Impact of Methyl Cellulose Surfactant in Uniform Dispersion of Carbon Nanotube Suspension

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Abstract - In this paper, experimental synthesis of uniform dispersion of carbon nanotube using four different surfactants have been presented. Carboxy Methyl Cellulose sample is a better surfactant to disperse CNT in an aqueous solution rather than in organic solutions. The uniformly dispersed sample is coated on silicon substrate and the surface morphology is studied using AFM and SEM and I-V characteristics are studied for the effective sample using PXI 4110 slot of National Instruments.

Keywords - Carbon Nano Tube, Synthesis, Carboxy Methyl Cellulose, CNTFET, AFM, SEM

1. Introduction
Carbon Nanotubes (CNT) are gaining much importance as one of the candidates to replace the silicon channel due to the existing limitations in conventional MOSFET scaling [1]. CNT has excellent strength, unique electrical properties, and thermal conductivity. The electrical properties owe to the electronic structure of graphene itself that can roll up to form a hollow cylinder. A carbon nanotube’s bandgap is directly inclined by its chirality and diameter [2]. Also, CNTs are also quasi one-dimensional materials, which minimizes losses due to scattering [3]. The semiconducting CNTs that fall across two metal strips source and drain form a Field Effect Transistor [4]. Before using CNT as a channel material, a nano suspension has to be created without sedimentation and with equal dispersion. For all industrial applications, a uniform and stable dispersion of sub-micron particles are very important as well as critical. This paper presents an experimental work to identify a suitable uniformly dispersion CNT nanosuspension, before being applicable in CNTFET (CNT Field Effect Transistor).

2. Non-Uniform Dispersion Nature Of CNT
In the nano-scaled Carbon Nano Tubes, uniform dispersion is a challenge, since the attractive force between the particles increases with the surface area. The parameters required to optimize the behavior of these nanocomposites depend on lot of factors, among them, the most important are the quality of CNT dispersion, the final aspect ratio and the strength of the CNT matrix interfacial properties [5]. The solubility of carbon nanotubes is necessary for their chemical and physical properties, since it allows ease of characterization. This research addresses the methods to overcome the poor solubility of the CNT in either water or organic solvents. Also, Carboxy Methyl Cellulose, a derivative of cellulose that offers 20 times higher stable aqueous dispersion of CNTs than any other surfactants are experimented [6].

3. Preparation Of Nanosuspension Of Carbon Nanotube
MWCNT (Multi walled CNT) has been experimented because of their homogeneous mixtures. The SEM micro structural analysis of the CNT is done using JEOL JSM-6390 microscope [7]. The sample is ultrasonically dispersed in ethanol, deposited on a carbon film supported on a copper grid and subjected for SEM analysis. The SEM patterns of CNT taken showed that the CNT was multiwalled with outer diameter 10-15nm and inner diameter as 2-6nm with the length range from 0.1μm to 10μm as shown in Figure 1. The dispersion technique here uses both ultrasonic treatment and surfactant adsorption, so as to provide high local shear throughout the nanotube bundle and to separate the nanotubes individually from the bundle [8]. Generally, ionic surfactants are preferable for water soluble solution.

Fig. 1: SEM picture of CNT in secondary electron mode
Alternatively, nonionic surfactants can be used where organic solvents have to be used [9]. The origin of surfactant, its concentration, and form of interaction are known to play

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a crucial role in the phase behavior of classical colloids as well as carbon nanotubes. The surfactant aided dispersions of carbon nanotubes will be according to the mediums' nature [10].

Four different CNT nano suspensions are prepared with low viscosity solvents and versatile solvent as shown in Table 1 to visualize the uniform dispersion of CNTs.

**Table 1: Composition of Nano suspension samples**

| Sample | Composition |
|--------|-------------|
| A      | H$_2$O (20ml) + CMC (0.2g) + CNT (60mg) [Figure 2] |
| B      | Toluene (20 ml) + CNT (60mg) [Figure 3] |
| C      | Toluene (20ml) + CMC (0.2g) + CNT (60mg) [Figure 4] |
| D      | Ethanol (20ml) + CMC (0.2g) + CNT (60mg) |

This resulted in a uniform dispersion of using Hielscher UP 400s for 5 minutes and placed in ultrasonic agitator for 10 minutes adding ice in the surrounding to avoid collapse of CMC.

In sample A, 0.2g of Carboxy Methyl Cellulose (CMC) is mixed with water using a magnetic stirrer for half an hour until CMC completely dissolves. To this solution, 60mg of CNT is added and the solution is cup horn sonicated CNT as shown in Figure 2. This shows that uniform dispersion of CNT in water happens due to the anionic surfactant and weak binding polymer CMC. The same procedure is repeated for preparing sample B with another low viscosity solvent toluene but it could not help in dispersing CNT as shown in Figure 3. Sample C is prepared with toluene and CMC, but it also could not aid the uniform dispersion of CNT. This is shown in Figure 4. Sample D is prepared with organic solvent ethanol and CMC. However, the CNT dispersion using water and CMC excelled in uniform dispersion of CNT than the other combinations. The ultrasonication process is repeated twice before using the solution for drop casting. The solution is casted on glass substrate by drop casting using micropipette. The area of cast is confined so that the volume of the solution is identical in all the sample preparation resulting in identical sample thickness. From the thin films prepared Sample ‘A’ was found to be good because CMC helps in the uniform complete dispersion of CNT in the water.

Drop casting is the process adapted from different coating techniques such as drop casting, spin coating, dip coating and sputtering [11]. Since carrying drops of liquid in the micromolar to millimolar variety is a simple process. Glass substrates are washed with fine brush surfactants as per the normal practice, followed by ultrasound of the submerged substrates in the surfactant solution, water, and acetone. The cleaning procedure is repeated for several times and air dried completely before use. A bubble is made on the surface of the wafer using a micropipette and all the solvent was allowed to evaporate. This fabrication is rather simple and resulted in a uniform thin film which is due to the shear stress of sonication procedure and the low viscosity offered by CMC.

The effective sample A that yielded uniform dispersion of CNT as found on a glass substrate is coated on the silicon wafer that is crystalline, cubic, single side polished and it without any dopant. Its boiling point is 2355°C (lit.) and melting point is 1410°C (lit.). It has a diameter of 2 inches, thickness of 0.5mm and the density of 2.33g/mL at 25°C. The cut silicon wafer is first cleaned in 20ml distilled water with the help of agitator for 30mins to remove the physical dirt in the wafer. It is ultrasonicated for half an hour. The process is repeated with isopropyl alcohol and acetone. Isopropyl alcohol removes all the oil content in the wafer and acetone removes the grease. The cleaned wafer is kept in the oven at 80°C for a day. The effective sample-A is coated on the wafer as shown in Figure 5.

![AFM picture](image)

**AFM picture of the effective sample is taken for the drop casted substrate as shown in Figure 6. This picture shows the**
surface roughness of the material coated on the substrate. The thickness of the material is found to be $Z=1.2 \mu m$. The Because of prepared sample of carbon nano tube AFM shows large clusters and better defined [12].

![Fig 6: AFM image of the surface of the sample coated substrate](image)

From the CNT coated surface, leads are taken for testing the current conductivity as shown in Figure 7. It is then kept for drying for about 120 mins. The end-to-end conductivity is checked using PXI 4110 slot in National Instruments.

![Fig. 7: Leads taken for source and drain](image)

4. Results and Discussion

As shown in Figure 8, I-V characteristics are studied for the effective sample for an applied voltage of 0-6V, the current varied from 0 to 5.5 micro ampere. When voltage is increased the current values also gets increased.

![Fig. 8: Plot showing the V – I curve between two leads of effective sample over silicon substrate](image)

5. Conclusion

This experimented aimed in finding the best surfactant to have uniform CNT dispersion. Out of all the samples, Sample A prepared with 20ml of H$_2$O, 0.2gm of CMC and 60mg of CNT gave the better uniform dispersion of CNT. Hence it is proven that Carboxy Methyl Cellulose is a better surfactant to disperse CNT in an aqueous solution rather than in organic solutions. From the V-I graph it can be concluded that the same potential can be used to switch various sequential devices if CNT is used as the channel. The uniformly dispersed MWCNT sample experimented using drop casting method worked well for a range of voltage from 0-6 volt yielding a maximum current of 5.6µA.

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