Growth of Group III-V Nanowires using Nanosphere Lithography, Vacuum Evaporation, and MOCVD

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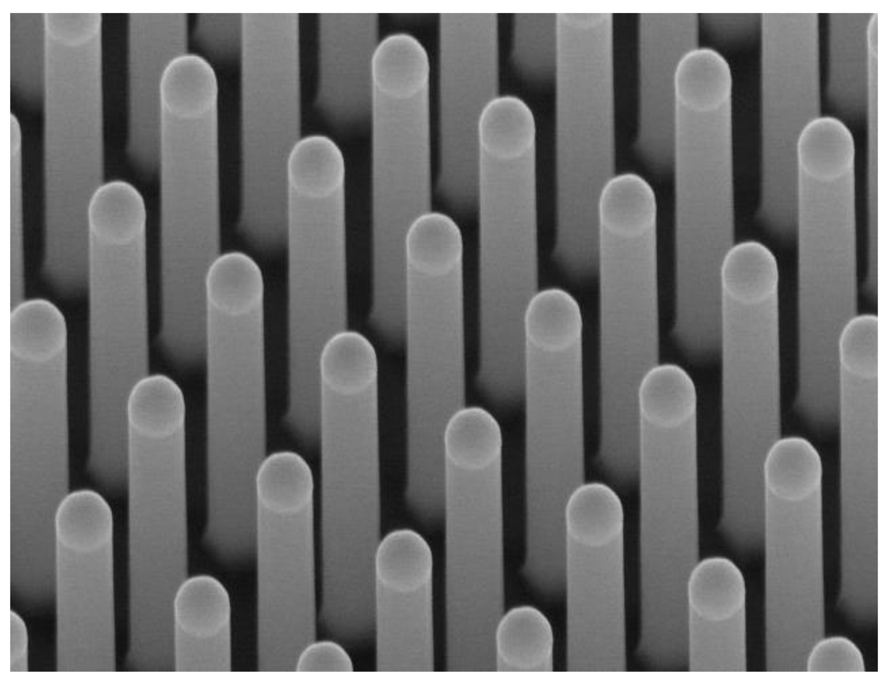
Introduction

- Nanowires made from Group III-V elements have semiconductor properties
- Could be used in photovoltaic applications.
- Solar cells with these nanowires could be much more efficient than solar cells today.
- This would lead to cheaper and more widely available solar power.

- Used a "bottom-up" construction method for nanowires: we grew them at the atomic level.
- The two elements used were Gallium (Group III) and Arsenic (Group V)
- The catalyst used to initiate and facilitate the growth of nanowires was Gallium.
- Using Gallium as a catalyst eliminated potential for contamination of the nanowire composition by foreign elements

- Solar Cell Applications:
- Nanowires would be vertically aligned
- Arranged in an orderly pattern
- Maximize light capture

Image taken from http://arstechnica.com/science/2013/01/wires-smaller-than-light-waves-boost-solar-cell-efficiency/



Vertically Aligned Nanowire Array

Conclusion and Future Work

- Definitively found that narrow nanowires of extreme length can be grown
- Extremely difficult to reproduce the exact growth conditions that did this
- Failed to accurately identify the material composition of the nanowires
- Do not know for sure that the wires were made of Gallium Arsenide
- More growths/tests should be done to replicate exact growth conditions and confirm nanowire composition

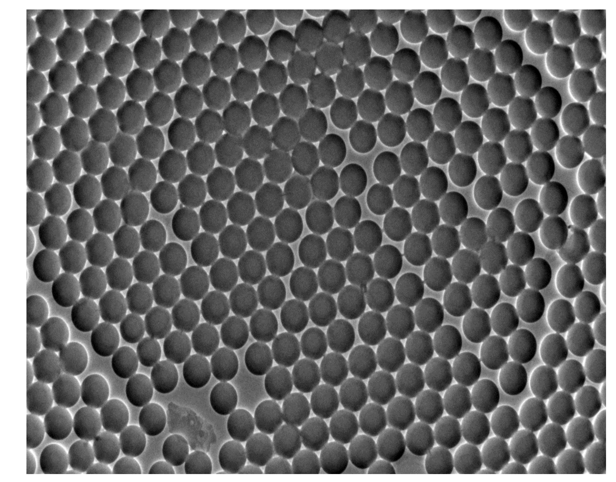
- Successfully achieved nanosphere lithography
- Successfully dissolved the nanospheres, leaving hexagonal array of catalyst droplets
- Didn't grow nanowires out of hexagonal array due to time constraints.

- Future Work: Grow nanowires on (111)substrate to create vertically aligned nanowires
- Potential Difficulties: different elements present/not present during the growth process – EX: oxygen, molybdenum, carbon
- Nanowires on a solid substrate would need to be specially prepared for TEM observation
- Would also need a high resolution SEM (<10nm resolution)

Procedure

1) Nanosphere Lithography

We created hexagonal arrays of polystyrene nanospheres approximately 500nm in diameter by dropping a solution of water and nanospheres onto our substrate and allowing the water to evaporate for 6 to 12 hours.

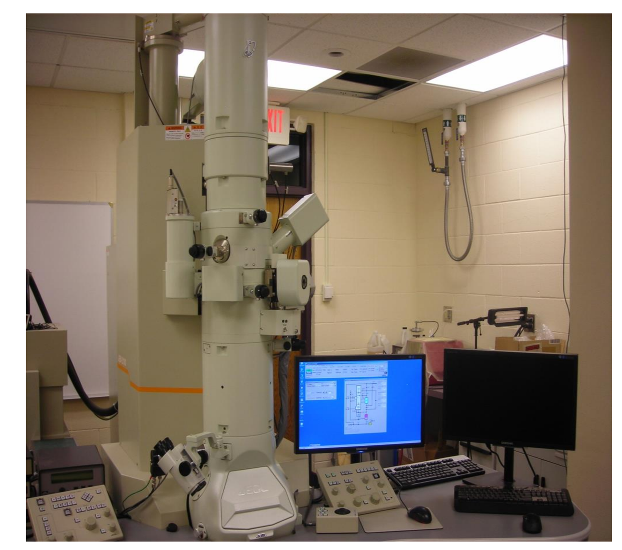


Hexagonally patterned nanospheres

Vacuum Evaporator

2) Vacuum Evaporation

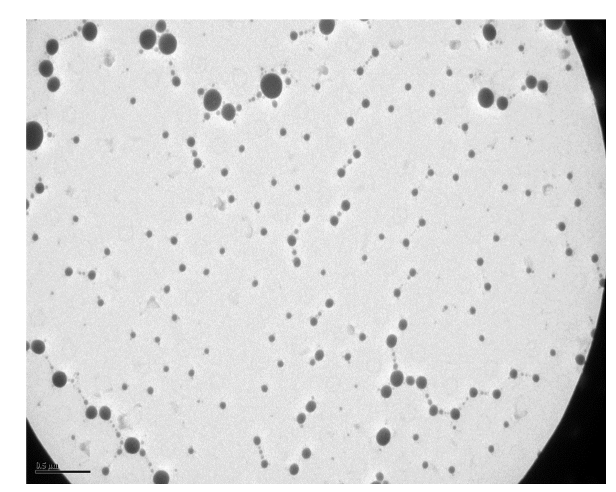
We evaporated our catalyst (gallium) onto the nanosphere array by placing it in a wire basket and running a high current through the wire. The gallium condensed onto the sample, creating a thin and somewhat even coating.



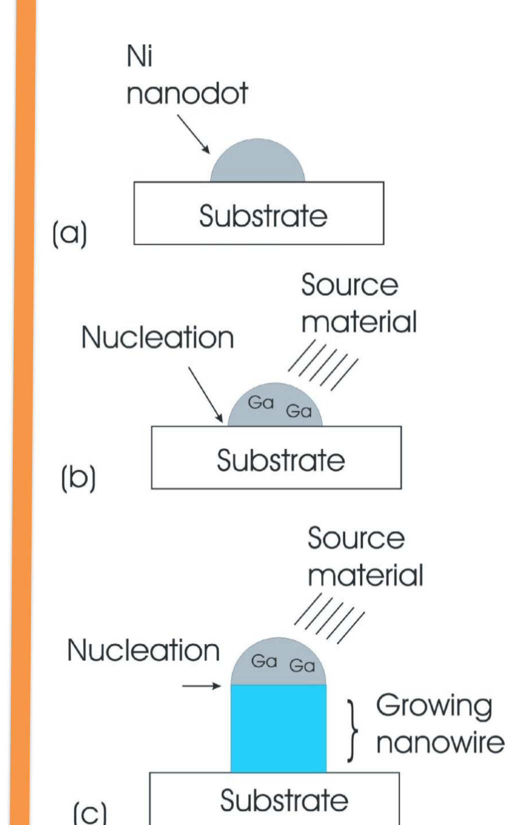
TEM – Transmission Electron Microscope

3) Dissolving the Nanospheres

By soaking the Gallium coated nanospheres in chloroform, we managed to dissolve the nanospheres away in small patches, leaving only the gallium that was in the small spaces between the spheres, which results in a hexagonal pattern of Gallium.



Gallium droplets after dissolving nanospheres



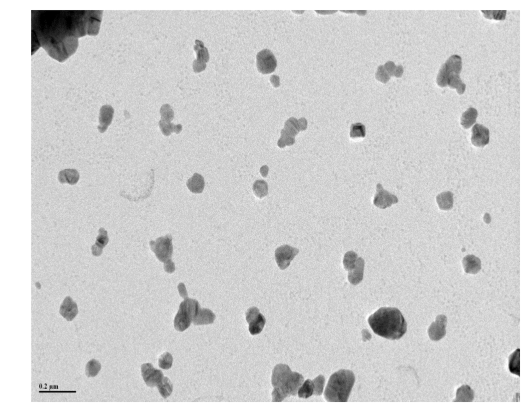
MOCVD Machine: the growth chamber is on the left (above), and an illustration of the VLS mechanism (left). Nickel is used as a catalyst in the picture for example purposes

Image taken from: http://www.depts.ttu.edu/ntc/ResearchAndPublications/Nanophotonics/nanowires.php

4) Metal Organic Chemical Vapor Deposition (MOCVD) Process

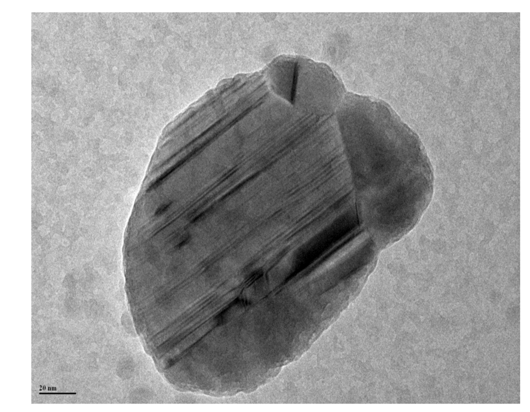
The MOCVD process uses a vapor-liquid-solid (VLS) growth mechanism. The Gallium droplets were heated to form a liquid. Then, the nanowire materials (Gallium and Arsenic) were flowed into the chamber and absorbed by the Gallium droplets. Finally, the materials started condensing onto the substrate beneath the droplets, growing nanowires.

Results

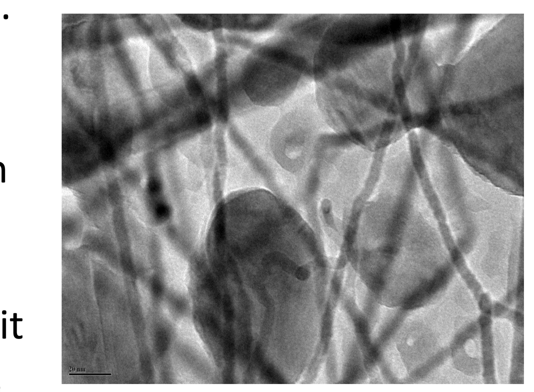


G1: Gallium Arsenide Chunks

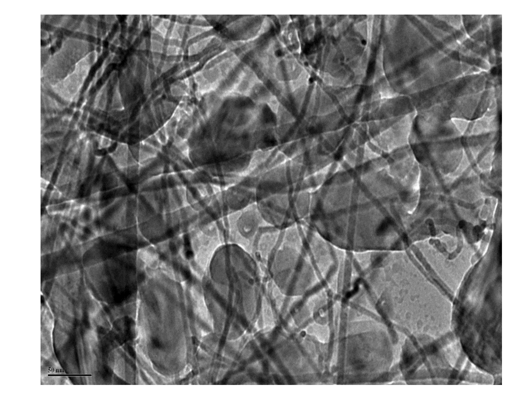
Initial results from the MOCVD machine (see left) revealed large chunks of Gallium Arsenide, but no nanowire growth. An element detector confirmed the elements. However, the Gallium Arsenide was definitely still in a hexagonal pattern, proving that we could achieve growth using a catalyst arranged in a specific pattern.



G1: Close up of GaAs chunk

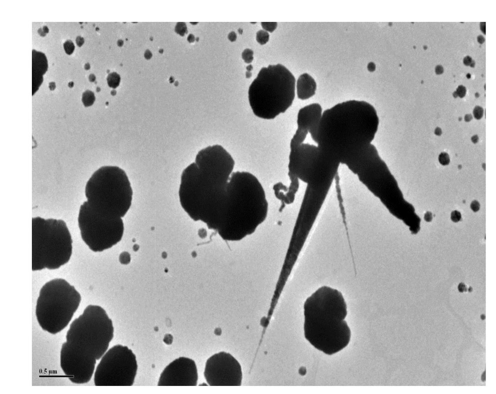


G2: Nanowires – difficult to focus



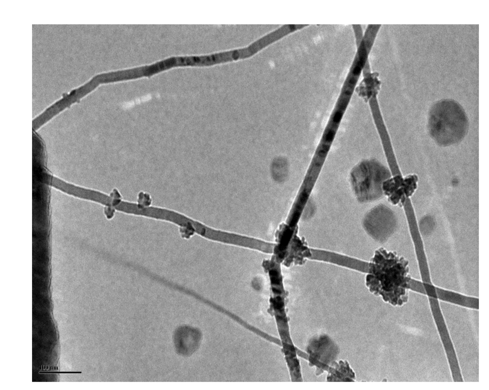
G2: Long, thin nanowires

The second iteration of the MOCVD machine (see right) was unexpected, as it revealed many long, narrow nanowires – 5nm thick and several micrometers long. However, to save time, we did not use an ordered array for the catalyst, and we could not confirm the presence of Gallium Arsenide. This is likely due to the large droplets of Gallium visible in the background of the pictures at right.

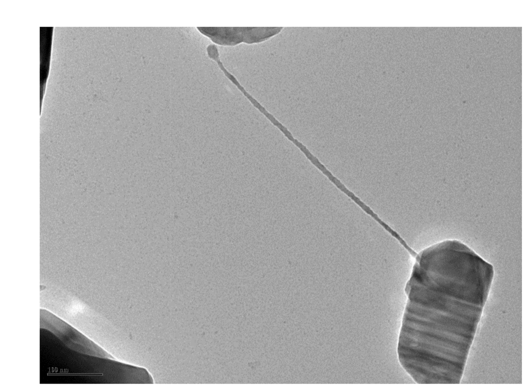


G3: Large nanorods

The third iteration (left) of the MOCVD process yielded large Gallium Arsenide rods – proving we could grow nanowire-like objects of Gallium Arsenide using Gallium as a catalyst. However, we again did not use nanosphere lithography, and we couldn't confirm the composition of the smaller nanowires (bottom picture at left).

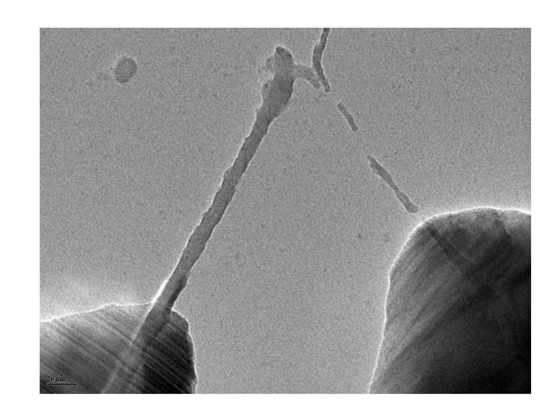


G3: Thin nanowires



G4: Nanowire and GaAs crystal

The fourth iteration revealed some interesting nanowires (see right). Very thin wires or wire like objects appear to be growing out of large Gallium Arsenide chunks. Because of the clear mass difference between the wires and the chunks, we could not confirm the composition of the wires. It should be noted that the images show a specific part of the sample; most of it had no nanowire-like objects at all.



G4: Nanowire like object

Acknowledgments

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