Carbon Nanotubes in Hydrogen Sulfide Adsorption

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Abstract
Different types of carbon nanotubes were studied to understand the adsorption between carbon nanotubes and hydrogen surfide (H_2S). It is found that multi-wall carbon nantubes have linear relations between fluorescence intensity and H_2S concentration, but untreated single-wall carbon nanotubes have no this relation. The reason for this result is explained.

Keywords: H_2S, Carbon Nanotubes, adsorption

Introduction

Contemporary approaches to measuring H_2S require a large amount of H_2S samples. This has limited the applications of these approaches. Carbon nanotubes can be developed into a nano sensor to measure a low concentration and small amount of H_2S [Wu et. al, 2006, 2008, and 2009]. However, optimization of carbon nanotubes in terms of types and configurations to the measurement of H_2S is worth to be investigated.

Materials and Methods

Different sources of carbon nanotubes have been used in the experiments. MW1 was self made multi-wall carbon nanotubes. They were also treated at 450 $^{\circ}C$ in vacuum. MW2 and SW1 were purchased from manufactories. Here MW2 is multi-wall carbon nanotubes and SW1 is single wall carbon nanotubes. Figure 1 shows a typical transmission electron microscope (TEM, Philips CM-10) image of the multiwall carbon nanotubes. The average outer diameter of the carbon nanotubes is approximately 25 nm and the average inner diameter is approximately 5 nm

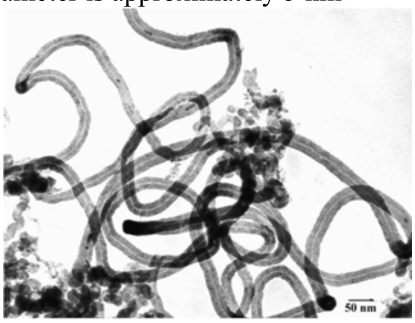

Fig. 1. TEM image of carbon nanotubes.

Different concentrations of H_2S were also made at the same method as published [Wu et. al, 2006].

Confocal microscopy was used in the experiment to measure the fluorescence of the nanotubes after adsorption of hydrogen sulfide. The methods and conditions of the confocal measurement can refer to Wu et al. [2006].

Three types of carbon nanotubes were immersed in sufficient distilled water, 10, 20, 30, 40, and 50 M H_2S water solutions, respectively, for 2 min, and the resulting carbon nanotubes were dried at room temperature for confocal measurement. It is noted that for each of these concentrations, a different carbon nanotube was used.

Results and Discussion

The confocal measurement for MW1, MW2, and SW1 is shown in Figure 2, 3 and 4, respectively.

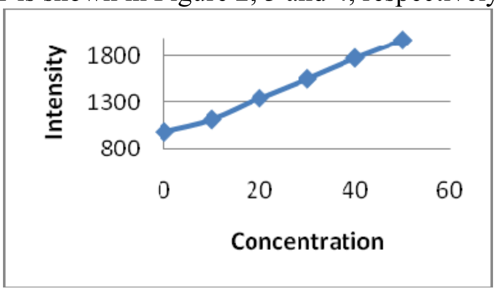

Fig 2: Confocal fluorescence of the MW1 carbon nanotubes treated with distilled water and with different concentrations of H_2S in water, respectively.

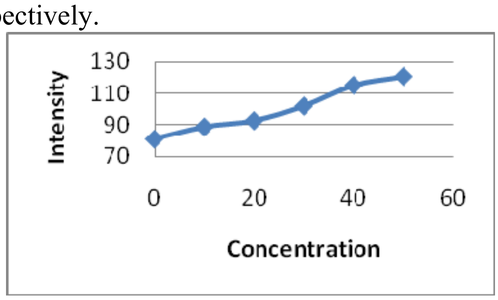

Fig 3: Confocal fluorescence of the MW2 carbon nanotubes treated with distilled water and with

different concentrations of H_2S in water, respectively.

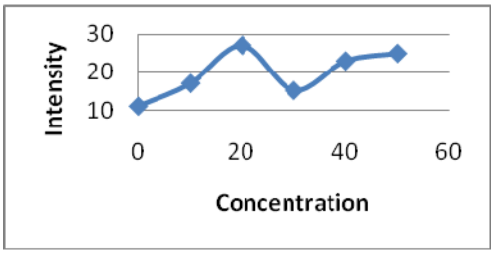

Fig 4: Confocal fluorescence of the SW1 carbon nanotubes treated with distilled water and with different concentrations of H_2S in water, respectively.

Form the results, it can be seen that the intensity for multi-wall carbon nanotubes increases with the increasing of H_2S concentration; however, this relation does not appear on single-wall carbon nanotubes.

It is reported that carbon nanotubes can absorb H_2S in aqueous media [Wu et. al., 2006]. Here, either heat treated or non heat treated multi-wall carbon nanotubes has this character. However, non heat treated single-wall carbon nanotubes does not show this character.

It is known that in adsorption by carbonaceous surfaces, both physical and chemical adsorptions happen [Bandosz, 2002]. In physical adsorption, the surface, pore volume, and pore size is very important. The pore sizes of micropores (d<20 A) are better in adsorption than those with the pore sizes of mesopores and macropores [Fraissard 1997].

Chemical adsorption usually happens in aqueous condition. Chemical adsorption results in the formation of surface oxygen-containing complexes and elemental sulfur which suggests that the adsorption of H_2S on carbon surface was dissociative [Mikhalovsky et al., 1997].

The interlayer distance in multi-walled nanotubes, which is similar to tube pores in activated carbon, is about 3.4 A [Ge et al., 1993]. Compared to single-wall carbon nanotubes, H_2S is not only absorbed by the surface of the nanotubes, but by the interlayer as well. The product of chemical adsorption on the interlayer is hard to lose in further processing, compared to the surface. Because of these, the intensity increases with the increasing H_2S concentration in multi-wall carbon nantoubes.

In chemical adsorption, the unsaturated carbon atoms are likely responsible for absorbing H_2S. However, the unsaturated carbon atoms can easily act with oxygen and thus decrease the H_2S adsorption. Different carbon nanotubes may have a different number of unsaturated carbon atoms, though they may come from the same sample. As such, single-wall carbon nanotubes could likely involve some uncertainty in absorbing H_2S.
The above phenomena may also affect multi-wall carbon nanotubes MW2, however, compared to interlayer, the effect of surface can be ignored.

It is reported [Feng et. al., 2005] that heat treatment can improve the adsorption because it can remove oxygen during high-temperature N_2 treatment, which leaves unsaturated carbon atoms. It is possible to make them work if single-wall carbon nanotubes are heat treated. With the same reason, heat treated multi-wall carbon nanotubes may have a better performance in H_2S adsorption than multi-wall carbon nanotubes without heat treatment.

Summary
Multi-wall carbon nanotubes can be used to measure H_2S concentrations because of their tube pore and interlay structures and large surface. The fluorescence of multi-wall carbon nanotubes mainly comes from their interlayer. Single-wall carbon nanotubes show uncertainty in H_2S measurement because of surface oxidization. Heat treatment may eliminate this uncertainty.

References

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