

THE DEPENDENCE OF GALLIUM NITRIDE NANOWIRES PROPERTIES ON SYNTHESIS PRESSURE AND TEMPERATURE

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Abstract – The main task of the investigation was to perform the synthesis of gallium nitride nanowires using a low pressure chemical vapor deposition system. The nanowires were grown via a catalyst-assisted reaction based on the vapor-liquid-solid mechanism. The influences of catalyst, temperature and pressure on the growth of gallium nitride nanowires were explored. Optimal results were obtained at a temperature of 750°C and a pressure of 400 to 500 mTorr.

I. INTRODUCTION

Among the various kind of investigated nanowire systems, Gallium Nitride (GaN) nanowires are of particular interest because this III-V semiconductor has already showed interesting properties in bulk form. The growth parameter to be varied was the temperature. The following experiments were performed with nickel as the catalyst as successful growth of nanowires was obtained with this metal. Temperature is a very important parameter to tune in nanowire growth as changes of a few tens of degrees have been reported to produce nanowires with very different morphologies. GaN is well-known for its resistance to temperature, strain and high electric fields. As a result it is a material of choice for high power/high temperature applications. In addition to, the optical properties of GaN are useful for optoelectronic device operating at ultraviolet and blue wavelengths [1].

II. EXPERIMENTAL RESULTS

In our case, four temperatures were tested: 700°C, 750°C, 800°C, and 850°C. SEM images below show typical nanowire morphology obtained for 750°C, 800°C temperature (Figure 1). By lowering the temperature, it was expected to avoid the formation of the NiSi₂ compound and reach the temperature region where NiSi start to aggregate. The trial at 800°C resulted in successful growth of a high density of nanowires on the Si substrates. Although some nanowires grew straight with a smooth surface most of them exhibited a rough surface. The nanowire body could be seen as a succession of cones stacked all along the main axis.

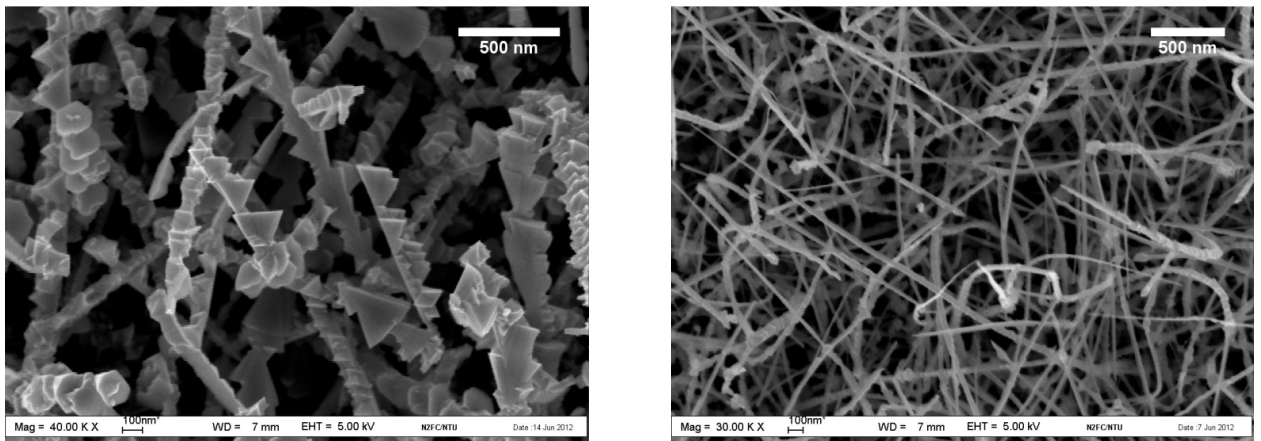


Figure 1. SEM images of nanowires obtained at 800°C, 750°C temperatures.

The photoluminescence (PL) spectra of the GaN nanowires were obtained under excitation at 260 nm [2]. Figure 2 shows the PL spectrum obtained for GaN nanowires at different temperatures. For each temperature, the spectrum is characterized by two main peaks: an intense and broad peak which corresponds to the near band-edge emission and a much weaker peak centered around 300 nm. Influence of the growth temperature on the PL spectrum of the GaN nanowires is clearly visible. As the temperature increases from 700°C to 800°C, the emission peak becomes broader: peak fitting rises

from 65 nm at 700°C to 200 nm at 800°C. Moreover, at 800°C, the near band-edge emission seems to result from the overlapping of multiple peaks centered at 407 nm, 425 nm and 440 nm. A red-shift of the emission peak can also be observed with increasing temperatures from 390 nm at 700°C to 425 nm at 800°C. The near-band-edge peak normally located around 360 nm for GaN material is shifted towards red wavelengths for our GaN nanowires by more than 30 nm. Previous comparisons between luminescence from GaN bulk and nanowires have shown that emission from nanowires is usually broader and red-shifted due to strain as well as surface and impurity states. Therefore, the decrease in peak broadening seems to indicate that the structures grown at lower temperatures exhibit a lower density of defects than those grown at higher temperatures. Correlation between the previous observations and the nanowire morphology shows that the stacked-cone nanowires grown at 800°C have a quite broad luminescent peak whereas the very thin nanowires grown at 700°C exhibit a narrower emission peak; however the peak intensity in the latter case is reduced by one third.

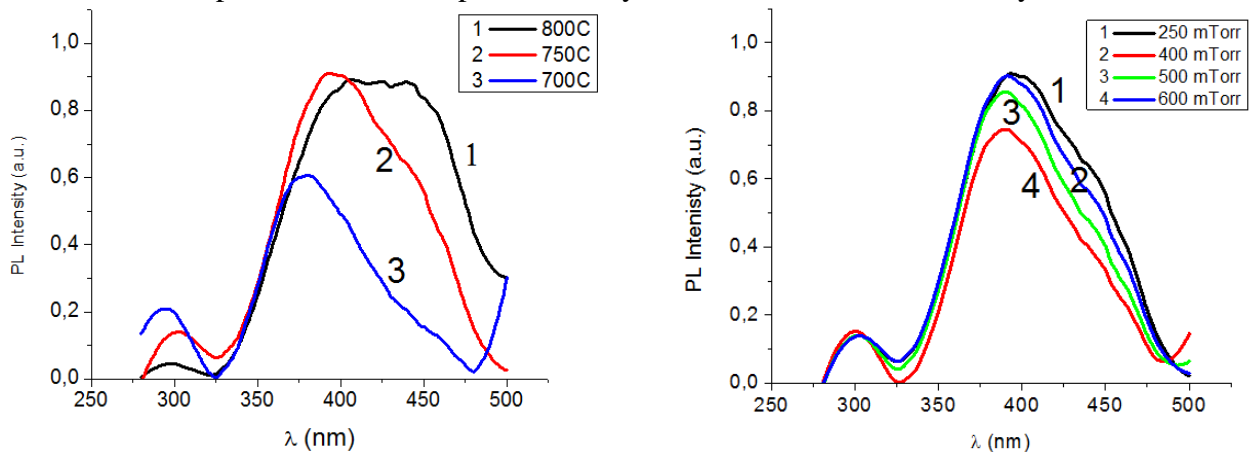


Figure 2. PL spectra of GaN nanowires synthesized at different temperatures and different pressures.

For nanowires grown under various pressure conditions, the PL spectra exhibit a more consistent shape. This is in agreement with the observed morphology of the wires. The PL spectra present a near band-edge emission around 390-395 nm and a UV-emission centered at 300 nm. We can observe an increase in the peak intensity and width when the pressure increases from 400 mTorr to 600 mTorr: the tops of the fitted peaks goes from 115 nm at 400 mTorr to 158 nm at 600 mTorr. The broadest emissions are obtained at 250 mTorr and 600 mTorr. This seems to confirm that rough surface nanowires induce peak broadening as they incorporate a higher amount of defects than smooth and thin nanowires.

III. CONCLUSION

These results indicate that the optical quality of 1-D GaN nanostructures can be improved by controlling their dimensions and their diameter in particular. In our case, the lowest growth temperatures (750°C-700°C) at which thin nanowires have been produced gave the best optical results. PL spectra at these temperatures exhibited narrower emission peak and a reduced red-shift. However it can be observed that the decrease in peak broadening is also associated with a reduction in peak intensity. The conclusions drawn from these photoluminescence measurements are expected to be confirmed with further experiments including electrical measurements and Raman spectroscopy. At these pressures, nanowires with stacked cone features were observed.

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