Exploring Microfabrication Parameters of Template-Based Carbon Nanotube Arrays for Gene Transfer

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Primary CNF Tools Used: AJA Ion Mill, PT 740 RIE

Abstract:

Carbon nanotube (CNT) arrays are a promising new technology which can greatly reduce the costs of novel gene therapies for fighting cancer. It has been fabricated at the Cornell Nanoscale Facility (CNF) using a template-based manufacturing technique. Exploration of the various manufacturing parameters involved in the fabrication would allow for the development of a streamlined and optimized recipe. CNF tools were utilized to study various manufacturing recipes to gain insight into how they affect the surface structure of the device.

Summary of Research:

Carbon nanotube (CNT) arrays are a promising technology towards developing safer, more economically and technologically accessible method for the transfection of genetic and biomolecular load into cells. Current treatments for diseases like cancer require dangerous and toxic processes. Novel treatments for leukaemia involve gene therapies, the introduction of proteins into white blood cells modifying them to identify cancer. CNT arrays can be used to transfer these proteins into cells. [1–6]

CNT arrays are manufactured from an initial Anodic Aluminum Oxide (AAO) template. Aluminum forms a self-aligned hollow honeycomb-like porous surface when oxidized anodically, allowing AAO to be a commonly used mask for microfabrication at the nanoscale for freestanding nanostructures. Carbon is coated into the pores by means of a chemical vapor deposition (CVD) process. Carbon coated AAO templates are processed at the CNF using the AJA ion mill and PT 740 reactive ion etching (RIE) tools. [7-9] Resulting in a CNT array device with tips of carbon tubes exposed on the surface.

Previous research at the CNF was focused on the scale up of the CNT array manufacturing process. In that work, the manufacturing process was altered by introducing ion milling and employing a larger carrier wafer for producing devices at a larger scale. The work done since that report has built further upon the initial improvements. Exploring alternative starting templates and exploring manufacturing parameters were steps taken towards optimizing the manufacturing process.

The current standard for AAO templates is 13mm diameter disks, this limits the number of cells which can be cultured on each device. A 47 mm diameter template provides a much larger surface area for cell transfer. Figure 1 shows a silicon water affixed with 6 carbon-coated 47mm templates. Fabrication of these devices at the CNF confirmed the capabilities of the current tools and manufacture larger devices. However, the following standard recipe for 13mm did not produce devices with exposed tubes, due to insufficient carbon deposition during the CVD step.

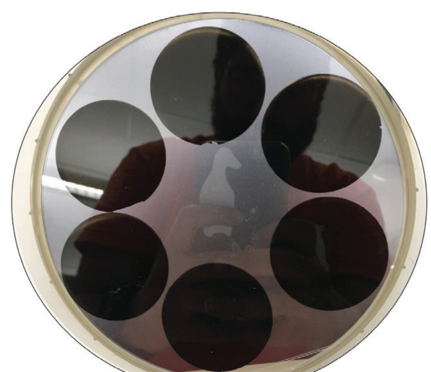

Figure 1:Carbon coated 47mm diameter AAO templates on a carrier wafer.

Alternative 13mm diameter templates were tested. A template with smaller pore diameters and larger pore density resulted in devices with thicker nanotubes when undergoing the standard fabrication process. Due to a smaller starting diameter and constant carbon mass flow rate during CVD. Templates of similar properties from other manufacturers were also tested and showed similar surface parameters as standard devices when undergoing the standard fabrication process.

A parametric study of the RIE process time and power was conducted, these parameters are likely to produce the largest impact on the final device. An initial test was conducted to determine the maximum tube height over etch time, as longer etch time is expected to lead to linear growth in exposed tube heights. Followed up by a study of RIE power to determine how increasing power affects tube height. The standard values for RIE etch were 2 hours at 50W power, the experiments covered increasing etch time to 3,4,5 hours and increasing power to 150W and 250W.

Figure 2 and Figure 3 show the results of these experiments; the measurable outputs were the tube height and tube thicknesses of the exposed CNT tips. As shown in the figures, tube heights increase as power and time increase, while tube thickness is maintained until a noticeable drop in thicknesses at larger parameter values. Micrographs showed that at higher powers and etch time the nanotubes tended collapse upon themselves due to lateral etching thinning them down.

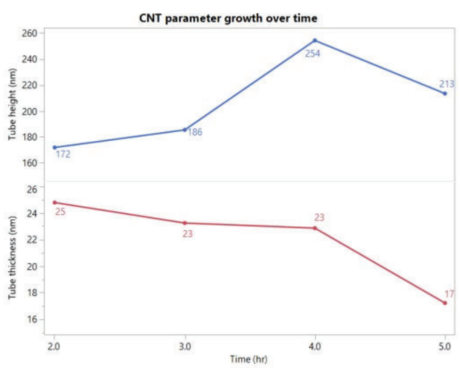

Figure 2: CNT parameters over time.

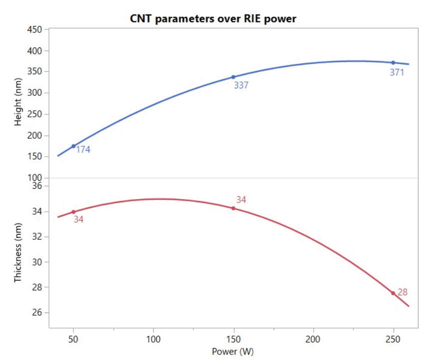

Figure 3: CNT parameters over power.

Conclusions and Future Steps:

Exploring alternative starting templates gives an insight into how to scale up the CNT arrays further while making them more useful for researchers and healthcare companies.

Determining the effects of RIE parameters would help establish upper and lower boundaries for future experiments to optimize the process. Next steps would include optimizing the process for 13 mm diameter devices and establishing a working recipe for 47mm diameter AAO templates.

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