Clay Minerals Affect the Stability of Surfactant-facilitated Carbon Nanotube Suspensions

Zhantao Han[1,2], Fawang Zhang[2], Daohui Lin[1] and Baoshan Xing[1],*

[1]Department of Plant, Soil and Insect Sciences, University of Massachusetts, Amherst, MA 01003

[2]Institute of Hydrogeology and Environmental Geology, Chinese Academy of Geological Sciences, Zhengding, China 050803.

*Corresponding author. Tel: (413) 545-5212; Fax: (413) 545-3958

E-mail address: **bx@pssci.umass.edu** (Xing).

Supporting Information

Total number of pages: 5
Number of tables: 4
Number of figures: 5

TABLE S1. Selected Properties of the Carbon Nanotubes

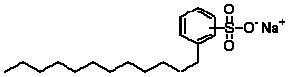
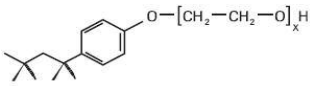
purity[a] (%)	length[a] (μm)	ED[b] (nm)	A_{surf}[c] (m^2/g)	V_{meso}[c] (cm^3/g)	V_{micro}[c] (cm^3/g)	ash[e] (%)	bulk EC[f] (%)			surface EC[g] (%)		CEC[h]
							C	H	O	C	O	Meq/100g
> 95	1-2	27.8±6.0	86	0.285	0.034	1.64	98.15	0.19	0.02	98.0	2.0	1.25

[a]Provided by manufacturer. [b]Exterior diameter (ED) measured by TEM, n = 100. [c]Surface area (A_{surf}), mesopore volume (V_{meso}), and micropore volume (V_{micro}) were calculated from the adsorption-desorption isotherm of N_2 at 77 K by multi-point BET method. [d]Water contents were measured by drying the CNTs at 105ºC for 24 h. [e]Ash contents were measured by calcine the CNTs at 900 ºC for 10 h, [f]Bulk dry weight-based elemental contents (EC) of the CNTs were determined using a Vario ELIII elemental analyzer and nitrogen content is neglegible; O contents were calculated by mass difference. [g]Surface elemental contents measured by X-ray photoelectron spectroscopy (XPS) measurements. They were performed on the CNTs in an ion-pumped Physical Electronics Inc. Quantum 2000 system using a Circumferential analyzer. An Al Kα anode, operated at 15 kV and 250 W with a photon energy of $h\nu$ = 1486.6 eV, was used. The base chamber pressure after a bakeout was ~5×10^{-10} Torr. The typical working pressure was ~1×10^{-8} Torr. The CNT samples were mounted onto a sample probe with double-sided tape and loaded into the main analysis chamber via a turbopumped antechamber. The C 1s core level at 284.4 eV, corresponding with the CNT oxidation state, was used to charge-reference the XP spectra (Xing et al., 2005). The XPS data were curvefitted using CasaXPS VAMAS processing software version 2.2 (Devon, United Kingdom) with a Shirley background subtraction and 70% to 30% Gaussian-Lorentzian line shapes (Xing et al., 2005). [h] Assume that one oxygen atom produces only one negative charge, we calculated the maximum cation exchange capacity (CEC) of pristine MWCNTs to be 1.25 meq/100g, from the bulk oxygen content (0.02%).

TABLE S2. Selected Characteristics of Clay Minerals

mineral	surface area(m^2/g)	averaged particle size (μm)	CEC(meg/100g)
montmorillonite	330	2.1	30
kaolinite	9	2.0	4

TABLE S3 Selected Characteristics of the Surfactants

surfactant	molecular formula	molecular weight	CMC (mg/L)	molecular structure
CTAB	$CH_3(CH_2)_{15}N(CH_3)_3Br$	364	340[a]	
SDBS	$CH_3(CH_2)_{11}C\circ\circ_6H_4NaO_3S$	348	490[b]	
TX100	$C_{14}H_{22}O(C_2H_4O)_{9.5}$	625	170[c]	

[a] from Cifuentes et al. (1997); [b] from Uemura et al. (1999); [c] from Yang et al. (2006).

TABLE S4. Surfactant Distribution Coefficients calculated from Adsorption Isotherms at C_e=30 mg/L

Surfactant	Adsorbent	K_d(L/kg)
CTAB	MWNTs	530
	WMont	3900
	CaMont	4130
	NaMont	3500
	WKao	560
	CaKao	580
	NaKao	530
SDBS	MWNTs	1280
	WMont	10
	CaMont	10
	NaMont	3
	WKao	30
	CaKao	10
	NaKao	4
TX100	MWNTs	2200
	WMont	2570
	CaMont	2570
	NaMont	2470
	WKao	180
	CaKao	170
	NaKao	160

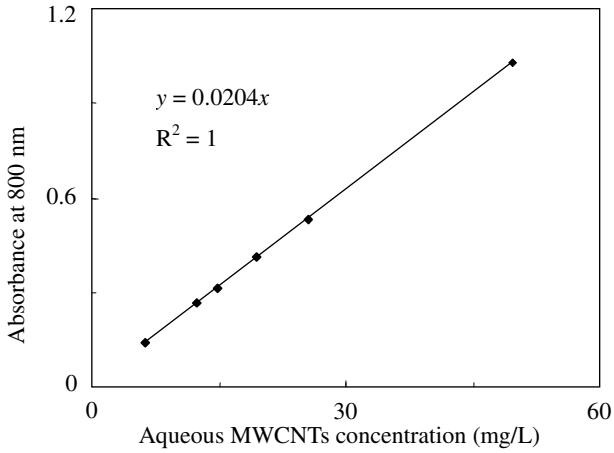


FIGURE S1. Calibration curve for aqueous MWCNTs concentration by UV-visible absorbance at 800nm

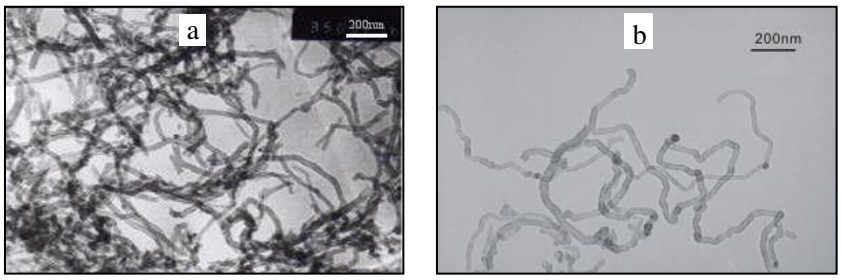


FIGURE S2. TEM images of MWCNTs. Sonicated without surfactant (a); Sonicated with SDBS (b).

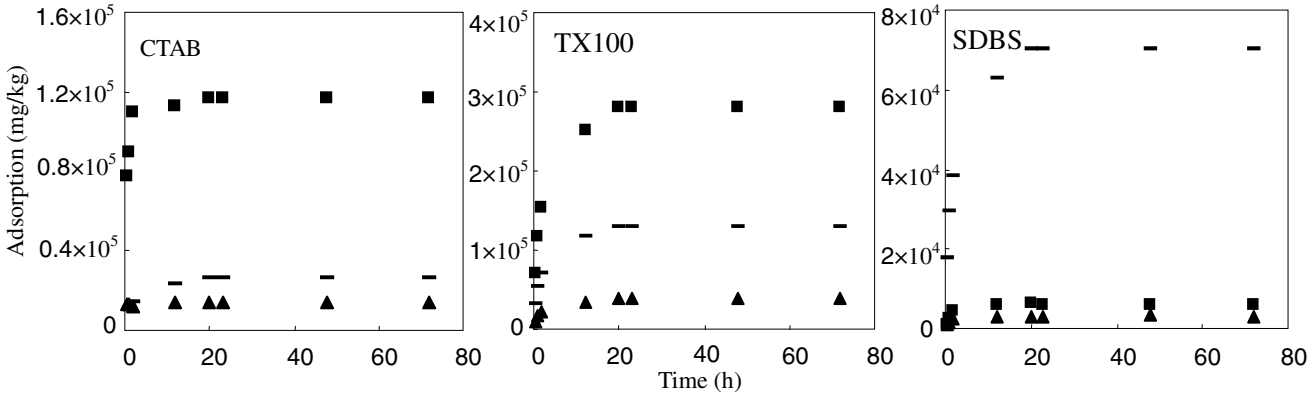


FIGURE S3. Adsorption kinetics curves of different surfactants on CaMont (■), CaKao (▲) and MWCNTs(—).

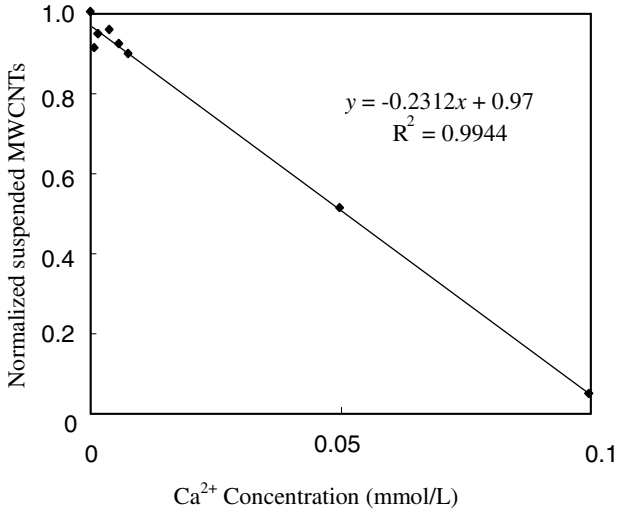


FIGURE S4. Influence of Ca^{2+} on the stability of CTAB-suspended MWCNTs.

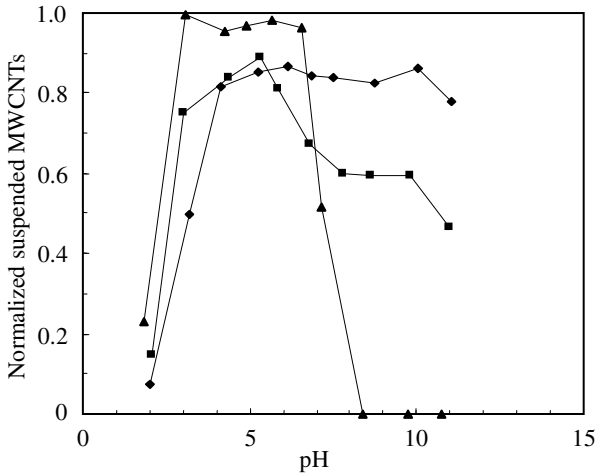


FIGURE S5. Effect of pH on the stability of MWCNTs suspensions. TX100 (♦); SDBS (■); CTAB (▲).

Literature Cited

Cifuentes, A.; Bernal, J. L.; Diez-Masa, J. C. Determination of critical micelle concentration values using capillary electrophoresis instrumentation. *Anal. Chem.* **1997,** *69*, 4271-4274.

Uemura, Y.; Moritake, I.; Kurihara, S.; Nonaka, T. Preparation of resins having various phosphonium groups and their adsorption and elution behavior for anionic surfactants. *J. appl. Polym. Sci.* **1999**, *72*, 371–378.

Xing, Y. C.; Li, L.; Chusuei, C. C.; Hull, R.V. Sonochemical oxidation of multiwalled carbon nanotubes. *Langmuir* **2005**, *21*, 4185-4190.

Yang, K.; Zhu, L. Z.; Xing, B. S. Enhanced Soil Washing of Phenanthrene by Mixed Solutions of TX100 and SDBS. *Environ. Sci. Technol*. **2006**, *40*, 4274-4280.