Thermal investigations of multiwall carbon nanotubes

K. S. Patil[1], and G. R. Gupta[2]*

[1] SST's College of Engineering and Technology, Bambhori, Jalgaon-425001(India)
[2] Institute of Chemical Technology, Nathalal Parekh Road, Matunga, Mumbai-400019 (India)
* Corresponding Author E-mail: grgupta83@gmail.com

Abstract

Multiwall-carbon nanotube (MW-CNT) composites have engrossed the attention of scientific community from industry as well as academia due to their outstanding and unique set of properties. This article presents a brief overview of the thermal analysis of MW-CNT material. The data obtained from the thermal analysis for MW-CNT material is first reviewed, including thermogravimetry and differential scanning calorimetry. The obtained thermal profile have explored towards the calculations of specific heat capacity (C_p) as a function of temperature for MW-CNT material.

Key words

Thermal analysis, Multiwall carbon nanotube, specific heat capacity

Introduction

Both single-walled carbon nanotubes (SW-CNTs) and multi-walled carbon nanotubes (MW-CNTs), which possess remarkable physical and mechanical properties including Young's modulus, remarkable thermal conductivity, exceptional electrical conductivity etc. are responsible for the development of the field of carbon nanotubes over the past decades [1]. Bio-technological exploitations of CNTs have recently been attracted huge academic and industrial interest. CNTs have been anticipated as machineries for DNA and protein biosensors, ion channel blockers and as bio-separators and biocatalysts [2]. Quite a large number of techniques to produce pure single and multiwalled carbon nanotubes with accountable advantages and setbacks in the literature [3]. However, an analytical tool is to be tuned to analyze the extent of purity and the structural confinement of the resulting material. In this regard, we thoroughly examine the thermal response of MW-CNT material by performing thermos-gravimetry and differential scanning calorimetry (TGA-DSC) measurements and the data obtained was further processed to determine the specific heat capacity as a function of temperature for MW-CNT.

Materials and Methods

The MW-CNT material was procured from Nanocyl, KCl and urea were purchased from sd fine Pvt. Ltd, Mumbai, India, while cyclodextrins were obtained from Sigma-Aldrich. All the chemicals were used without further purification.

Methods

The TGA-differential scanning calorimetry (DSC) analysis of KCl, urea, α-CD, β-CD as a standard and MW-CNT material was performed on TA instrument (model: SDT Q 600 V 20.9), which was kept in an air-conditioned lab having a humidity of 5–10% with sample temperature accuracy ±0.5 K under N_2 atmosphere. Samples having weights in the range of 4 to 10 mg were used for the measurements. The sample volumes of the alumina pans were 10 mm^3 with a cell volume of 3.4 ml and were subjected to nitrogen purging with a flow rate of 50 $ml \cdot min^{-1}$. The heating rate of the sample was always kept at 5 $K \cdot min^{-1}$ for KCl, urea, and cyclodextrins, while MW-CNT was studied at 10 $K \cdot min^{-1}$. After calibrating the instrument and setting up proper conditions, we subjected our samples of KCl, urea, cyclodextrins as a standard and MW-CNT sample for obtaining the thermograms and heat flow measurements by differential scanning calorimetry over the temperature range of 308-758 K. The details of the calculation of sample deflections with appropriate corrections have already reported in our earlier communication [4, 5]. The accuracy of the instrument was verified by determining the specific heat capacity of KCl, urea, and cyclodextrins (Figure 1). The estimated accuracy of the measured values was over this temperature range when the data were compared with the literature data [6, 7].

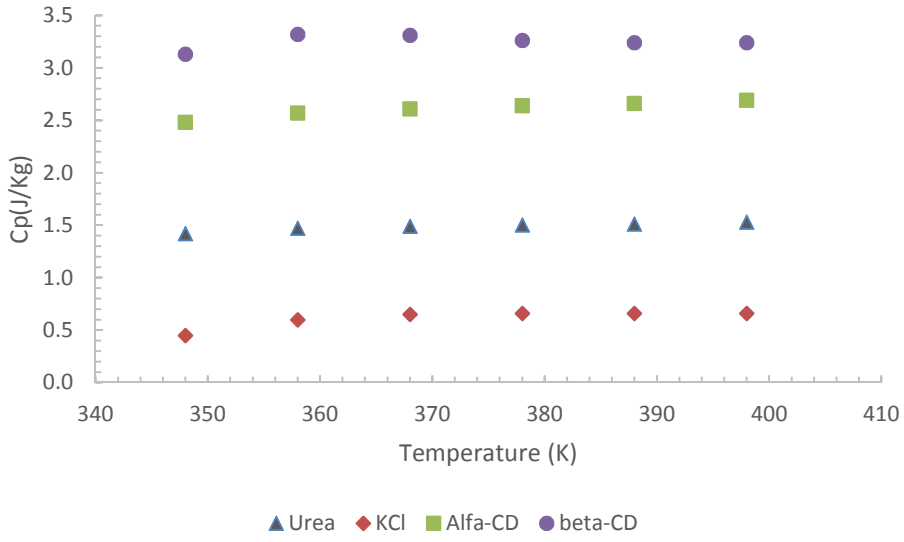


Figure 1. Specific heat capacity data for the standards urea, KCl, α-CD, and β-CD as a function of temperature.

Results and Discussion

After finalizing the calibration thermal analysis of the standards was performed and the data obtained was explored for the calculations of the specific heat capacity of the standard samples, it is delighted to note that the data reported in the literature for the standards was found in harmony with our specific heat capacity data [4-7]. Thereafter, we performed the thermal analysis of MW-CNT material under similar experimental conditions. The thermogravimetric analysis (Figure 2) of the MW-CNT indicates that the material was very labile towards heat and starts disproportioning with the rise in temperature.

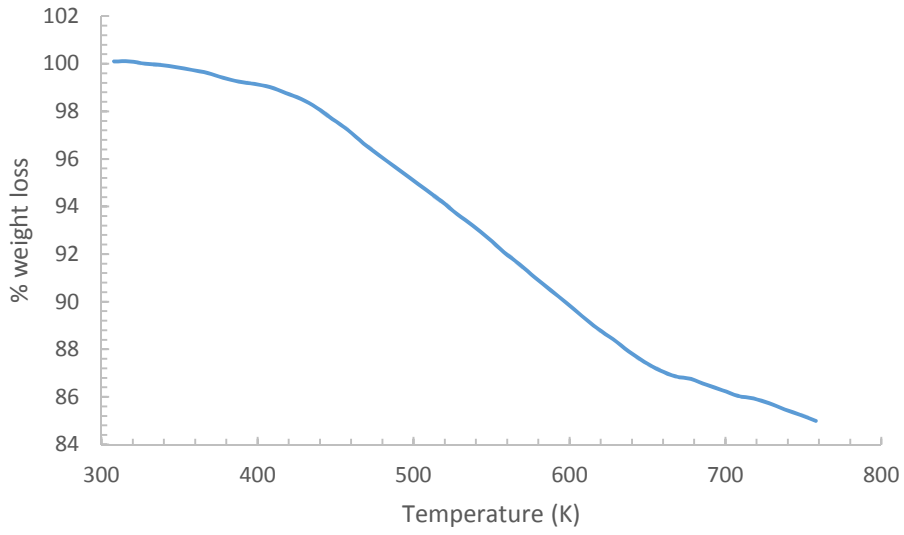


Figure 2. TGA of MW-CNT at the heating rate of 10 K·min^{-1}

In the DSC thermogram, the constant increase in the heat flow was observed for MW-CNT in the temperature range of (380-640K). However, initially, a thermal kink in between 340-360K was found in the DSC.

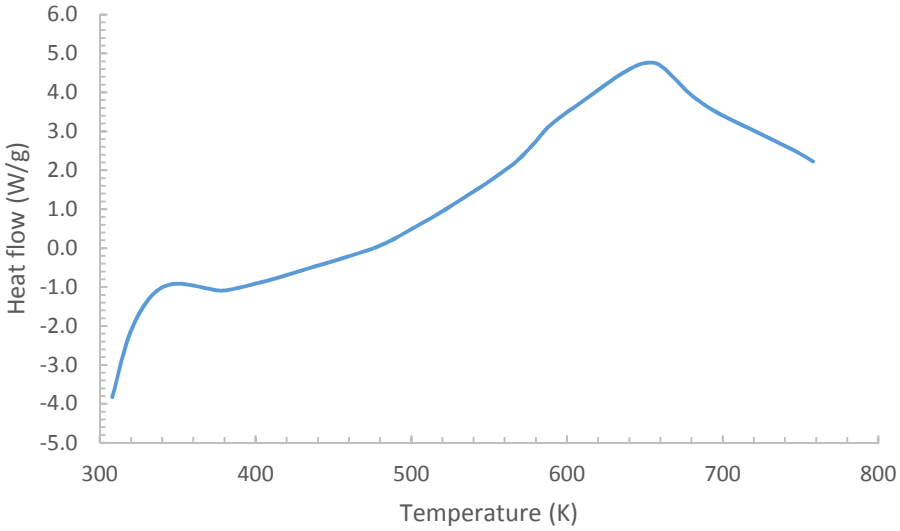


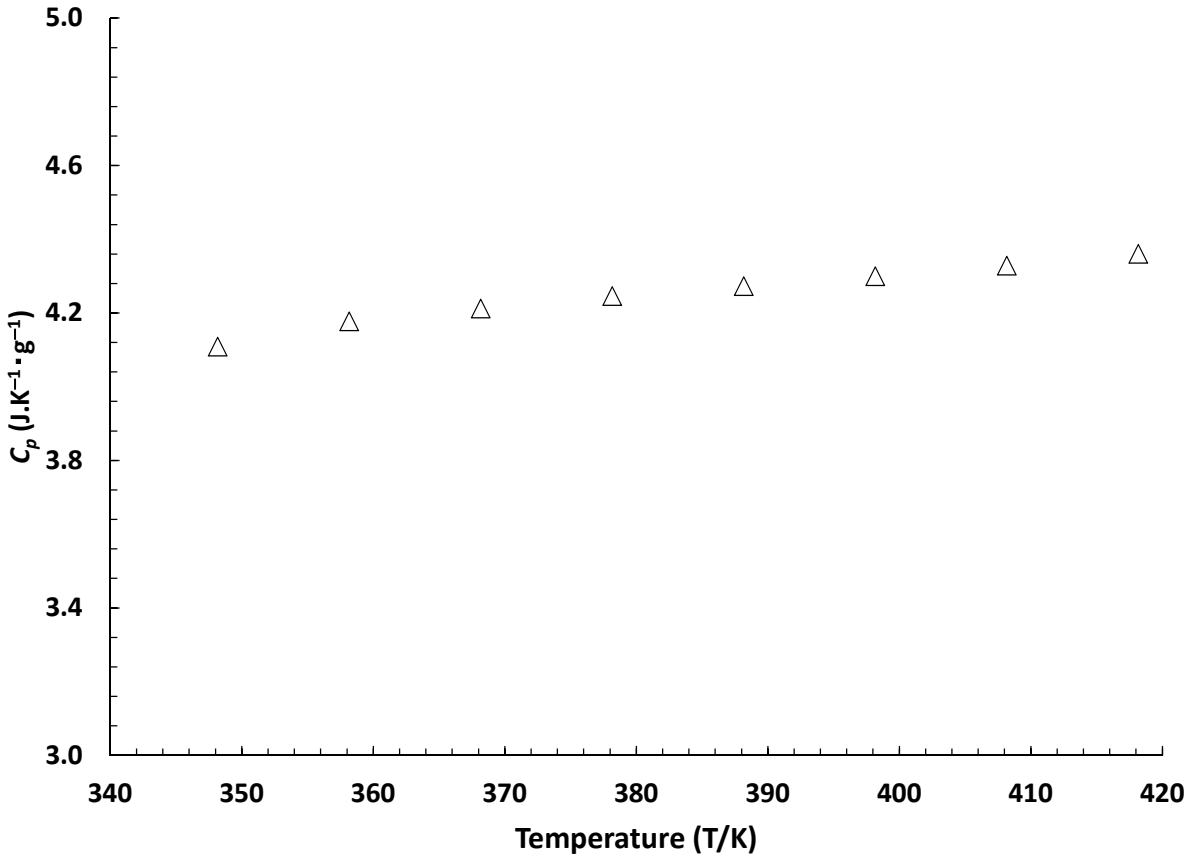
Figure 3. DSC of MW-CNT at the heating rate of 10 K·min^{-1}

Notable thermal transitions were found in the thermograms of the MW-CNT material (Figure 2 and Figure 3) but very interestingly the pattern for specific heat capacity was found very smooth for MW-CNT material (Table 1 and Figure 4). The closer scrutiny of the Table 1 revealed that the specific heat capacity values of MW-CNT were increases with increase in temperature.

Table 1. Specific heat capacity data for MW-CNT

Temperature		MW-CNT Cp
°C	T/K	J/K. g
65	338	3.91
75	348	4.11
85	358	4.18
95	368	4.21
105	378	4.25
115	388	4.27
125	398	4.30
135	408	4.33

145	418	4.36
155	428	4.39
165	438	4.42
175	448	4.47
185	458	4.51
195	468	4.56
205	478	4.60
215	488	4.64
225	498	4.67
235	508	4.70
245	518	4.73
255	528	4.76
265	538	4.79
275	548	4.81
285	558	4.84
295	568	4.85



Conclusion

The TGA and DSC profiles for MW-CNT have been interpreted in terms of the decomposition of nanotubes as a function of temperature. The specific heat capacity values of the MW-CNT are quite higher than the organic as well as inorganic materials but are very close towards organic metals polyanilines [8]. Probably the thermotropic mesomorphic changes in the carbon skeleton were responsible for the higher specific heat capacity of the MW-CNT. In addition to thermal analysis electrical response and spectral analysis of the MW-CNT with other physical and chemical characterizations will help to confirm the purity of the CNTs with high precision in the results.

References

1]. (a) Berber MR, Hafez IH. *Carbon Nanotubes Current Progress of their Polymer Composites*. AvE4EvA MuViMix Records, **2016**; (b) Pop E, Mann D, Wang Q, Goodson KE, Dai HJ. *Nano Lett*., **2006**, *6(1)*, 96; (c) Kim P, Shi L, Majumdar A, McEuen PL. *Phys Rev Lett*., **2001**. *87(21)*, 215502; (d) Liu P, Lam A, Fan Z, Tran TQ, Duong HM. Mater Design., **2015**, *87*, 600.

2]. (a) Bianco, A., Kostarelos, K., Partidos, C.D., et al. *Chem. Commun*., **2005**, *7*, 571; (b) Rüdiger K, Robert BS. *Carbon Nanotubes for Biomedical Applications.* Springer-Verlag Berlin Heidelberg, **2011**.

3]. Dirk MG, Nazario M. *Carbon Nanotubes and Related Structures Synthesis, Characterization, Functionalization, and Applications*. WILEY-VCH, Weinheim, **2010**.

4]. Gupta GR, Patil PD, Shaikh VR, Kolhapurkar RR, Dagade DH, Patil KJ. *Current Science*, **2018**, *114*, 2525.

5]. Gupta GR, Shaikh VR, Patil KJ. *Current Physical Chemistry* (Accepted) **2018.**

6]. Burns JA, Verrall RE. *Thermochim. Acta*., **1974**, *9*, 277.

7]. Dortmund Data Bank. http://www.ddbst.com/en/EED/PCP/HCP_C4577.php

8]. Patil KS, Zope PH, Patil UT, Patil PD, Dubey RS, Gupta GR. *Bulletin of Materials Science*, (Accepted) **2018**.