# Gallium Nitride Nanowire Growth, and FET Device and Biosensor Fabrication

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**Abstract:**

Gallium nitride nanowires (GaN NWs) may be used to fabricate devices such as field effect transistors (FETs) and bio-/chemical sensors. This study focused on controlling the growth of the nanowires for fabrication of FETs. GaN NWs were grown using annealed Ni as catalyst. To control nanowire growth density, the anneal time and temperature were varied. The initial thickness of the Ni and the nanowire growth conditions were varied as well. Using standard lithography processes, several Ni patterns were created and nanowires were grown from the patterns. FETs were created by putting a source and drain over the patterned nanowires. Current/Voltage measurements of these transistors showed that nearly every device behaved as a transistor, however, pinch-off was not observed and there was little gate modulation.

## Introduction:

Nanowire research is important to the development of nanoscale electronics. One of the properties that makes GaN nanowires interesting is that GaN has a wide direct band gap of 3.4eV at room temperature. Since GaN can be doped to be either a p- or n-type semiconductor, electronic devices like diodes can be made from the nanowires. Other devices such as Field Effect Transistors (FETs) have also been made. Our research concentrated on forming a high-yield fabrication process for GaN NW FETs. To get the high yield we desired, it was important to learn to control the density of NW growth by varying several growth conditions. The geometry of the transistor design was also important. By shaping the transistor as in Figure 1, a NW growing in almost any direction will connect the source and drain.

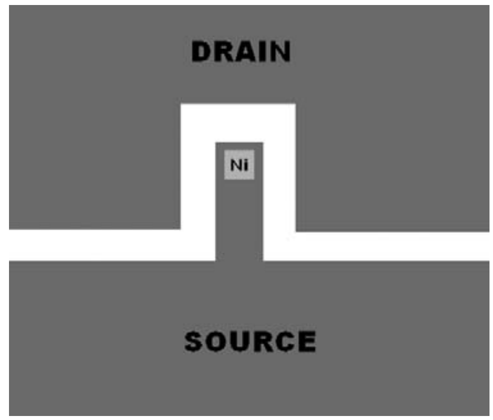



*Figure 1*

## Materials and Methods

### Catalyst Preparation:

One to two nm of Ni was e-beam evaporated onto a Si substrate with 40 nm of thermally grown $SiO_2$. These samples were then put in the rapid thermal annealer (RTA) for temperatures ranging from 850-1050°C and times from 1-3 min. This process caused the Ni to form balls all over the surface. Some samples were re-annealed at the same temperature to see if this had any affect on Ni ball formation. Ni balls were then characterized using AFM as in Figure 2.

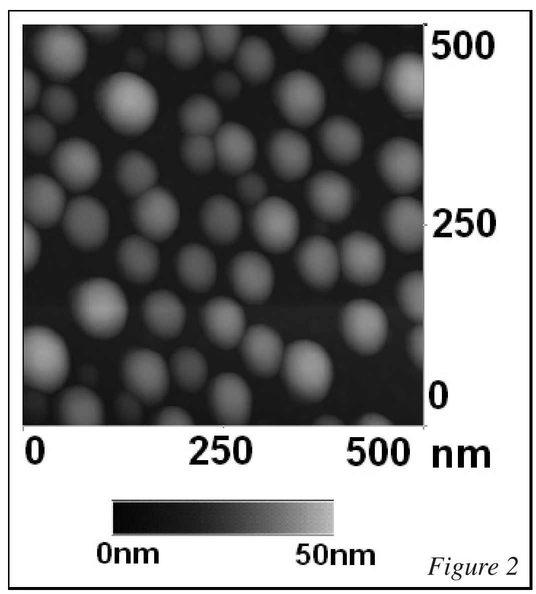



*Figure 2*

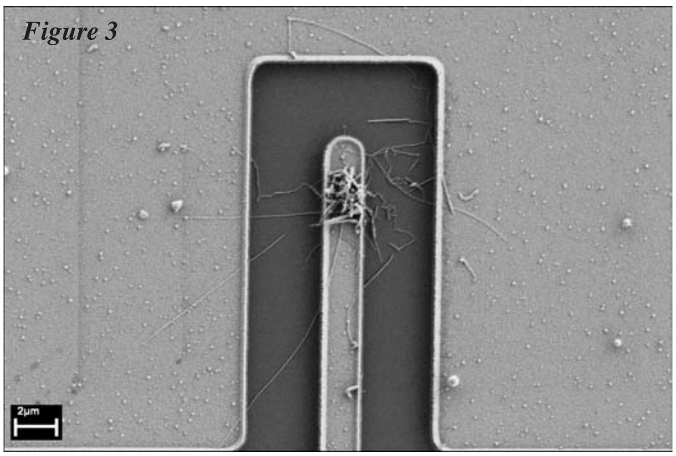
### Nanowire Growth:

Nanowires were grown in a homemade furnace. A drop of Ga was placed upstream of the annealed substrate and the chamber was pumped down. Typical growth conditions had 200 sccm of ammonia flowing through the chamber with another 200 sccm $H_2$ as carrier gas. The reaction occurred at 1 atm. The furnace was heated to 900°C for the growth and the reaction time was 30 min.

## FET Fabrication:

Using standard lithography processes small dots of Ni (0.5-1 $\mu$m squares) were patterned over a wafer. NWs were grown from the Ni pattern and 15nmTi/150nmAl/50nmTi/50nmAu source/drains were patterned on top of the NWs. The distance between the source and the drain was varied from 1-3 $\mu$m. The natural oxide layer was etched off the back of the samples before current/voltage measurements were taken.

*Figure 3*




## Results and Conclusions:

All of the FET devices that we looked at with the SEM had more than 2 NWs connecting the source to the drain. The device with the fewest connecting NWs is shown in Figure 3. In the case where there was only 1 $\mu$m between the source and the drain, the NWs are so crossed and tangled it was not possible to count how many NWs were connecting the source and drain. This study has shown that for a 1 NW connection, only one Ni dot is necessary for each FET and that the distance between the source and drain (for our geometrical configuration) should probably be between 4-6 $\mu$m.

Current/voltage curves showed little modulation as the back gate voltage was changed. This may be because we had not put a metal contact on the back of the devices. Some of the devices were asymmetrical about the y-axis, which may be caused by poor contact with the GaN NW (see Figure 4). Despite these imperfections, almost every single device measured demonstrated FET electrical behavior: a linear relationship between source and drain current and voltage until high voltages were reached and current was close to constant.

## Further Studies:

Further studies of GaN FETs will include adding a metal back gate to see if that increases gate modulation and if the FETs will be pinched off. The metals used for the source and drain will also be optimized to ensure ohmic contact. Once these studies have been made, the use of GaN NWs as a biosensor will be able to be investigated.


## Acknowledgements:

The author wishes to thank Prof. Michael Spencer, Huaqiang Wu, the CNF, NNIN and NSF.


*Figure 4*