Electronic Supplementary Information (ESI)

Rigid thermosetting epoxy/multi-walled carbon nanotube foams with enhanced conductivity originated from a flow-induced concentration effect

Yu Xu, Ying Li, Jianjun Bao, Tao Zhou and Aiming Zhang

State Key Laboratory of Polymer Materials Engineering of China, Polymer Research Institute of Sichuan University, Chengdu, Sichuan 610065, China.

1. Materials

Table S1. Properties of epoxy resin.

Trade name	EEW g/eq.	Color (Gardner)	Flash point °C	Viscosity (25 °C) cps	Density g/cm^3	HC ppm
NPEL-128	184-190	1.0	> 150	12000-15000	1.16	< 1000

EEW, epoxy epoxide equivalent; HC, hydrolysable chlorine

Table S2. Properties of Polyether Amine.

Trade name	AHEW g/eq	Gel time min	Proportion PHR	Viscosity (25 °C) mPa·s	Curing condition
EC-301	~ 61	>550	32	9-10	2 h/80 °C + 3 h/125 °C

AHEW, amine hydrogen equivalent weight; PHR, parts of hundreds of resin (EEW, 180-190 g/eq)

Table S3. Properties of MWCNTs.

Properties	Parameters	Properties	Parameters
Outer Diameter	10-30 nm	Conductivity	> 100 S/cm
Inner Diameter	5-10 nm	Tap density	0.14 g/cm^3
Purity	> 90 wt%	True density	~ 2.1 g/cm^3
Length	10-30 μm	Ash	< 8 wt%
Special Surface Area	> 140 m^2/g		

Table S4. Properties of EXPANCEL™.

Trade name	Particle size μm	Densities g/cm^3	T_{start} °C	T_{max} °C
031DU40	10-16	< 0.012	32	9-10

T_{start}, start expansion temperatures; T_{max} maximum allowable temperatures

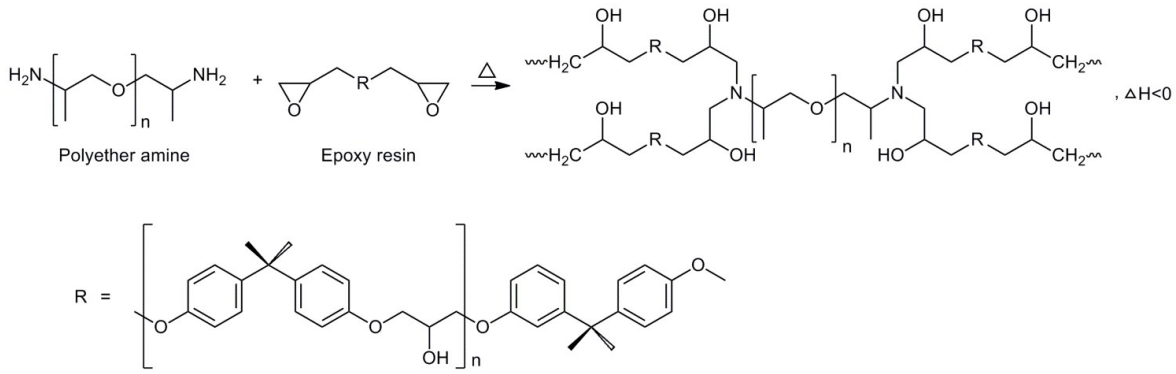

Fig. S1. Chemical reaction of epoxy resin with polymer amine.

2. Foam structures

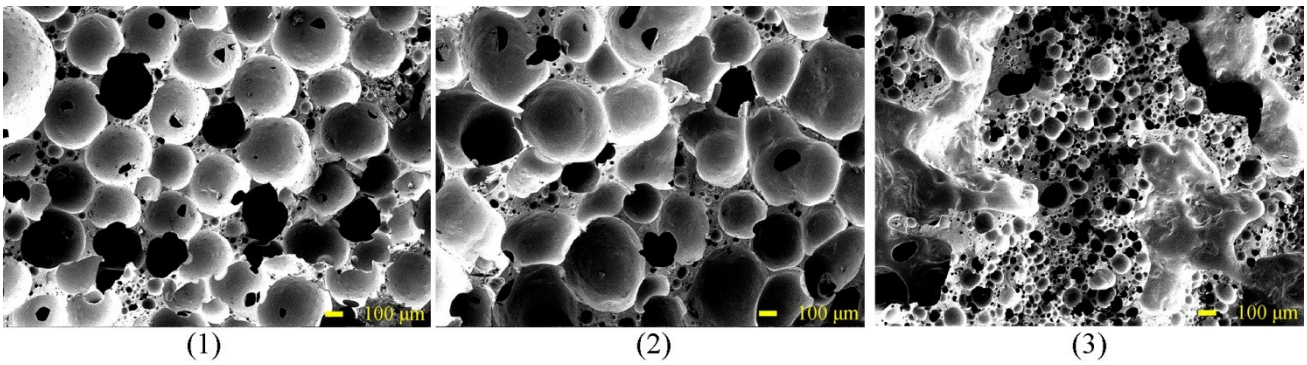

Fig. S2. SEM images of the conductive MWCNTs/epoxy foams prepared under different MWCNT contents: (1) 0.5 wt%; (2) 2 wt%; (3) 4 wt%. The weight proportion of epoxy resin to PEA, the microsphere contents, the foaming temperatures, the prepolymerization temperatures and time are respectively fixed at 100:32, 2 wt%, 80 °C, 45 °C and 90 min.

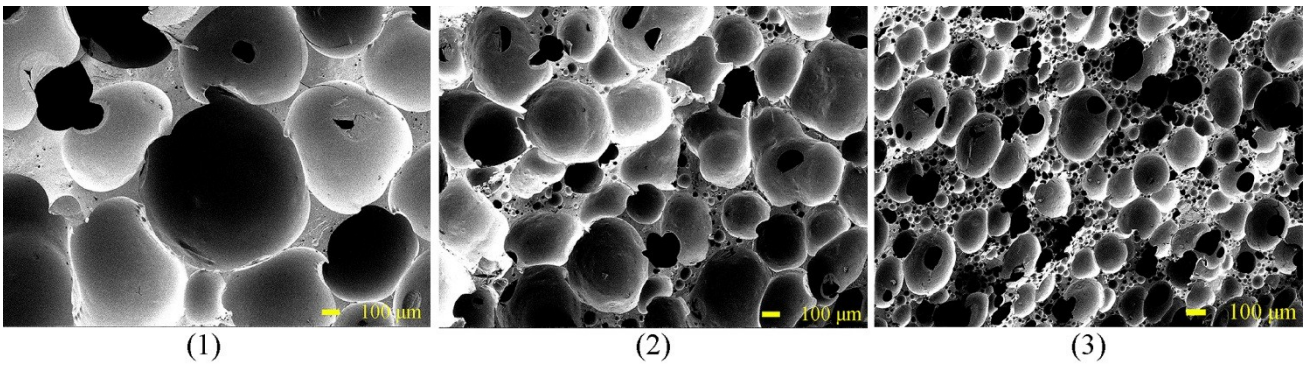

Fig. S3. SEM images of the conductive MWCNTs/epoxy foams prepared under different prepolymerization time: (1) 80 min; (2) 90 min; (3) 105 min. The weight proportion of epoxy resin to PEA, the microsphere contents, the MWCNT contents, the foaming temperatures, and the prepolymerization temperatures are respectively fixed at 100:32, 2 wt%, 2 wt%, 80 °C, and 45 °C.

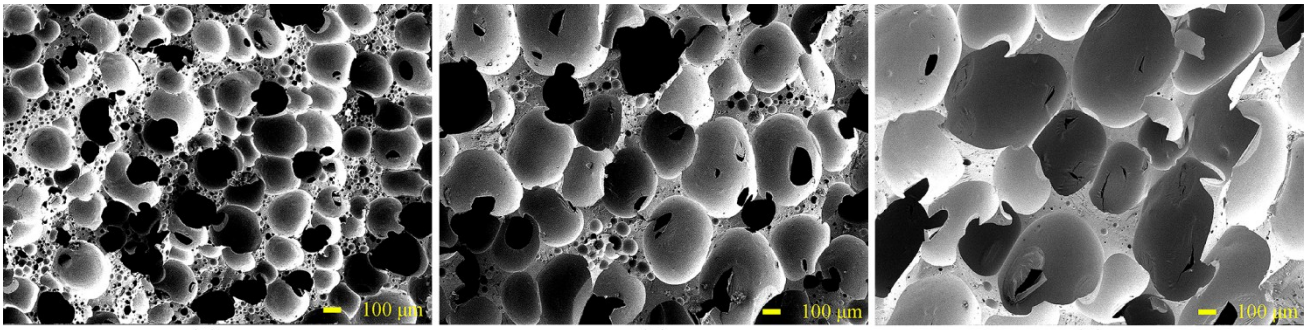

Fig. S4. SEM images of the conductive MWCNTs/epoxy foams prepared under different foaming temperatures: (1) 60 °C; (2) 80 °C; (3) 100 °C. The weight proportion of epoxy resin to PEA, the microsphere content, the MWCNT content, the prepolymerization temperature and time are respectively fixed at 100:32, 2 wt%, 2wt%, 45 °C and 90 min.

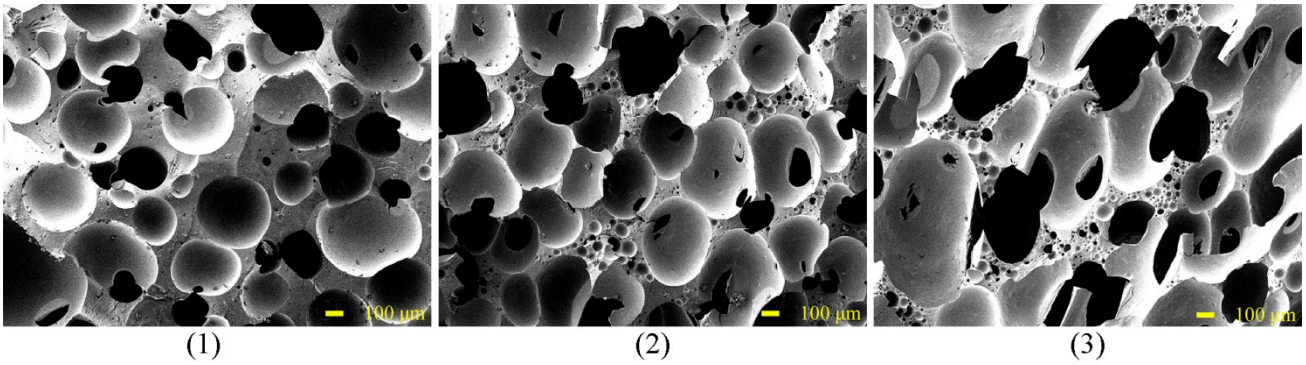

Fig. S5. SEM images of the conductive MWCNTs/epoxy foams prepared under different microsphere content: (1) 1 wt%; (2) 2 wt%; (3) 3 wt%. The weight proportion of epoxy resin to PEA, the MWCNT content, the foaming temperatures, the prepolymerization temperature and time are respectively fixed at 100:32, 2 wt%, 80 °C, 45 °C and 90 min.

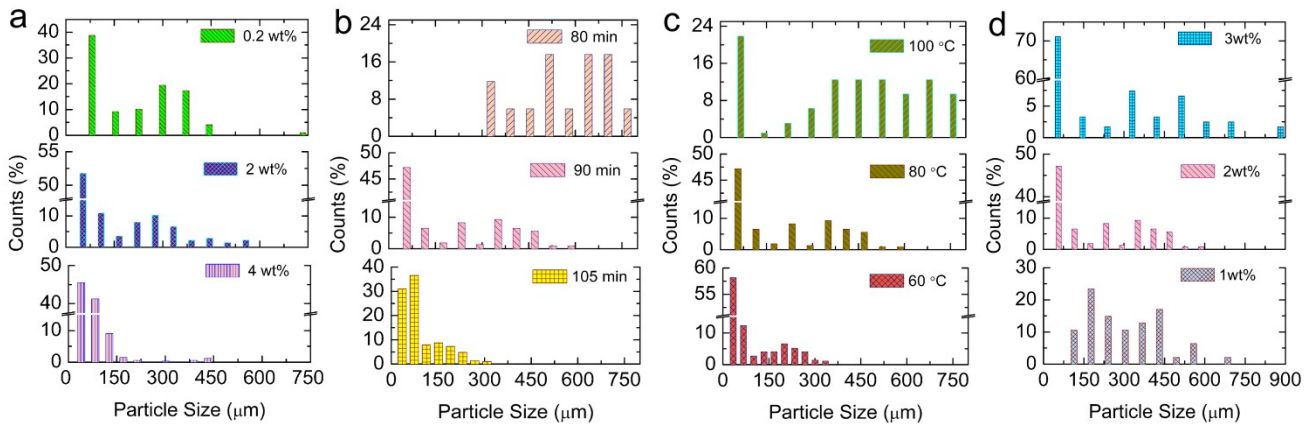

Fig. S6. Particle size distribution histograms corresponding to **(a) Figure S2, (b) Figure S3, (c) Figure S4, and (d) Figure S5.**

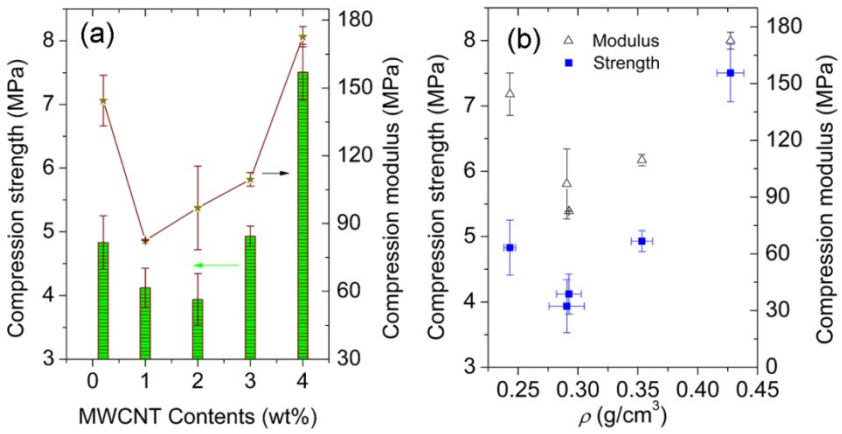

Fig. S7 (a) Effect of MWCNT contents on the compression properties of conductive MWCNTs/epoxy foams; (b) Non-linear relationships between compression properties and densities of the foams with different MWCNT content. The preparation formula of the foams here corresponds to Group A in Table 1.

Table S5. Densities of MWCNTs/epoxy foams corresponding to those discussed in our studies.

EXPANCEL wt%	Density g/cm³	t_{pre} min	Density g/cm³	T_F (°C)	Density g/cm³	MWCNT wt%	Density g/cm³
1	0.418 ± 0.001	80	0.243 ± 0.005	60	0.350 ± 0.001	0.2	0.243 ± 0.005
2	0.292 ± 0.010	90	0.292 ± 0.010	70	0.310 ± 0.016	1	0.292 ± 0.010
3	0.192 ± 0.009	100	0.285 ± 0.03	80	0.292 ± 0.010	2	0.291 ± 0.015
4	0.181 ± 0.007	105	0.371 ± 0.007	90	0.252 ± 0.008	3	0.353 ± 0.001
5	0.218 ± 0.001	115	0.924 ± 0.003	100	0.256 ± 0.005	4	0.427 ± 0.011

t_{pre}, time of prepolymerization; T_F, foaming temperature.