

Research Article

Electrochemical Properties of PVA/PVP: GO Based Polymer Electrolytes

SK. Shahenoor Basha¹, B. Ranjit Kumar¹, K. Veera Bhadra Reddy² and M.C. Rao^{3*}¹Solid State Ionics Laboratory, Department of Physics, K. L. University, Guntur – 522502, India²Department of Physics, NRI Institute of Technology, Vijayawada Rural-520010, Krishna District, India³Department of Physics, Andhra Loyola College, Vijayawada- 520008, India**Abstract**

Graphene oxide (GO) nanoparticles were dispersed in PVA/PVP blend polymers for preparation of nanocomposite polymer films by solution cast technique. An electrochemical cell has been fabricated with the configuration of $Mg^{+}/(PVA/PVP: GO)/(I_2+C+electrolyte)$ and its cell parameters were calculated for a constant load of 100 k Ω . The nanocomposite polymer films of PVA/PVP: GO holds great promise in many potential applications such as electrode material for an electrochemical cell application. Electrochemical properties were performed on the prepared sample and found that the best performance is for PVA/PVP: GO (0.30:0.3) combination.

Keywords: PVA/PVP, Graphene oxide, Solution cast technique, Electrochemical

***Correspondence**

Author: M.C. Rao

Email: raomc72@gmail.com

Introduction

The development of membrane technology and its versatility in terms of structure and properties have led to the existence of a large number of membranes in multiple applications. Nowadays, graphene and graphene oxide (GO) membranes are a key component in energy conversion and storage [1]. Graphene and graphene oxide is one of the earth abundant elements which are easily available from earth crust and it is used in many applications due to their low production cost and excellent structural, electrical, thermal and magnetic properties [2-5]. Graphene and graphene based composite materials are expected to bring a drastic change in wide range of technological applications in industrial fields such as conductive coating, sensors [3], microwave absorbing [4] and energy storage devices etc [5]. Graphene, a monolayer of hexagonally packed carbon atoms has revolutionized both the academic and industrial world ever since it comes to experimental existence [6, 7].

Graphene has excellent physical and mechanical properties such as high thermal conductivity, good mechanical strength, high specific surface area and high mobility of charge carriers [8]. Graphene is also used in many applications such as batteries, solar cells, fuel cells and super capacitors [9, 10]. Polyvinyl pyrrolidone (PVP) and polyvinyl alcohol (PVA) have chosen because they have excellent characteristics such as optical, mechanical and electrical as well as displaying dissolubility, stability, high dielectric constant, compatibility and resistance and large scale screen printing of electrolyte films at low cost [11]. Rao et al. presented the results in their earlier studies [12-82]. In the present investigation, nanocomposite polymer films were prepared by dispersed GO nanoparticles with PVA/PVP blend polymers to improve the ionic conductivity which is suitable for battery application.

Experimental**Chemicals Required**

Graphene (acid treated 99% purity) were purchased from Loba chemicals Ltd., India; polyvinyl pyrrolidone and polyvinyl pyrrolidone with average molecular weight of 36,000 were purchased from Sigma Aldrich chemicals Ltd., India.

Preparation of Nanocomposite Polymer Films

Nanocomposite polymer films are prepared with the combination of GO, PVA and PVP. Take 200 ml round bottom flask and add 30 ml of distilled water in blend polymers PVA/PVP: wt% (0.20/0.20, 0.25/0.25 and 0.30/0.30) (equal wt% ratios of PVA/PVP). Stir all the mixtures till the polymers get dissolved in water, later reduced nanoparticles of GO: x% (0.1, 0.2 and 0.3g) were added to the homogenous mixture and sonicate the solution to get fine dispersion,

which was poured in polypropylene dishes and placed in hot air oven at 70 °C. A fine nanocomposite polymer thin film was obtained which is kept in a decicator until further test.

Results and Discussion

Electrochemical Properties

Electrochemical cell has been fabricated with maximum ionic conductivity that was obtained from polymer electrolyte of 0.30 PVA/0.30 PVP: 0.3 GO combinations. The galvanostatic charge/discharge performance was carried-out from 0.5 to 2.5 V for configuration of $Mg^{+}/(PVA/PVP+GO)/(I_2+C+electrolyte)$ as shown in **Figure 1**. The electrochemical stability of the polymer blend electrolyte membrane has been found to be stable up to ~2.4 V as shown in **Figure 2**.

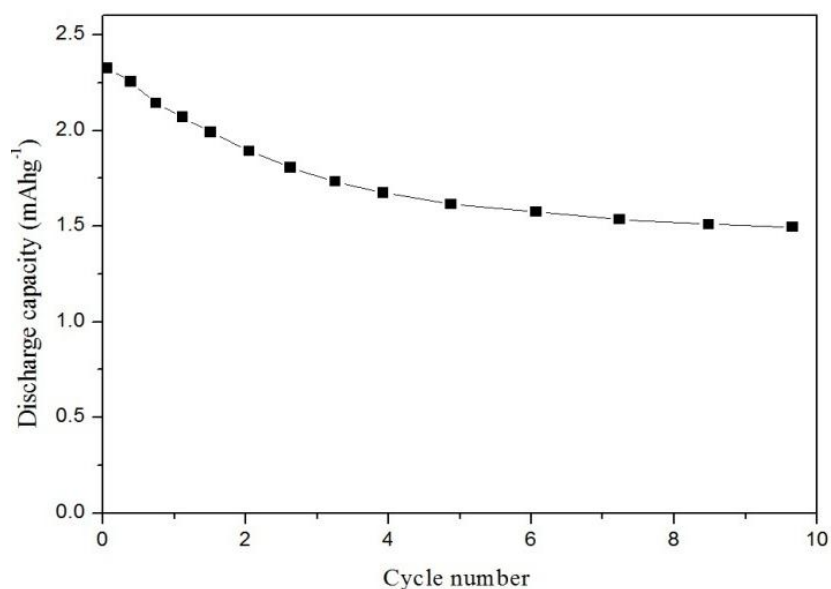


Figure 1 Variation of cycle number with discharge capacity of polymer electrolyte films for (0.30:0.3) wt% ratio

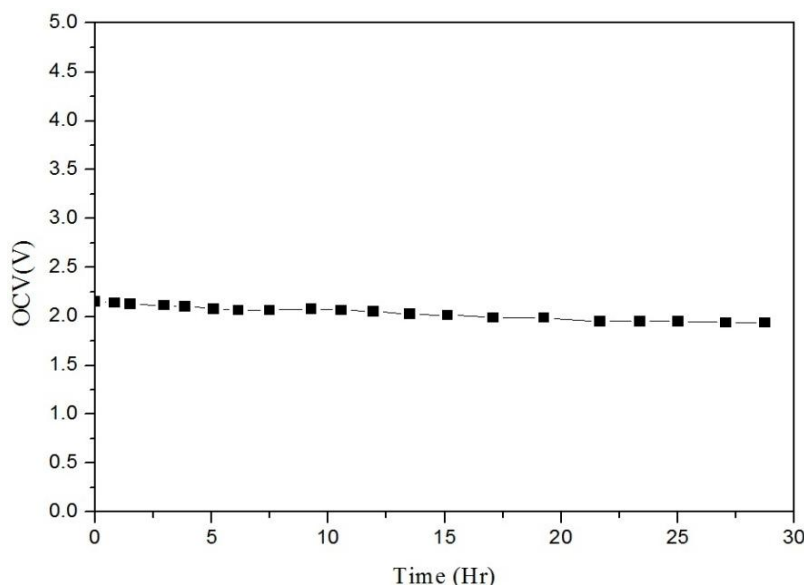


Figure 2 OCV of solid polymer electrolyte film for (0.30:0.3) wt% ratio

The anode and cathode materials were made in the form of pellets, which enhances its electronic conductivity [83]. Cell parameters such as open circuit voltage (OCV), discharge capacity have been evaluated. Initially a rapid decrease in the voltage is occurred; it may be due to the polarization and the formation of thin layer of magnesium salt at the electrode/electrolyte interfaces [84, 85]. The performance of polymer electrolyte of PVA/PVP: GO membrane is measured by varying the current intensity as a function of potential as shown in **Figure 3**.

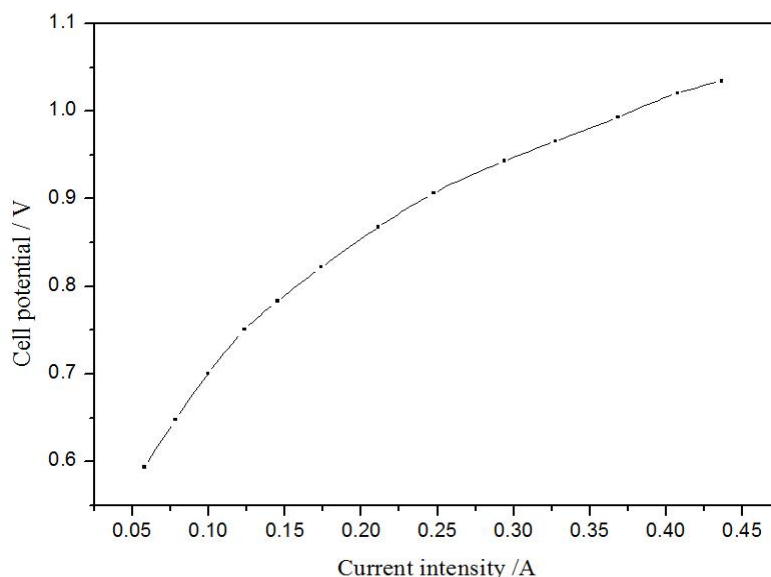


Figure 3 Cell parameters of polymer films for (0.30:0.3) wt% ratio

The obtained results showed that as increasing the current intensity the potential increases predominantly. Initially due to polarization of ions the cell potential is steady state and after a long time of polarization before stabilizing at a much lower level at 1.5 eV. The migration of the ions under the influence of the electric field therefore leads to an enrichment of the mobile species in the region of the electrolyte adjacent to one electrode and depletion near the other electrode [86]. The ionic motion is then opposed by a chemical potential gradient and after a short time; this has increased sufficiently to counter balance the electric field, the migration stops. The cell is then said to be concentration polarized.

Figure 4 shows the variation of time with respect to cell potential. As shown in figure, during discharge, the cell voltage decreases initially and then remains constant for a particular duration (time of stable performance of the cell) and after which, voltage declines. Thus the current starts decreasing with time as the drift of ions is balanced by diffusion of ions due to their concentration gradient induced by the electrode which blocked the ions, but still active towards electrons and hence the cell gets polarized. The initial sharp decrease in the voltage may be due to the activation polarization and/or to the formation of thin layer on potassium at electrode-electrolyte interface [87-90]

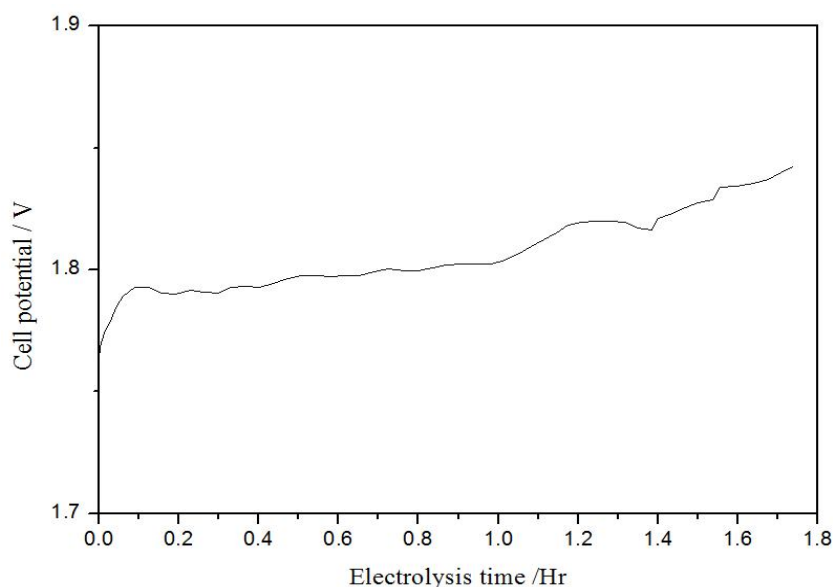


Figure 4 Variation of time vs potential of electrolyte polymer electrolyte films for (0.30:0.3) wt% ratio

As the fabricated cell was allowed to equilibrate for 30 min and the OCV was measured to be 2.1 V; the charging curve (plateau potential) indicates that Mg^{2+} deintercalation occurs at the cathode. The cell was cycled

galvanostatically at $10 \mu\text{A}$ as shown in **Figure 5**. The electrochemical performance of cell shows the number of cycles at 2.1 V for about 24 h when the test was terminated as shown in **Figure 6**. The complexed nanocomposite polymer electrolyte ratio of 0.30 PVA/0.30 PVP: 0.3 GO exhibits the highest performance, which is more suitable for fabricating solid state polymer batteries.

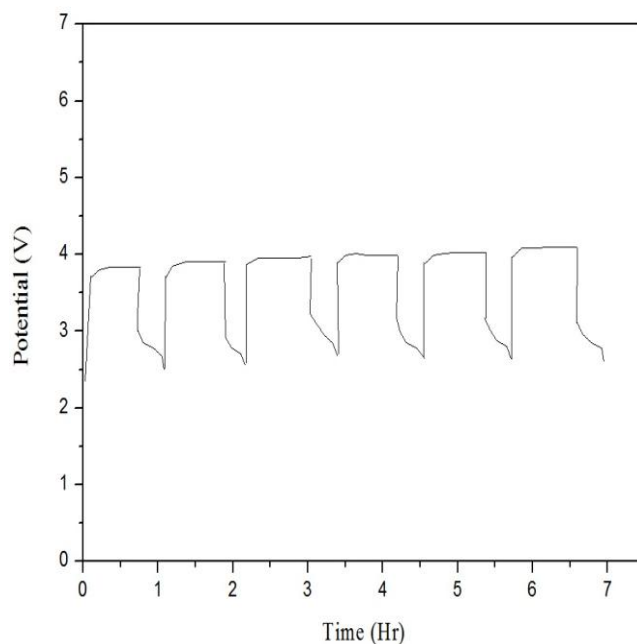


Figure 5 Variation of time vs potential of polymer electrolyte films for (0.30:0.3) wt% ratio

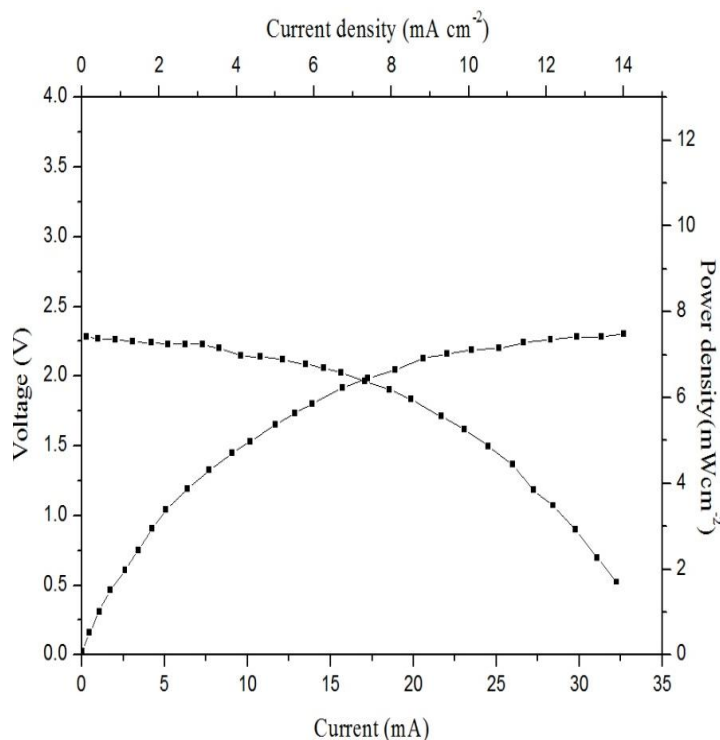


Figure 6 Cell parameters of polymer films for (0.30:0.3) wt% ratio

Conclusions

Nanocomposite polymer thin films were prepared with the combination of PVA/PVP: GO by Solution cast technique. Cyclic voltammeter studies have been carried-out for the composition of PVA/PVP: GO (0.30:0.3). The electrochemical performance of cell shows the number of cycles at 2.1 V for about 24 h.

References

- [1] Deshmukh K, Khatake SM, Joshi GM, *J Polym Res* 2013, 20, 286-296.
- [2] Wang GX, Yang J, Park J, Gou XL, Wang B, Liu HJ, *Phys Chem C* 2008, 112, 8192-8195.
- [3] Yoo E, Kim J, Hosono E, Zhou HS, Kudo T, Honna I, *Nano Lett* 2008, 8, 2277-2282.
- [4] Wang X, Zhi L, Muellen K, *Nano Lett* 2008, 8, 323-327.
- [5] Guo S, Dong S, Wang E, *ACS Nano* 2010, 4, 547-555.
- [6] Zhang L, Shi GJ, *Phys Chem C* 2011, 115, 17206-17212.
- [7] Li N, Cheng W, Ren K, Luo F, Wang K, Fu Q, Chin, *J Poly Sci* 2013, 31, 98-109.
- [8] Lin L, Deng H, Gao X, Zhang S, Bilotti E, Peijs T, Fu Q, *Poly Int* 2013, 62, 134-140.
- [9] Gao X, Zhang S, Mai F, Lin L, Deng Y, Deng H, Fu Q *J Mater Chem* 2011, 21, 6401-6408.
- [10] Di CA, Wei DC, Yu G, Liu YQ, Guo YL, Zhu DB, *Adv Mater* 2008, 20, 3289-3293.
- [11] Stoller MD, Park S, Zhu Y, An J, Ruoff R.S, *Nano Lett* 2008, 8, 3498-3502.
- [12] Rao M C, Hussain O M, *J Alloys Compd* 2010, 491(1), 503- 506.
- [13] Rao M C, *J Crys Growth* 2010, 312(19), 2799- 2803.
- [14] Rao M C, Ramachandra Rao K, *Int J ChemTech Res* 2014, 6(7), 3931- 3934.
- [15] Rao M C, *Optoelect Adv Mater (Rapid Commu)* 2011, 5, 85-88.
- [16] Muntaz Begum Sk, Rao M C, Ravikumar R VS S N, *J Inorg Organometa Poly Mater* 2013, 23(2), 350-356.
- [17] Rao M C, *Res J Recent Sci* 2013, 2(1) 1-8.
- [18] Rao M C, *J Optoelect Adv Mater* 2011, 13, 428-431.
- [19] Muntaz Begum Sk, Rao M C, Ravikumar R VS S N, *Spectrochim Acta Part A Mol Biomol Spec*, 2012, 98, 100-104.
- [20] Rao M C, *Der Pharm Che* 2016, 8(4) 243-250.
- [21] Rao M C, Hussain O M, *Eur Phys J Appl Phys*, 2009, 48(2), 20503.
- [22] Rao M C, *J Optoelect Adv Mater* 2010, 12, 2433-2436.
- [23] Rao M C, Hussain O M, *IOP Conf Series Mater Sci Eng*, 2009, 2, 012037.
- [24] Rao M C, Hussain O M, *Ind J Eng Mater Sci*, 2009, 16, 335-340.
- [25] Rao M C, *Optoelect Adv Mater (Rapid Commu)* 2011, 5(5-6), 651-654.
- [26] Rao M C, Hussain O M, *Optoelect Adv Mater* 2011, 13(2-4), 1109-1113.
- [27] Rao M C, *J Optoelect Adv Mater* 2011, 13(1-2), 72-75.
- [28] Rao M C, Hussain O M, *Res J Chem Sci*, 2011, 1(7), 92-95.
- [29] Rao M C, *Int J Chem Sci*, 2012, 10(2), 1111-1116.
- [30] Rao M C, *Optoelect Adv Mater (Rapid Commu)*, 2012, 6, 511-515.
- [31] Prasad P V, Ramachandra Rao K, Rao M C, *J Mol Struc* 2015, 1085, 115-120.
- [32] Rao M C, *J Optoelect Adv Mater* 2011, 13, 78-81.
- [33] Rao M C, Muntaz Begum Sk, *Optoelect Adv Mater (Rapid Commu)* 2012, 6, 508-510.
- [34] Rao M C, *Res J Rec Sci* 2013, 2(3), 67-73.
- [35] Rao M C, *Int J ChemTech Res*, 2014, 6(3), 1904-1906.
- [36] Rao M C, *Optoelect Adv Mater (Rapid Commu)* 2010, 4, 2088-2091.
- [37] Rao M C, Hussain O M, *Optoelect Adv Mater (Rapid Commu)* 2012, 6, 245-248.
- [38] Rao M C, *Optoelect Adv Mater (Rapid Commu)* 2012, 6, 508-510.
- [39] Rao M C, *Int J ChemTech* 2014, 7(1) 269-274.
- [40] Rao M C, *Res J Rec Sci* 2013, 2(3), 67-72.
- [41] Rao M C, Hussain O M, *Res J Chem Sci* 2011, 1(7), 76-80.
- [42] Rao M C, *AIP Conf Proc* 2016, 1728(1), 020077.
- [43] Ravindranadh K, Rao M C, *AIP Conf Proc* 2016, 1728(1), 020079.
- [44] Ravindranadh K, Rao M C, *AIP Conf Proc* 2016, 1536(1), 219-220.
- [45] Rao M C, *AIP Conf Proc* 2016, 1536(1), 215-216.
- [46] Rao M C, *Optoelect Adv Mater (Rapid Commu)* 2012, 6, 245-248.
- [47] Sivaram K, Rao M C, *Rasayan J Chem* 2017, 10(1), 69-76.
- [48] Sivaram K, Rao M C, *Rasayan J Chem* 2017, 10(1), 16-24.
- [49] Rao M C, *Optoelect Adv Mater (Rapid Commu)* 2016, 10, 889-892.
- [50] Tejaswi M, Rao M C, *Rasayan J Chem* 2016, 9(4), 697-705.
- [51] Jayaprada P, Rao M C, *Rasayan J Chem* 2016, 9(4), 588-596.
- [52] Sivasri J, Rao M C, *Rasayan J Chem* 2016, 9(4), 556-572.

- [53] Samuel T, Ramachandra Rao K, Rao M C, AIP Conf Proc 2016, 1728(1), 020080.
[54] Rao M C, Int J Pure Appl Phys 2010, 6, 365-370.
[55] Rao M C, AIP Conf Proc 2012, 1447, 613-614.
[56] Rao M C, AIP Conf Proc 2013, 1536, 27-28.
[57] Shahenoor Basha Sk, Sunita Sundari G, Vijaya Kumar K, Rao M.C, Rasayan J Chem 2016, 9, 348-354.
[58] Rao M C, J Chem Bio Phy Sci 2013, 3(2) 1412-1424.
[59] Rao M C, Int J Modern Phys Conf Series 2013, 22, 576-582.
[60] Rao M C, Int J Modern Phys Conf Series 2013, 22, 355-360.
[61] Shahenoor Basha Sk, Sunita Sundari G, Vijaya Kumar K, Rao M.C, J Inorg Organomet Polym 2016, 26, 1107-1452.
[62] Shahenoor Basha Sk, Sunita Sundari G, Vijaya Kumar K, Veera Bhadra reddy. K, Rao M.C, Rasayan J Chem 2017, 10, 279-285.
[63] Sunita Sundari G, Vijaya Kumar K, Shahenoor Basha Sk, Rao M.C, Rasayan J Chem 2017, 10, 298-304.
[64] Shahenoor Basha Sk, Sunita Sundari G, Vijaya Kumar K, Rao M.C, Chem Sci Rev Lett 2017, 6, 166-171.
[65] Rao M C, Int J ChemTech Res 2014, 6(7), 3935-3938.
[66] Rao M C, Int J ChemTech Res 2014, 6(11), 4697-4701.
[67] Rao M C, Int J ChemTech Res 2014, 7(1) 420-425.
[68] Rao M C, Int J ChemTech Res 2015, 8(2) 524-527.
[69] ParameswaraRao K, Der Pharm Lett 2016, 8(9), 341-348.
[70] ParameswaraRao K, Der Pharm Lett 2016, 8(9), 222-228.
[71] ParameswaraRao K, Der Pharm Lett 2016, 8(13), 259-266.
[72] ParameswaraRao K, Rasayan J Chem 2016, 9(3), 393-400.
[73] ParameswaraRao K, Der Pharm Lett 2016, 8(14), 132-139.
[74] ParameswaraRao K, Der Pharm Lett 2016, 8(15), 101-106.
[75] ParameswaraRao K, Der Pharm Lett 2016, 8(15), 125-132.
[76] Ramachandra Rao K, Mater Res Innov 2016, 20(7), 538-544.
[77] Muntaz Begum Sk, J Bionosci 2016, 10(5), 424-429.
[78] Muntaz Begum Sk, Optoelect Adv Mater (Rapid Commu) 2016, 10(11-12) 889-892.
[79] ParameswaraRao K, Int J Chem Sci 2016, 14(4), 2389-2396.
[80] ParameswaraRao K, Int J Chem Sci 2016, 14(4), 2433-2438.
[81] Rao M C, Mater Res Innov 2017, 21(2), 102-105.
[82] Rao M C, Optoelect Adv Mater (Rapid Commun) 2017, 11(3-4), 242-245.
[83] Yuxi X, Wenjing H, Hua B, Chun L, Gaoquan S, Carbon 2009, 47, 3538-3543.
[84] Stankovich S, Dikin DA, Piner RD, Kohlhaas KM, Kleinhammes A, Jia Y, Wu Y, Nguyen ST, Ruoff RS, Carbon 2007, 45, 1558-1565.
[85] Fu X, Yao C, Yang G, RSC Adv 2015, 5, 61688-61702.
[86] Morimun S, Kotera M, Nishino T, Goto K, Hata K, J Macr Mol 2011, 44, 4415-4421.
[87] Tyler T, Shenderova O, Cunningham G, Walsh J, Drobnik J, McGuire G, Diam Relat Mater 2006, 15, 2078-2081.
[88] Khan U, May P, Neill AO, Coleman JN, J Carbon 2010, 48, 4035-4041.
[89] Shahenoor Basha Sk, Sunita Sundari G, Vijaya Kumar K, Int J ChemTech Res 2016, 2,175-186.
[90] Ping G, Zhang J, Cheng Ling Shi J, Iran Polym J 2017, 26, 55-69.

Publication History

Received	08 th May 2017
Revised	25 th May 2017
Accepted	04 th June 2017
Online	30 th June 2017

© 2017, by the Authors. The articles published from this journal are distributed to the public under “**Creative Commons Attribution License**” (<http://creativecommons.org/licenses/by/3.0/>). Therefore, upon proper citation of the original work, all the articles can be used without any restriction or can be distributed in any medium in any form.