Optimization of Single-Walled Carbon Nanotube Dispersions and Polymer Wrapped Nanotubes

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Abstract
The goal of this research project was to optimize dispersions of single-walled carbon nanotubes(SWNT) in sodium dodecyl sulfate (SDS) and poly-N-vinylpyrrolidone (PVP) wrapped nanotubes in aqueous solutions. Experimentation has shown that we can maximize fluorescence through high-shear mixing and probe sonication pulses. The end goal of this study is to create individual nanotubes dispersions that are free from surfactants, then can be used for aerogels and nanomaterials.

Introduction
Carbon nanotubes are cylindrical carbon molecules that are at least 117 times stronger than steel and 30 times stronger than kevlar. The goal is to use single carbon nanotubes to strengthen plastics, use this as a building component, and even make aerogels. Unfortunately carbon nanotubes tend to clump together, which allows them to slide past each other in composites, limiting the amount of reinforcement, so the problem is how to disperse these clumps of carbon nanotubes and how to keep them separated.

There can be semi-metallic, metallic, and semi-conductive nanotubes. For this project, the nanotubes are about ⅓ metallic and ⅔ semi-conductive. The kind of nanotubes that are able to fluoresce is semi-conductive nanotubes. The fluorescence will quench when the semi-conductive nanotube touches other nanotubes. Therefor the fluorescence intensity can be used as a measurement of the number of individual semi-conductive nanotubes present. Also, fluorescence can disappear when the nanotube is damaged, so maximizing the amount of fluorescence gives the best balance between good dispersions and low damage.

Figure 1. SEM image of bundles and ropes between of Single-Walled Nanotubes at 500 nm.[1]

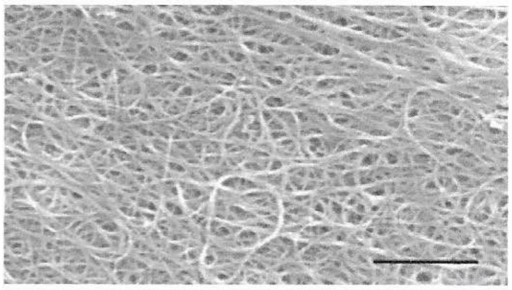
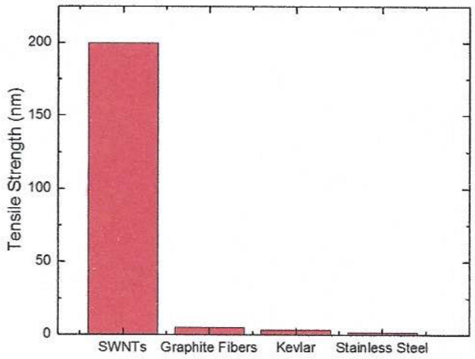


Figure 2. Comparison of the tensile strength of Single-Walled Carbon Nanotubes, Graphite, Kevlar, and Stainless Steel.



Hypothesis

Dispersing single-walled carbon nanotubes (SWNTs) in sodium dodecyl sulfate (SDS)/water using high-shear mixing and probe ultrasonication, replacing SDS with a long-chain linear polymer such as poly-N-vinylpyrrolidone (PVP), and purifying the sample through ultracentrifugation/decanting/resuspension and/or dialysis will produce samples of PVP-wrapped SWNTs dispersed in water with no detectable free polymer or surfactant.

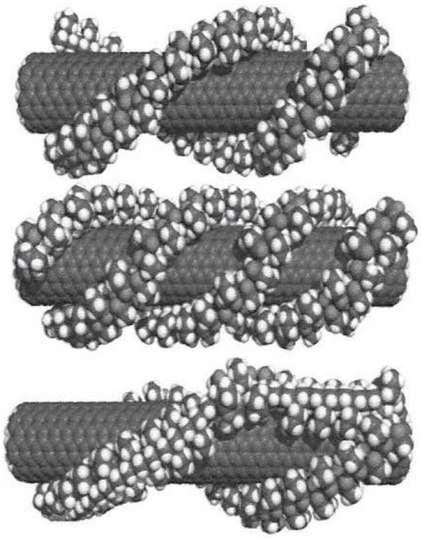


Figure 3. Model of different variations of PVP wrapping on a carbon nanotube.[1]

General Methods

Materials

Sodium Dodecyl Sulfate was purchased from Fisher Scientific. Poly-N-Vinylpyrrolidone was purchased from Polyscience Inc. Single-Walled Carbon Nanotubes were purchased from SouthWest NanoTechnologies Inc.

Experimental Methods

High-Shear Mixer IKA T18- Long turbine with small blades at the end that will break large clumps of nanotubes.

Probe Ultrasonicator CV334 - Sound waves are emitted in the aqueous solution, a high frequency and a low frequency. The high frequency waves create bubbles in the solution and the low frequency waves causes the bubbles to violently explode on itself.

L8-70M Ultracentrifuge- Ultracentrifugation is used to separate the nanotube bundles from the water surfactant at high speeds.

NS1 NanoSpectralyzer- This machine helped determine the fluorescence intensity of a solution, which represents how well the nanotubes were dispersed.

Cary-50- Device that read the amount of absorbance for a aqueous solution.

Procedure

Start with a certain concentration of Single-Walled Nanotubes to Sodium Dodecyl Sulfate then mix the two (Generally, 2.5mg of SWNTs and 50 ml of SDS). Then put the solution through high-shear mixing and after that probe ultrasonicate the mixed solution to disperse the nanotubes in the aqueous solution for a certain amount of time. Once dispersed, add a certain amount of the polymer, poly-N-vinylpyrrolidone (Usually 500 microliters) for 1 hour. Once done wrapping, use the fluorimeter to determine the fluorescence intensity, then the Cary-50 to find the absorbance of the dispersed nanotubes in the sodium dodecyl sulfate.

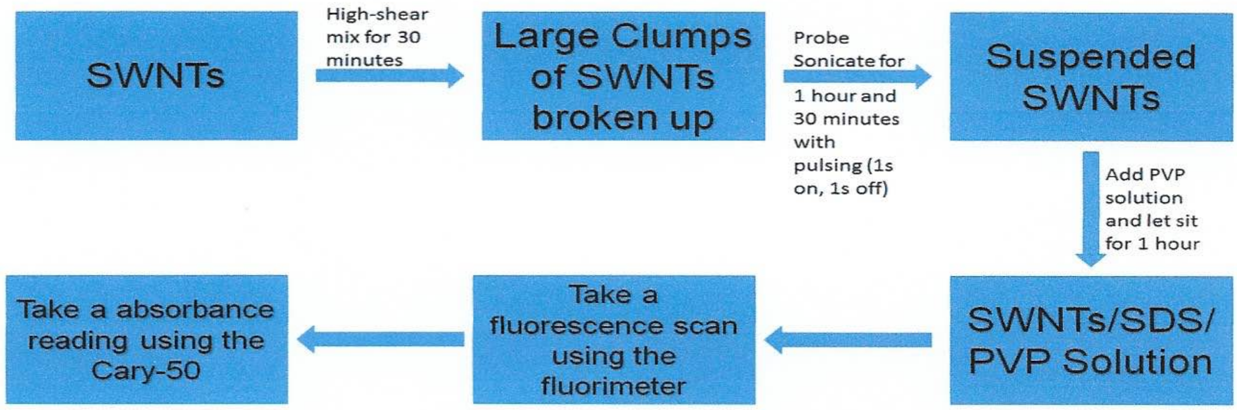


Figure 4. Basic procedure to disperse the single-walled carbon nanotubes in an aqueous solution.

Results

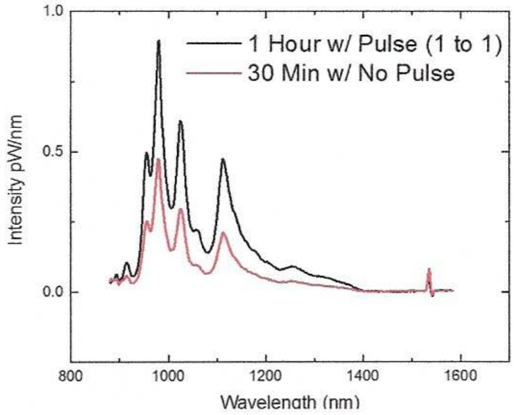


Figure 5. Comparison of using a pulse with the probe sonicator vs. no pulse.

Using a pulse during probe ultrasonication (1 second on, 1 second off) can help maximize the amount of fluorescence when dispersing carbon nanotubes in sodium dodecyl sulfate.

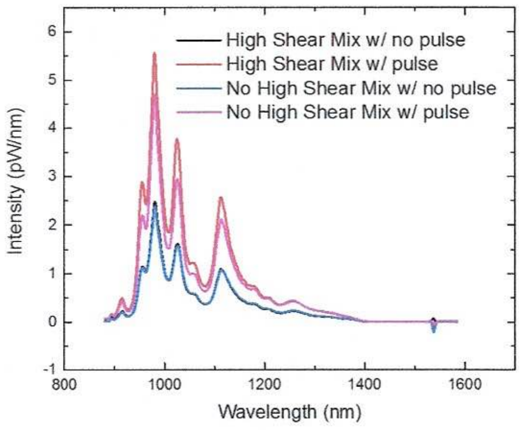
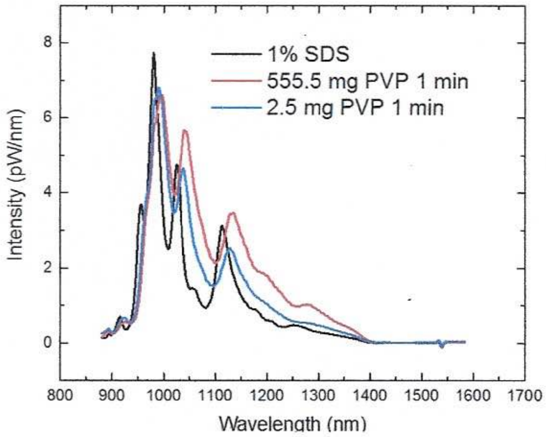


Figure 6. Variations of high-shear mixing and pulses to determine the best method of dispersing nanotubes.

When combining both high-shear mixing and using a pulse during probe ultrasonication can maximize the amount of fluorescence.

Figure 7. Chromatic shifts of different concentrations of SWNTs and poly-N-vinylpyrrolidone.



When there is a increase in fluorescence intensity, that determines how well the individual nanotubes were dispersed, and when there is a shift to the right, that means that there are more individually wrapped nanotubes.

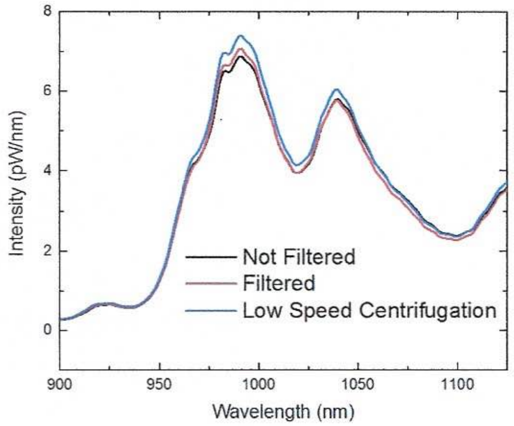


Figure 8. Comparison of a filtered solution of SWNT/SDS/PVP vs. a filtered solution vs. a low speed centrifuged solution.

Using filtering processes such as a track etched membrane filter or low speed centrifugation acting as the filter, can help maximize the amount of fluorescence.

Conclusion

Using pulses would help maximize the amount of fluorescence when dispersing the carbon nanotubes in the aqueous solution. Also when adding high-shear mixing and filtering processes, would help to get the best dispersions. The higher intensity of the excess PVP solution implied that there were more individual single-walled nanotubes. Then the shift of that solution told us that there were more individually wrapped nanotubes.

Acknowledgments

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References

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Signatures

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