Electronic Supplementary Material (ESI) for Physical Chemistry Chemical Physics

Supplementary Information

Individual dispersion of carbon nanotubes in epoxy via a novel dispersion-curing approach using ionic liquids

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Optimization of IL amount as dispersion-curing agent. In this study we have investigated the use of IL a curing agent for epoxy resin as well as a dispersion agent for MWCNTs. The amount of IL was a significant challenge as we have to find the right balance of these two requirements and there were no previous similar studies of epoxy curing using a combination of IL and amine curing agent. The amount of $BMMIBF_4$ was chosen based on a number of repeated sample preparation and characterisation steps. We have prepared epoxy thermosets with a wide range of $BMMIBF_4$/4,4'-methylenedianiline (MDA) combinations as curing agent. Thermosets containing 0.1 up to 1 wt% $BMIMBF_4$ with respect to epoxy was prepared and a stoichiometric amount of MDA was used in all the cases. We have examined the glass transition and tensile mechanical properties of these thermosets. Based on these physical properties 0.5wt% IL was optimized as amount of $BMMIBF_4$ that provides a mechanically and thermally strong matrix for CNT dispersion. Moreover this study focus on the preparation of composites with low MWCNT loading (0.1 to 1wt%). The experimental results are given in Table S1.

Differential Scanning Calorimetry. DSC experiments were performed using 5–10 mg of the samples under an atmosphere of nitrogen gas with a TA-DSC model Q200 instrument. The samples were first heated to 100 °C and held at that temperature for 5 min to remove the thermal history. Then, the samples were cooled to -80 °C at the rate of 20 °C / min, held for 5 min, and again heated from -80 to 250 °C at 20 °C / min (second scan). The T_g values were taken as the midpoint of the transition in the second scan of the DSC thermograms.

Thermogravimetry analysis. Thermogravimetry analyses (TGA) were performed on Netzsch STA 409 thermogravimetric analyser over a temperature range of 25–600 ^{o}C at a heating rate of 10 ^{o}C /min. The measurement was performed using 5–10 mg of the sample under an atmosphere of nitrogen gas. The decomposition temperature (T_d) was obtained from the onset value of the weight loss curve.

Table S1. The tensile mechanical and glass transition of properties of thermosets using various amounts of $BMIMBF_4$.

Wt% of $BMMIBF_4$ in epoxy	Tensile Strength (MPa)	Tensile Strain (%)	T_g (DSC) °C
0	50.12 ± 2	4.87	172
0.1	50.9 ± 2	4.98	173
0.2	51.32 ± 1	5.10	175
0.3	52.87 ± 2	5.46	178
0.4	54.11 ± 1	5.89	181
0.5	55.68 ± 2	6.17	183
0.6	53.11 ± 2	6.16	180
0.7	51.86 ± 3	6.08	175
0.8	49.54 ± 3	5.98	169
0.9	47.01 ± 2	5.55	163
1	43.89 ± 4	5.05	154

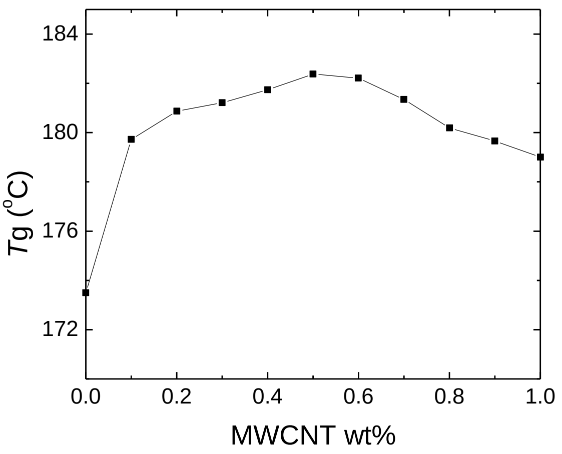

Figure S1. The T_g-composition plots of epoxy+BMIMBF$_4$+MWCNT composites obtained from DSC.

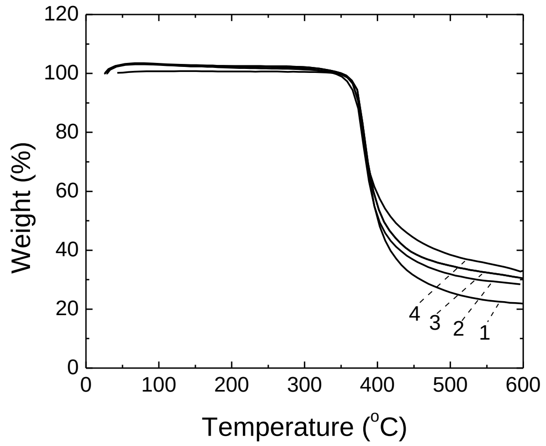

Figure S2. Thermogravimetric curves of composites; 1 – 0 wt%, 2 – 0.1 wt%, 3 – 0.5 wt%, 4 – 1 wt% MWCNT reinforced epoxy composites.

Table S2. Comparison of Epoxy/CNT composites prepared using various methods to improve the thermo-mechanical properties.

Epoxy Composite	Method of dispersion/preparation	Maximum Gain					
		T_g (°C)	Storage Modulus (%)	Young's Modulus (%)	Tensile Strength (%)	Tensile Elongation (%)	K_{1C} (%)

Epoxy/ MWCNT[26]	Modified polydimethylsiloxanes based block copolymer dispersion			17	-8	-38	
Epoxy/ MWCNT[27]	COOH-functionalized MWCNTs/ ultrasonication	0	20				
Epoxy/ MWCNT[28]	Ozone treatment/ high-speed mixer/ three-roll mill	2		3	23	100	52
Epoxy/ MWCNT[29]	High intensity sonication/ice bath		25	0			40
Epoxy/ MWCNT[30]	Amine functionalization of MWCNT	- 20					
Epoxy/DW CNT[29]	Amine Functionalization/high shear mixing			14	8		43
Epoxy/MW CNT[31]	Amine Functionalization/high shear mixing			9	<1		30
Epoxy/ MWCNT[32]	Acetone dispersion/ ultrasonication/ high pressure homogenizer/ high shear mixer/ three-roll milling						80

Epoxy/SW CNT[33]	Functionalized with polyamidoamine generation-0 dendrimer/ Acetone dispersion			26	15	2	17
Epoxy/MW CNT[34]	Acetone/Non-ionic surfactant (Tergitol) dispersion	- 4					
Epoxy/MW CNT (present study)	**IL/sonication**	**9**	**48**	**13**	**23**	**36**	**95**