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2009

Fam, D. W. H., & Tok, A. I. Y. (2009). Mono-distributed single-walled carbon nanotube channel in field effect transistors (FETs) using electrostatic atomization deposition. *Journal of Colloid and Interface Science*, 338, 266-269.

<https://hdl.handle.net/10356/92386>

<https://doi.org/10.1016/j.jcis.2009.06.003>

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Manuscript Number: JCIS-08-1389R1

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Article Type: Regular Article

Section/Category: K. Clusters, Nanomaterials and Self-Organization

Keywords: Carbon nanotubes, electrostatic atomization, monodispersed

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Graphical abstract

The agglomeration of Carbon Nanotubes was reduced via electrostatic atomization and a Schottky junction was formed easily.

Mono-distributed Single-walled Carbon Nanotube Channel in Field Effect Transistors (FETs) using Electrostatic Atomization Deposition

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Abstract

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deposited double-walled carbon nanotubes and it yielded low-density bundles and even isolated double-walled carbon nanotubes [21]. Electrostatic atomization (EA) is a form of deposition in which a jet of liquid is exposed to an electric field which leads to a dispersion of the particles arising from either liquid polarization or free charge repulsion. This jet of liquid will then break into droplets when it is released at a controlled flow rate through a stainless steel needle [22]. The EA schematic is as seen in Figure 1. The solution is pushed into the capillary tube and into the needle at a constant flow rate whereby it experiences an electric field set up due to the potential difference between the needle tip and the ground electrode. The field at the tip then overcomes the surface tension of the liquid which results in a jet forming from the breakup of the liquid surface. This jet consists of extremely small liquid droplets which would be accelerated towards the stage, which is below the ground electrode hence depositing the liquid droplets onto the substrate on the stage. EA has been widely applied since its initial use on paints [23]. EA has also been applied to hydrocarbons [24, 25], ceramics [26] and a variety of other materials [27] to obtain self-assembled nanostructures [28]. However, one of the most poignant uses of EA was to create a mono-distributed thin film [29, 30]. Hence, this paper shows a novel method of preparing a transistor with a mono-distributed network of CNT via electrostatic atomization.

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Single-walled carbon nanotubes (SWNTs) were bought from Carbon Solutions, Inc. and were used as bought. The SWNTs are then suspended in ethanol due to its low surface tension so that a stable cone-jet mode can be reached when it is atomized. SWCNTs, because of their nanoscale dimensions, they typically agglomerate in polar solvents like water. Hence surfactants would normally be used to suspend the nanotubes in the solvents and in this work; poly (4-vinyl pyridine) (P4VP) bought from Sigma Aldrich was used as the surfactant.

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Sonication was applied to separate the nanotube bundles. After which, centrifugation was done to separate the free nanotubes from the agglomerated ones. S1 is a solution of 99.99wt% absolute ethanol and 0.01wt% P3 SWNTs (functionalized with carboxylic acid (-COOH) groups). S1 was made to sonicate for 20mins and centrifuged at 14000rpm for 75mins. The suspension characteristics like its conductivity, surface tension, viscosity and dielectric constant were then measured with a SCHOTT conductivity meter, Contraves low shear rheometer, contact angle measuring equipment and the Alpha TDR 5000 meter respectively. The extracted supernatant solution was then drop-cast or electrosprayed onto the device (Figure 2) channel as the semiconductor layer using a pipette. The stable cone jet mode for EA was achieved at 0.07ml/hr and the process was done for 3mins. Field emission scanning electron micrographs were then taken of the channel to compare its dispersity. The transfer characteristic, namely the drain current (I_D) against drain voltage (V_D) with different gate voltages (V_G) was then measured using a Keithley 4200 parametric analyzer. The I_D was swept from -5V to 5V and V_G was stepped from -5V to 5V.

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10 **Acknowledgements**

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Figures

Figure 1. Schematic of the Electrostatic Atomization setup which shows the needle under DC voltage bias and the computer connected to the microscopic camera recording the shape of the jet.

Figure 2. Transistor with back gate

Figure 3. FESEM image showing agglomeration of CNTs, seen in the bottom right

Figure 4. Metallic CNT junction created from drop-cast method

Figure 5. FESEM image of monodispersed SWNTs deposited by EA in channel

Figure 6. CNT device fabricated by EA showing gate control

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Acknowledgements

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Figures

Figure 1. Schematic of the Electrostatic Atomization setup which shows the needle under DC voltage bias and the computer connected to the microscopic camera recording the shape of the jet.

Figure 2. Transistor with back gate

Figure 3. FESEM image showing agglomeration of CNTs, seen in the bottom right

Figure 4. Metallic CNT junction created from drop-cast method

Figure 5. FESEM image of monodispersed SWNTs deposited by EA in channel

Figure 6. CNT device fabricated by EA showing gate control