Increasing Microfabrication Yield of Template-Based Carbon Nanotube Arrays for Gene Transfer

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Primary CNF Tools Used: AJA Ion Mill, PT 740 RIE, KLA P7 Profilometer, GCA AS200 i-line Stepper, OXFORD 81 RIE

Abstract:

Carbon nanotube (CNT) arrays template-based fabricated biomedical devices used for gene transfer, they can be used to transport novel gene therapies into cells which help combat illnesses such as HIV and some types of cancers. These devices are a more economical and efficient alternative for delivery of gene therapies as compared to conventional methods [1]. The Cornell NanoScale Facility (CNF) offers tools used to fabricate these devices, research conducted there has increased production yield and reduced production time.

Summary of Research:

CNT arrays produced using template-based fabrication have been shown in previous studies to possess the capability of supporting gene transfer. They have been reported to achieve 85% of plasmid DNA transfer into cells and show a three times higher efficiency for transfection in stem cells than standard lipofection methods [2]. Carbon nanotubes are produced on Anodic Aluminum Oxide (AAO) templates using a multistep fabrication process which involves cleanroom fabrication.

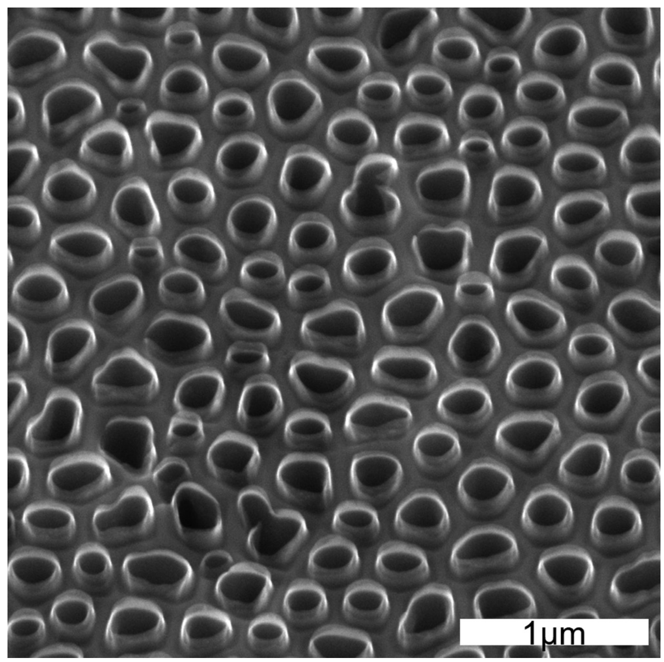

Figure 1: SEM of fabricated CNT.

Etching tools at the CNF were utilized to create free standing tubes, Figure 1 shows Scanning Electron Micrograph (SEM) image of a CNT array device produced at CNF. The micrograph shows carbon tubes protruding from the surface of AAO, these tubes stand approximately 200 nm off the surface of the AAO substrate.

Commercially available AAO templates consist of self-aligned pores covered by an interconnected later of AAO creating a 'lattice'-like web of material that inhibits biomolecule transfer by creating a bottleneck — this is referred as a lattice layer; during the fabrication of CNT arrays this layer needs to be removed, due to the size constraints and limitations of mechanical methods ion milling using the AJA ion mill at CNF was utilized to remove the top 1 μm of the AAO, exposing the pores.

Figure 2 shows a schematic visualizing from a side view the effects of ion milling on the AAO template, we noticed etch depth correlates to visible hydraulic pore diameter. The figure shows the AAO being etched away over time removing the lattice layer at the top to reveal the wider pores underneath. Ion mill time was optimized 1hr after it was noted that the pore diameter at both times were reported to be statistically similar. This was reconfirmed by various repeats before being implemented into the standard procedure used to fabricate CNT arrays.

The devices are 13 mm disks with a thickness of 60 μm, these pieces are too small to fit into the CNF tools which are built to work with 4'' and 6'' wafers. A carrier wafer was designed and produced to hold multiple CNT arrays to increase production yield up to 60 devices at a time. Figure 3 shows a carrier wafer with CNT arrays placed into the square holders, the carrier consists of two silicon wafers patterned and etched to fit atop each other with windows exposing the CNT arrays placed between them, the carrier shown in Figure 3 is the bottom and will be covered by a top wafer to secure the wafers in place preventing any slippage into the cleanroom tools.

Conclusions and Future Steps:

Optimizing ion mill parameters and developing a carrier wafer to hold pieces led to an increase in production yield. Further studies are to be conducted to optimize other clean room processes that are utilized in the fabrication of these devices.

References:

[1] Siddiqui, Mujtaba Yar Khan, "Application of ICP RIE Techniques to Produce CNT Arrays" (2023). Thesis. Rochester Institute of Technology. Accessed from: https://repository.rit.edu/theses/11656.

[2] Golshadi, Masoud, "Carbon Nanotube Arrays for Intracellular Delivery and Biological Applications" (2016). Thesis. Rochester Institute of Technology. Accessed from: https://repository.rit.edu/cgi/viewcontent.cgi?article=10360&context=theses.

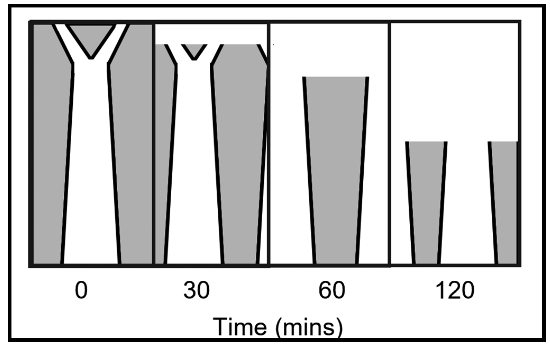

Figure 2: Schematic depicting effect of ion mill time on lattice layer evolution.

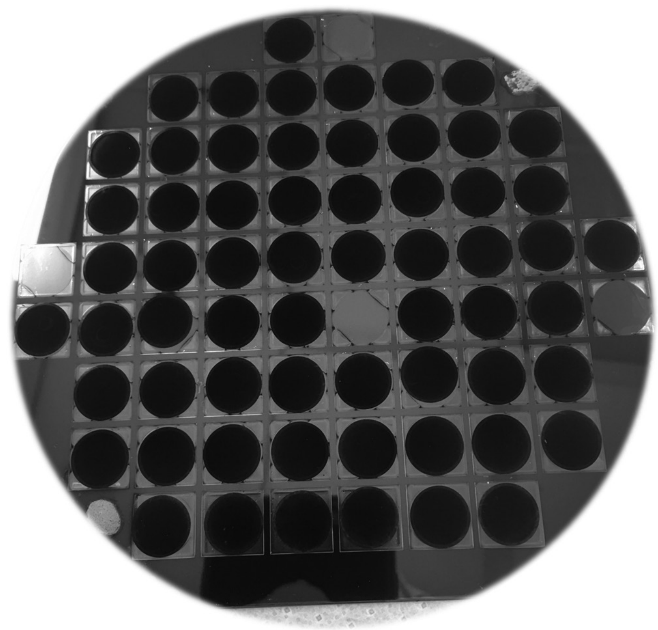

Figure 3: Silicon carrier wafer to hold CNT arrays during cleanroom fabrication.