure.

RESULTS AND DISCUSSION

The optical transmission spectra of MLG films prepared at different GO concentrations are shown in FIGURE 2. It can be clearly seen that the transmittance decreased significantly from 69-71 % ($\lambda=550$ nm) to 62 % when the GO concentration increased from 7-8 mg/ml to 9 mg/ml. This can be explained by the formation of thicker MLG film and uniform coverage of MLG over the substrate. However, the transmittance started to increase as the GO concentration further increased to 10 and 11 mg/ml due to poor film quality. The crack and void can be clearly observed from the photograph of the corresponding MLG films deposited from concentrated solution (FIGURE 3).

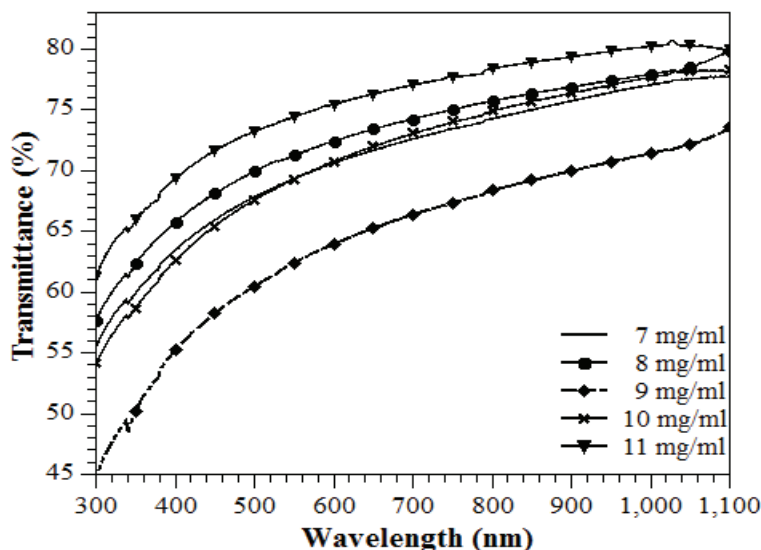


FIGURE 2. The optical transmission spectra of MLG films prepared at different GO concentrations.

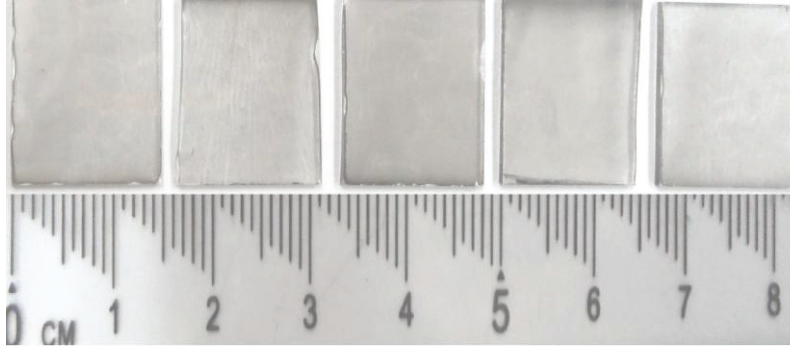


FIGURE 3. The photograph of MLG films prepared at GO concentrations of 7, 8, 9, 10, and 11 mg/ml (from left to right).

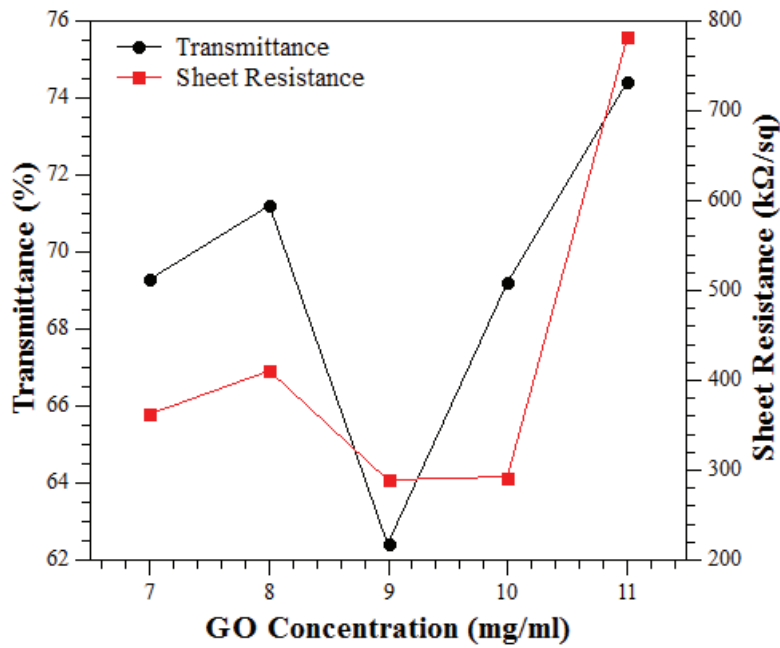


FIGURE 4. The transmittance and sheet resistance of MLG films as a function of GO concentration.

TABLE (I). The transmittance and sheet resistance of MLG films prepared at various GO concentrations

Concentration (mg/ml)	Transmittance (T, %)	Sheet Resistance (SR, kΩ/sq)	T/SR
7	69.3	362.14 ± 49.44	0.19
8	71.2	410.09 ± 35.69	0.17
9	62.4	289.79 ± 12.81	0.22
10	69.2	291.95 ± 63.07	0.24
11	74.4	781.96 ± 299.7	0.10

FIGURE 5 shows the current density–voltage (J–V) graph of DSSC constructed with 10 mg/ml MLG film as counter electrode in dark and under illumination of a simulated AM 1.5 G sunlight at 100 mW/cm². The DSSC showed power conversion efficiency (PCE) of 0.0027 % with short circuit current density (Jsc) of 26 μA/cm², open circuit voltage (Voc) of 0.42 V, and fill factor (FF) of 25 %. It should be noted that the present PCE was smaller than that of a similar DSSC with MLG as counter electrode reported recently because the substrate and thermal reduction temperature are different [13].

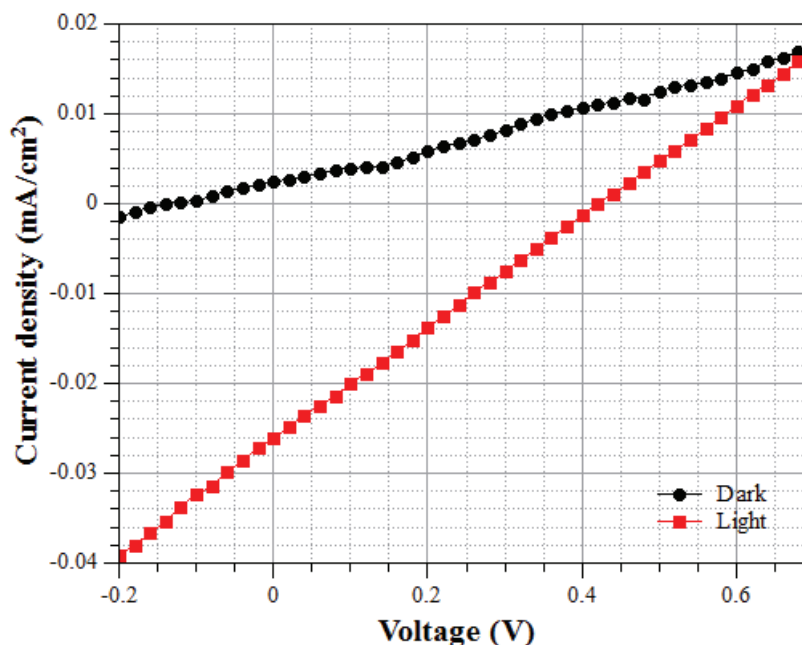


FIGURE 5. The J-V characteristic of DSSC in dark and under illumination.

CONCLUSION

The effect of GO solution concentration on the optical and electrical properties of MLG films has been investigated. The transmittance and sheet resistance decreased when the GO concentration increased from 8 mg/ml to 9 mg/ml as a result of formation of thicker MLG film and uniform coverage of MLG over the substrate. Further increase in GO concentration to 11 mg/ml results in higher transmittance and sheet resistance due to poor film quality. The MLG prepared at GO concentration of 10 mg/ml which showed the highest transmittance to sheet resistance ratio was studied as a transparent counter electrode in DSSC. The DSSC yielded J_{sc} of $26 \mu\text{A}/\text{cm}^2$, V_{oc} of 0.42 V, and FF of 25 %, resulting in PCE of 0.0027 %.

ACKNOWLEDGMENTS

This work has been carried out with the financial support of the Malaysian Ministry of Higher Education (MOHE), under the Research funding ERGS/1/2011/STG/UKM/02/62. The authors would like to thank Fitri Yenni Naumar, Siti Khatijah Md. Saad, Riski Titian Ginting, Eng Liang Lim for their contribution in this work and Mr. Zailan Bin Mohd Yusof in XRD characterization.

REFERENCES

1. H. Choi, H. Kim, S. Hwang, W. Choi and M. Jeon, *Sol Energy Mater Sol Cells* **95** (1), 323-325 (2011).
2. W. Hong, Y. Xu, G. Lu, C. Li and G. Shi, *Electro. Commun.* **10** (10), 1555-1558 (2008).
3. E. Kymakis, E. Stratakis, M. Stylianakis, E. Koudoumas and C. Fotakis, *Thin Solid Films* **520** (4), 1238-1241 (2011).
4. X. Li, Y. Zhu, W. Cai, M. Borysiak, B. Han, D. Chen, R. D. Piner, L. Colombo and R. S. Ruoff, *Nano Lett.* **9** (12), 4359-4363 (2009).
5. H. Park, J. A. Rowehl, K. K. Kim, V. Bulovic and J. Kong, *Nanotechnology* **21** (50), 505204 (2010).
6. H. Hu, Y. Liu, Q. Wang, J. Zhao and Y. Liang, *Mater. Lett.* **65** (17-18), 2582-2584 (2011).
7. J. Huang, L. Zhang, B. Chen, N. Ji, F. Chen, Y. Zhang and Z. Zhang, *Nanoscale* **2** (12), 2733-2738 (2010).

8. Y.-L. Huang, A. Baji, H.-W. Tien, Y.-K. Yang, S.-Y. Yang, C.-C. M. Ma, H.-Y. Liu, Y.-W. Mai and N.-H. Wang, *Nanotechnology* **22** (47), 475603 (2011).
9. W. S. Hummers Jr and R. E. Offeman, *J. Am. Chem. Soc.* **80** (6), 1339 (1958).
10. C. M. Weber, D. M. Eisele, J. P. Rabe, Y. Liang, X. Feng, L. Zhi, K. Müllen, J. L. Lyon, R. Williams and D. A. V. Bout, *Small* **6** (2), 184-189 (2010).
11. J. Wu, H. A. Becerril, Z. Bao, Z. Liu, Y. Chen and P. Peumans, *Appl. Phys. Lett.* **92**, 263302 (2008).
12. H. A. Becerril, J. Mao, Z. Liu, R. M. Stoltenberg, Z. Bao and Y. Chen, *Acs. Nano.* **2** (3), 463-470 (2008).
13. M. I. Ali Umar, C. C. Yap, R. Awang, M. Hj Jumali, M. Mat Salleh and M. Yahaya, *J. Mater. Sci. Mater. Electron* **24** (4), 1282-1286 (2013).
14. D. Polsongkram, P. Chamninok, S. Pukird, L. Chow, O. Lupan, G. Chai, H. Khallaf, S. Park and A. Schulte, *Phys. B* **403** (19), 3713-3717 (2008).
15. E. L. Lim, C. C. Yap, M. Yahaya and M. M. Salleh, *Semicond. Sci. and Tech.* **28** (4), 045009 (2013).
16. A. Castro Neto, F. Guinea, N. Peres, K. Novoselov and A. Geim, *Reviews of modern physics* **81**, 109-162 (2009).