The Growth of GaN Nanowires using Ni Nano Particles as Catalyst

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Abstract:

In this work, photolithography is used to create nickel disks on a silicon substrate. These disks aid the growth of uniform wires. Half of the samples are N_2 plasma etched, creating a rough surface for the wires to grow from. Rough and smooth surfaces were then compared in their ability to grow wires more uniformly. After the samples were properly prepared, they were placed into a furnace and heated to 1000°C in a gallium and ammonia environment for 20 minutes. This process resulted in the growth of nanowires in the range of 5-7 µm in length and approximately 50-90 nm in diameter.

Introduction:

Gallium Nitride (GaN) nanowires are semiconductor wires that are grown through chemical-vapor deposition. These wires have many different uses and applications including lasers and diodes. GaN is a wide bandgap semiconductor material and this allows for the emission of blue and ultra-violet light. Due to its ability to emit light, GaN can be used in data storage, because of its high frequency and short wavelength. This makes it far superior to modern technology and thus an interesting option in the development of new technology.

To aid in the growth of our wires, a Nickel (Ni) catalyst was chosen to increase the rate of reaction. The Ni catalyst typically decreased the time taken to grow by 2 hours. GaN nanowire growth has been achieved in the past but in a matrix form. A pattern of Ni disks was chosen to control both the size and location of the nanowires. This was to ensure a sample that contained uniform nanowire growth.

Experimental Procedure:

The first thing that was done was to create the Ni disks for the GaN to grow on. We started out by cleaning and preparing three different substrates: sapphire, quartz and silicon. These three substrates were washed with soap, and then doused with acetone and methanol to ensure a clean surface. After cleaning, through the process of photolithography, a pattern was placed on top of each of the substrates. The pattern contained 2 µm disks spaced 2 µm apart from each other. We had hoped for the nanowires to grow perpendicular to the surface of the substrate. We had also hoped for growth parallel to the surface from one disk to another. A bridge-like structure connecting the disks was wanted to regulate nanowire growth.

In the past nanowire growth has been in the form of a matrix. The matrix is a shapeless array of random nanowire growth. The precise size and direction of these wires cannot be predicted.

After the pattern is placed on the substrate, the sample is then put into the electron beam evaporator so the Ni can be deposited on the surface of the substrate. The desired thicknesses of the Ni disks were 35 nm. After deposition, liftoff was used. In liftoff, acetone is sprayed on the substrates and the excess Ni is shed away. The samples now have the Ni disks deposited on them (Figure 1).

Half of the samples are then placed into the plasma

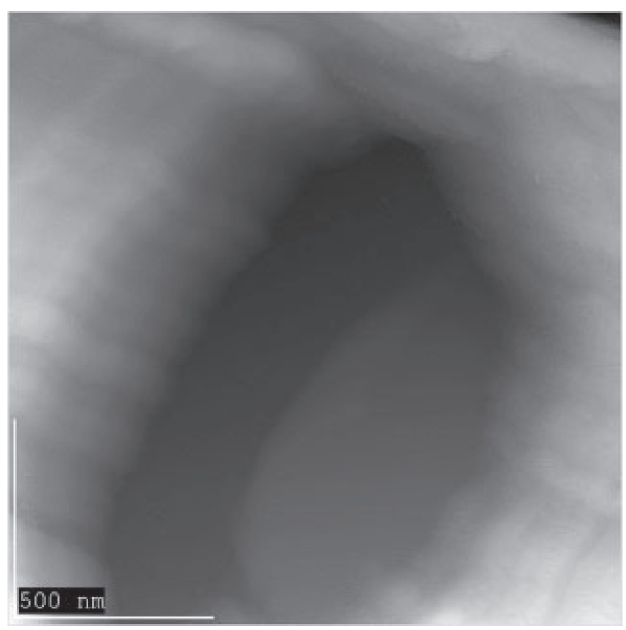

Figure 1: An unetched nickel disk before growth.

etch chamber to guarantee a rough surface for the nanowires to grow from. The samples were to undergo N_2 plasma etching for a period of 3 minutes and then we measured the surface profile by AFM. This process resulted in a rough, bumpy surface, like nano particles, for nanowire growth (Figure 2). The next step was the growth process.

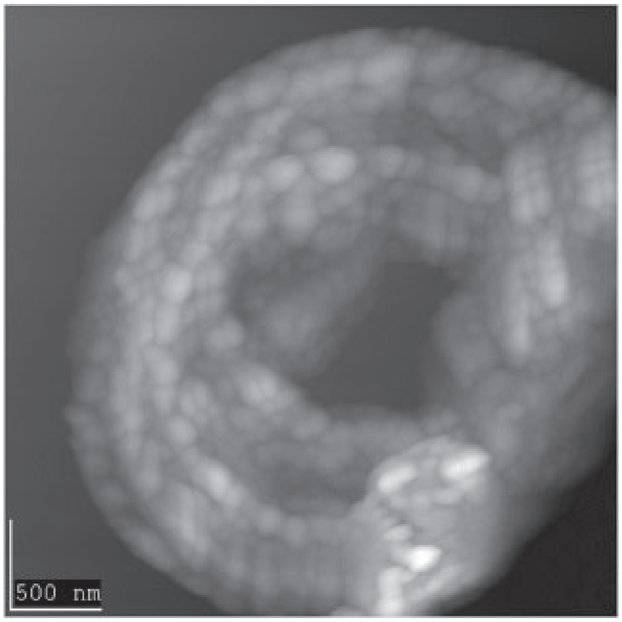

Figure 2: An etched Ni disk before growth.

The samples were placed into a quartz tube of a furnace behind gallium. The samples were then heated to 1000°C for 20 min while ammonia was flowed though the tube at a rate of 10 sccm and kept pressure at 10 torr. At the end of the growth process, the samples were measured by Scanning Electron Microscope (SEM) to observe their profile.

The Ni disks on the sapphire and quartz substrates did not become nano particles after N_2 plasma etch, so we did not use them for growing wires.

Results:

The etched Si substrate with Ni on it was able to produce nanowires in the 50-90 nm diameter range (Figure 4). These wires grew nearly perpendicular to the surface and had a sort of plant-like growth. The unetched silicon substrate was able to produce wires in the 200-300 nm diameter range (Figure 3). These were not nanowires; these are called whiskers. The etched sample did not contain nanosized particles.

Conclusion and Future Works:

From these experiments, we conclude that nanowire growth is largely based on nanoparticles. In the sample that contained nanosized dots on the disk, nanowires grew. If no nanoparticles were present either large wires or big crystalline structures would grow. In the future, if nanodisks were available, then individual wires may be able to grow. These nanodisks may be achieved through a process called self-assembly.

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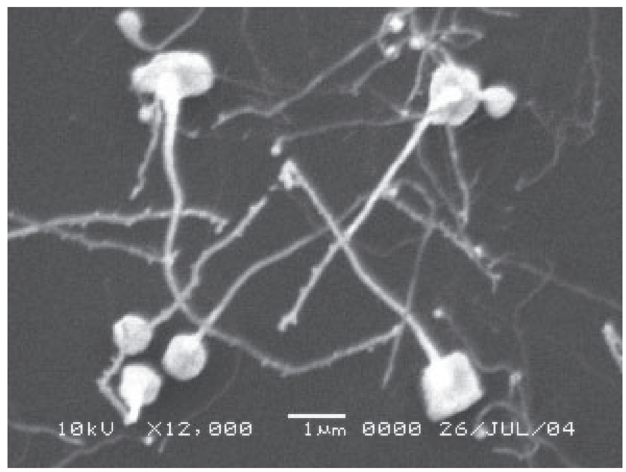

Figure 3, above:Unetched Ni disk after growth, size ~ 200-300 nm in diameter.

Figure 4, below: Etched Ni disk after growth, size ~ 50-90 nm in diameter.