Carbon nanotubes (CNTs) have received significant attention due to their unique material properties, for their nanostructure enables them to have high electrical and thermal conductivity, along with chemical stability and other properties. With these beneficial characteristics, CNTs can be used for a wide range of applications in electronics, optics, and sensing. However, current techniques of CNT fabrication cannot produce homogenous carbon nanotubes, and this prevents the widespread use of CNTs because their electrical nature (metallic or semiconducting) varies depending on the chirality. In this study, we explore a technique to separate CNTs by diameter and electronic type using the interaction of surfactants and CNTs. Surfactant encapsulation alters the buoyant density of the nanotubes, so the technique of density gradient ultracentrifugation (DGU) can be applied to separate nanotubes. In this technique, surfactants are added to nanotubes, placed in a density gradient, and then centrifuged at high speeds, causing the nanotubes to separate into colored bands of differing characteristics. We have successful recipes for electronic and chirality separation, and we are developing a recipe for separation of both types simultaneously. By analyzing the energy shift of the nanotubes with photoluminescence spectroscopy before and after surfactant wrapping, we are able to better understand the interaction between CNTs and surfactants. This will aid in knowing how different surfactants are selective for electronic type or diameter size, and this can help in further development of the separation process of DGU.
Separation of Carbon Nanotubes by Surfactant Selection and Density Gradient Ultracentrifugation

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**Introduction**

**Objective:** Develop methods to separate single-walled carbon nanotubes (SWCNTs) based on electronic type or chirality and create a model to understand the process.

**Why Carbon Nanotubes?**
- Structure: Hollow cylinders composed of carbon atoms arranged in hexagonal patterns; diameter = 0.7 – 2 nm.
- Properties: Electrical and thermal conductivity, mechanical strength, and chemical stability.
- Applications: Nanoscale electronics, optics, and sensors.

**Challenges:**
- CNTs currently produced are a heterogeneous mixture.
- Separation is necessary to isolate CNTs by type.

**Separation Method: Density Gradient Ultracentrifugation (DGU)**
- Sorts CNTs based on differences in buoyant density.
- Structure-dependent surfactant selection can separate by electronic type or chirality.

**Goals:**
1. Investigate surfactant/nanotube interaction.
2. Separate CNTs by chirality and electronic type.
3. Create model for surfactant wrapping of CNTs.

**Surfactant Types:**
- 1. Sodium dodecylbenzene (SDS):
  - Stands on surface, lighter packing with more SDS.
  - Benzene rings align with CNT wall structure; DOC lies along surface at a fixed angle.
- 2. Sodium deoxycholate (DOC):
  - Wraps close to surface, tighter packing with more SDS.
  - DOC + SDS wrapping (chirality separation):
  - DOC + SDS wrapping (no separation):

**Future Work**
- Simultaneous separation of CNTs by both electronic type and chirality is desired.
- Progress has been made using co-surfactants (dispersing with SDS + DOC).
- Further research is needed.

**References**
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