

Thermal Properties of Carbon Nanotube (CNT) Reinforced Polyvinyl Alcohol (PVA) Composites

Monirul Hasan¹, Sujan Kumar Das^{2,*}, Jahid M. M. Islam³, Md. Abdul Gafur⁴,
Enamul Hoque⁵, Mubarak A. Khan³

¹Department of Electrical and Electronic Engineering, Bangladesh University of Business and Technology (BUBT), Dhaka - 1216, Bangladesh

²Department of Physics, University of Chittagong, Chittagong - 4331, Bangladesh

³Institute of Radiation and Polymer Technology, Bangladesh Atomic Energy Commission, Dhaka - 1000, Bangladesh

⁴Pilot Plant and Process Development Centre, Bangladesh Council of Scientific and Industrial Research, Dhaka, Bangladesh

⁵Department of Physics, Jahangirnagar University, Savar, Dhaka - 1342, Bangladesh

*E-mail address: skdas@cu.ac.bd

ABSTRACT

Homogeneous Polyvinyl alcohol (PVA)/Carbon nanotube (CNT) composite has been prepared by solution casting method using gum acacia as a surfactant. CNT content in the composite was varied from 5-10 % by weight. The thermal properties of PVA/CNT composites were investigated by Thermo Gravimetric/Differential Thermal Analyzer (TG/DTA) and Thermo Mechanical Analyzer (TMA). TG/DTA results showed that higher thermal stability in higher percentage of CNT in the composites. The 10 % CNT containing PVA composite exhibit highest onset of melting, glass transition point and offset of melting temperature and the recorded values are 330.4K, 379K and 421.3K respectively. All of the result indicates that the developed PVA/CNT composite might be promising for use in solar cell application.

Keywords: CNT; PVA; composite; Thermal properties; Gum acacia

1. INTRODUCTION

Carbon is one of the most abundant elements existing in nature. For centuries diamond and graphite were considered to be the only two types of all carbon crystalline structure which naturally existed as allotropes. The discovery of C₆₀ also known as Fullerene [1], had an impact which extended way beyond the confines of academic chemical physics and marked the beginning of a new era in carbon science [2,3]. This C₆₀ molecule contains 60 carbon atoms arranged in a spherical way, as in a soccer ball [4].

Several years later, Iijima of NEC laboratories in Japan, discovered carbon nanotubes which proved to be the most important fruit of this research. Great attention has been attracted to this fascinating material which possesses extraordinary mechanical, electrical and thermal properties. One thing to note is that the carbon nanotubes observed by Iijima in 1991 [5]

contained at least two concentric graphitic layers, which means they were multi-walled carbon nanotubes (MWNTs). The synthesis of the first Single-Walled Carbon Nanotubes (SWNTs) was reported two years later in 1993. This proved to be an extremely important development, since SWNTs seem to have a seamless structure and possess the potential to be the ideal reinforcement filler for the next generation of high performance composites.

Over the last few years, several production technologies have been developed for CNT reinforced polymer composite processing. Qian et al. [6] have prepared and characterized 1 % carbon nanotubes (CNTs) in polystyrene matrix. The increase of tensile strength by 42 %, indicates significant load transfer across the CNT/Polystyrene nanocomposite. Zhang et al. [7] prepared SWNT / PVA composite films with polyvinyl pyrrolidone (PVP) and sodium dodecyl sulfonate (SDS) to assist the dispersion of the nanotubes. Several authors also have studied the characteristics of CNT reinforced polymer composites in different conditions [8-14]. To best of our knowledge, no investigation has been done on PVA/CNT composite with gum acacia to assist the dispersion of the CNT. Therefore, in our present work, we attempt to study the thermal properties of CNT reinforced PVA composite by using Thermo Gravimetric/Differential Thermal Analyzer (TG/DTA) and Thermo Mechanical Analyzer (TMA).

2. EXPERIMENTAL

2.1. Materials

Arc-discharge single walled carbon nanotubes (SWNTs) were used in this work as reinforcing material. PVA was supplied by MERK, Germany as matrix material. Gum acacia collected from Bangladesh Jute Research Institute (BJRI), which is used as surfactant.

2.2. Methods

Gum acacia used as the surfactant to disperse SWNTs in distilled water and sonicated for 2 hours by Digital Ultrasonic Bath (UBT-580). PVA was dissolved in distilled water along with varying percentages of dispersed CNTs to prepare various formulations. Table 1 shows six types of such formulations.

Table 1. Composition of different nanocomposite formulations (% wt).

Sample	PVA (gm)	CNT (gm)	Gum acacia (gm)	Distilled water (ml)
Pure PVA (0 % CNT)	5	0.00	0.10	100
5 % CNT containing PVA/CNT film	5	0.25	0.10	100
7 % CNT containing PVA/CNT film	5	0.35	0.10	100
8 % CNT containing PVA/CNT film	5	0.40	0.10	100
9 % CNT containing PVA/CNT film	5	0.45	0.10	100
10 % CNT containing PVA/CNT film	5	0.50	0.10	100

The formulated solutions were cast on silicon paper (release film) mounted on level glass plate. The solutions were kept at room temperature for about 48 hours. After formation

of the films, they were peeled off and cut into a dimension of $50 \times 10 \text{ mm}^2$. Average thickness of the films was 0.1 to 0.3 mm.

3. RESULTS AND DISCUSSION

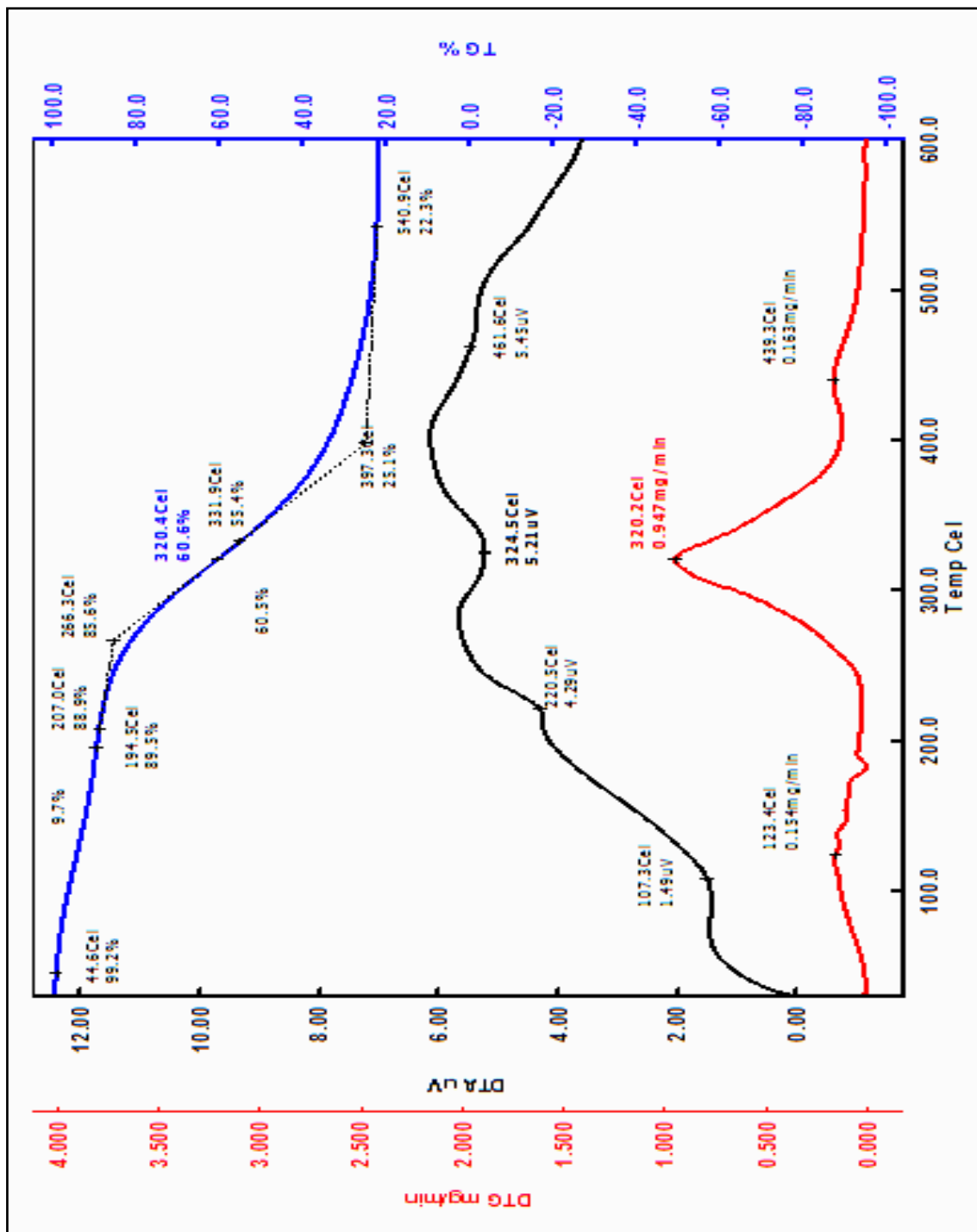


Fig. 1. TG, DTA and DTG for 0 % CNT containing PVA nanocomposite.

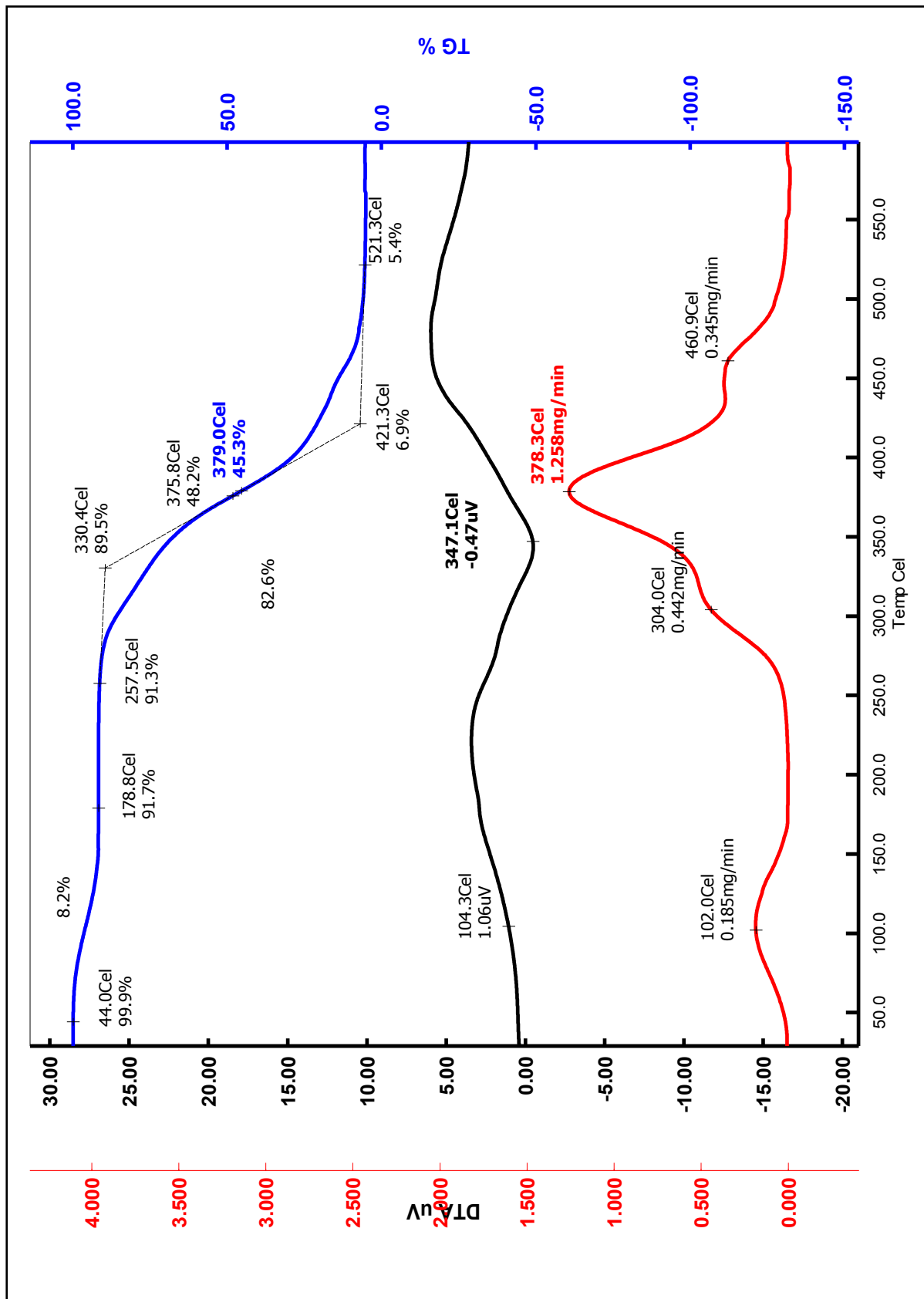


Fig. 2. TG, DTA and DTG for 10 % CNT containing PVA nanocomposite.

The thermal properties (Onset, offset of melting point and glass transition point) of the CNT reinforced PVA composites were evaluated using Thermo Gravimetric/Differential Thermal Analyzer (TG/DTA) and Thermo Mechanical Analyzer (TMA) under Nitrogen gas flow from 50 °C to 600 °C. The TG, DTA, and DTG curves only for 0 % and 10 % CNT containing PVA nanocomposite are given below (Fig. 1 and Fig. 2 respectively).

The Onset, offset of melting points and glass transition points of the pure PVA and the composites are given in Fig. 3. It has been found that the thermal properties of the composites improved significantly compared to pure PVA film.

The onset and offset of melting temperature for the pure PVA are found to be 266.5 °C and 375.5 °C respectively. The 10 % CNT reinforced PVA composite shows the highest onset and offset of melting temperature. It is clear from the bar diagram that the offset of melting point is increased up to 421.3 °C for 10 % CNT reinforced PVA composite.

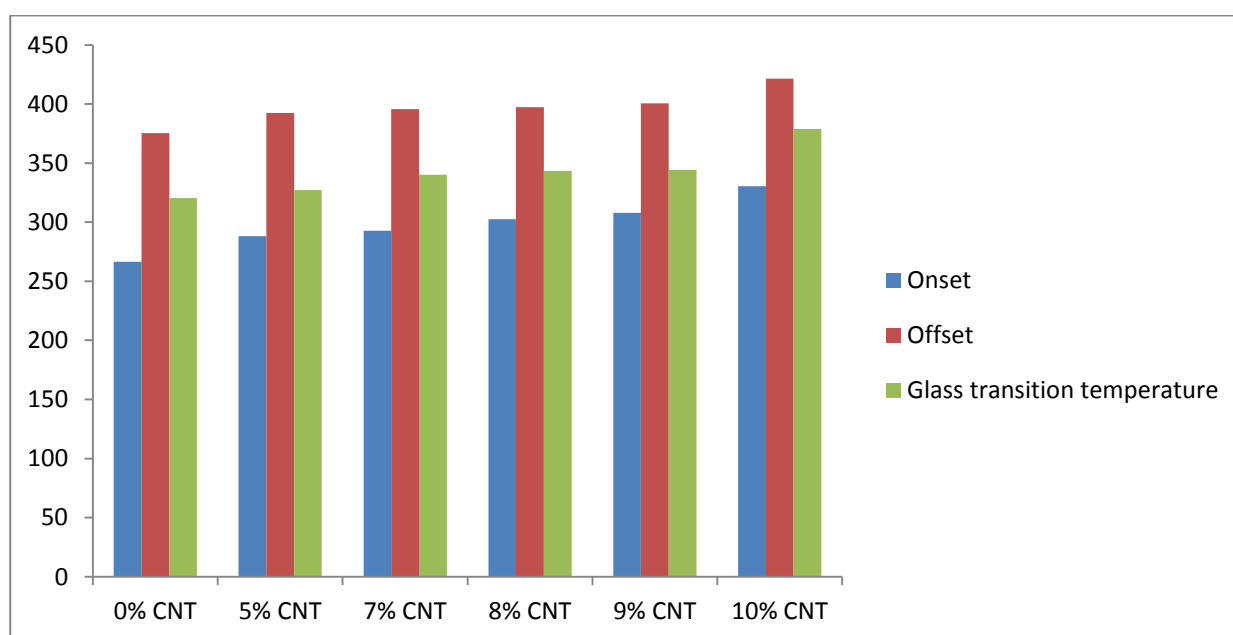


Fig. 3. Onset, offset of melting point and glass transition point temperatures for different % wt of composition.

Table 2. Glass transition temperatures for different % wt of compositions.

Compositions	0 %	5 %	7 %	8 %	9 %	10 %
Glass Trans. Temp. (°C)	320.4	327.2	340.2	343.3	344.3	379.0

An important thermal property – glass transition point temperature for the pure PVA was found to be 320.4 °C. The maximum glass transition point temperature was found for 10 % CNT containing composite. The glass transition point temperature increases with the increase of (% wt) CNT composition.

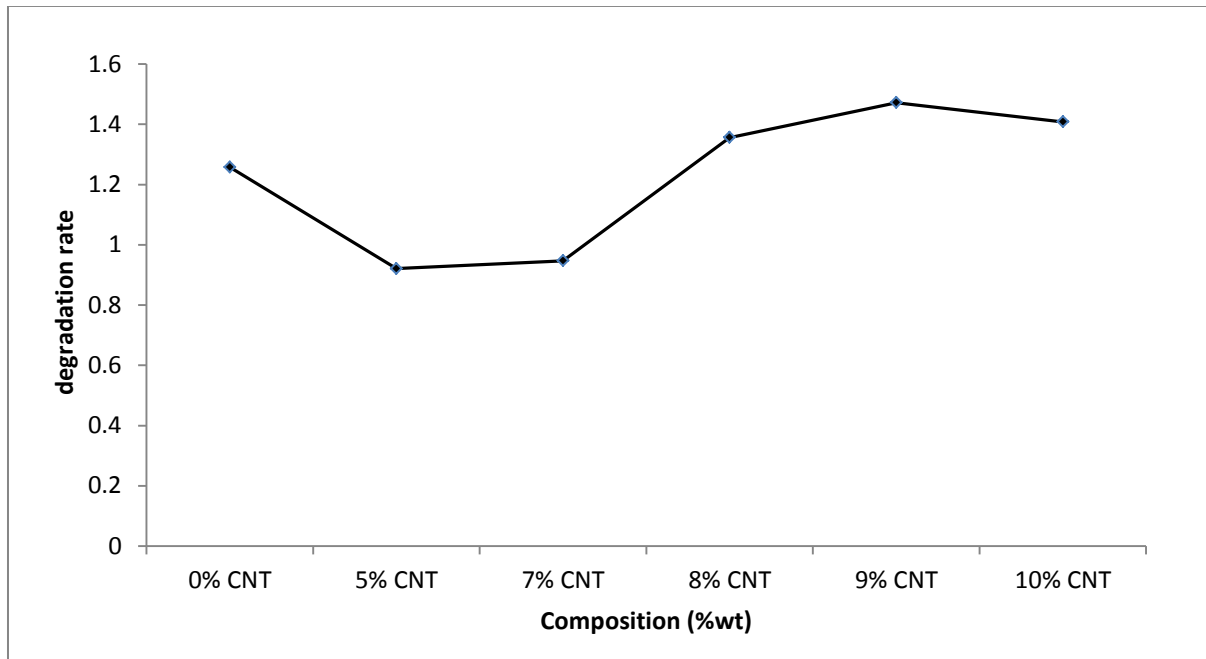


Fig. 4. Degradation rate for different % wt of composition.

Fig. 4 reveals that 9 % CNT containing PVA composite shows the maximum degradation rate. The maximum degradation rate of 9 % CNT containing PVA composite is 1.472 mg/min at 340.2K. The 5 % CNT containing shows the lowest degradation rate at 327.2K. Pure PVA shows the degradation rate of 1.285 mg/min.

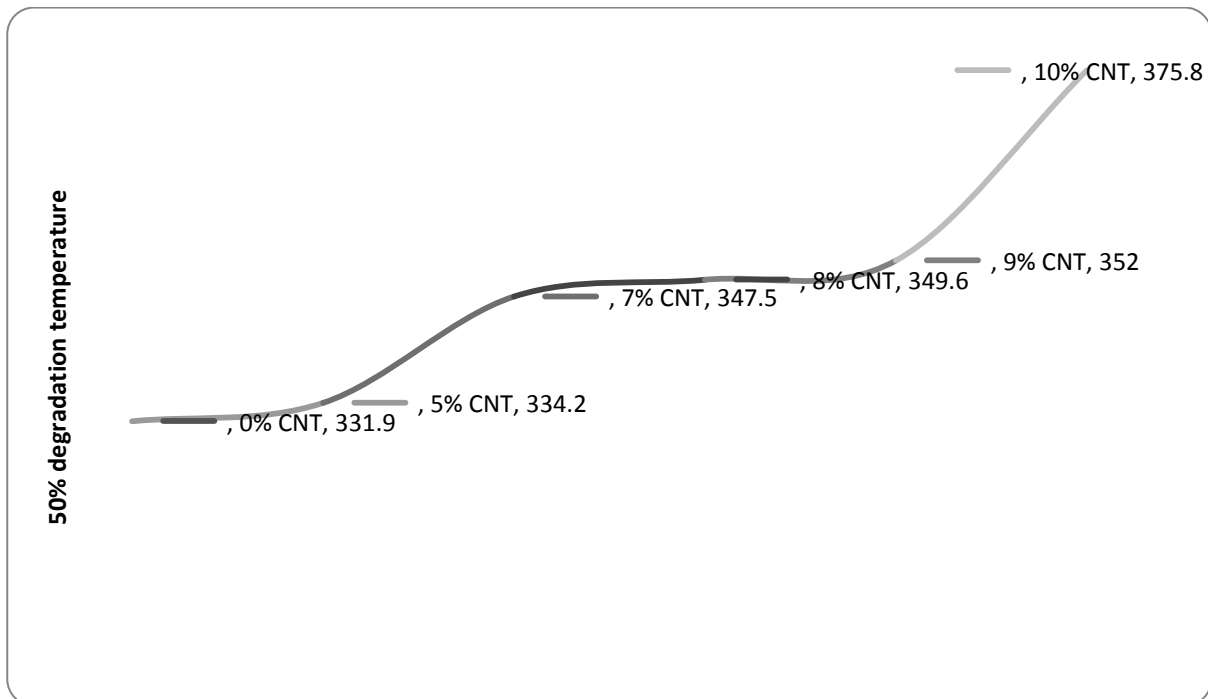


Fig. 5. 50 % degradation temperature for different % wt of composition.

From Fig. 5 it is clear that 5 % CNT containing composite has the lower 50 % degradation and maximum slope temperature (334.2K) than the other compositions. And 10 % CNT containing composite has the highest 50 % degradation and maximum slope temperature (375.8K). Fig. 5 also shows that pure PVA has the lowest highest 50 % degradation and maximum slope temperature at 331.9K.

From this investigation it is clear that the thermal stability of the composites improved dramatically when CNT is incorporated into the matrix.

4. CONCLUSION

We have successfully modified the PVA composite by adding CNTs. It was found that, with respect to concentrations 10 % CNT reinforced PVA composite showed the highest performance in thermal properties. The thermal properties have been drastically improved due to CNT content in the films. The glass transition temperature increases almost linearly due to increasing CNT content in the composite films. The present study also figured out the degradation study with temperature and revealed in which conditions the PVA/CNT composite degrade easily.

Acknowledgement

This research work was carried out in Institute of Radiation and Polymer Technology (IRPT) of Bangladesh Atomic Energy Research and Establishment (AERE), Department of Physics of Jahangirnagar University and Pilot Plant and Process Development Centre (PP & PDC) of Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka, Bangladesh.

References

- [1] Kroto H. W., *Rev. Mod. Phy.* 69 (1991) 703.
<http://www.des.upatras.gr/physics/christides/pdf%5CKroto.pdf>
- [2] Ishida H., Campbell S., Blackwell J., *Chem. Mater.* 12 (2000) 1260-1267.
- [3] Vaia R. A., Giannelis E. P., *MRS Bulletin* 26 (2001) 394-401.
DOI:10.1557/mrs2001.93
- [4] Cumings John, Zettl A., *Science* 289 (2000) 602-604.
<http://mse.umd.edu/~cumings/PDF%20Publications/02.Sci289cumings.pdf>
- [5] S. Iijima, *Nature* 354 (1991) 56-58.
<http://www.nature.com/physics/looking-back/ijjima/ijjima.pdf>
- [6] Qian D., Dickey E. C., Andrews R., Rantell T., *Appl. Phys. Lett.* 72 (1998) 188-190.
<http://dx.doi.org/10.1063/1.120680>
- [7] Zhang X., Liu T., Kumar, S., Moore V. C., Hauge R. H., Smalley R. E., *Nano Letters* 03 (2003) 1285-1288.
DOI: 10.1021/nl034336t

-
- [8] Chen XL, Liu YJ, *Computational Materials Science* 29 (2004) 1-11.
[http://dx.doi.org/10.1016/S0927-0256\(03\)00090-9](http://dx.doi.org/10.1016/S0927-0256(03)00090-9)
- [9] Iijima S., Ichlhashi T., *Nature* 363 (1993) 603-605.
doi:10.1038/363603a0
- [10] C. A. Cooper, S. R. Cohen, A. H. Barber, *Appl. Phys. Lett.* 81 (2002) 3873-3875.
- [11] Wagner H. D., *Chem. Phys. Lett.* 361(2002) 57-61.
DOI: 10.1016/S0009-2614(02)00948-X
- [12] Zaho Q., Nardali M.B., Bernholc J., *Phys. Rev. B* 65 (2002) 144105.
DOI:10.1103/PhysRevB.65.144105
- [13] Shaffer M. S. P., Windle A. H., *Advan. Mater.* 11 (1999) 937-941.
DOI: 10.1002/(SICI)1521-4095(199908)11:11<937::AID-ADMA937>3.0.CO;2-9
- [14] Lourie O., Wagner H. D., *Appl. Phys. Lett.* 73 (1998) 3527-3529.
<http://dx.doi.org/10.1063/1.122825>

(Received 02 August 2013; accepted 07 August 2013)