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In-situ catalytic growth of Gallium Nitride Nanowires

R.E. Diaz,* R. Sharma,** S. Mahajan,* and K. Jarvis*

* School of Materials, Arizona State University, Tempe, AZ85287
** Center for Solid State Science, Arizona State University, Tempe, AZ85287

Group III nitride large band gap semiconductors have attracted special interest for applications in optoelectronics devices such as blue-green light-emitting diodes (LED), blue-light laser diodes (LD), and ultraviolet detectors [1, 2]. Multi-layer epitaxial structures required for various devices are generally grown on (0001) sapphire and silicon carbide substrates, lattice mismatches between the III nitrides and these substrates result in a high density of dislocations, which in turn reduces the efficiency of the device. Despite all prior efforts to reduce dislocation densities [3], the development of optimum devices still has not been achieved. One possible solution for this problem is to substitute semiconductor nanowires for semiconductor epitaxial films. Nanowires often have stress-free surfaces and similar or even better electrical and optical properties [4]. Vapor-liquid-solid (VLS) catalytic growth is one of the most common methods used to synthesize 1-D nanostructures [5]. Although ex-situ catalytic growth of gallium nitride (GaN) nanowires has been achieved [6,7], there is not a complete understanding of the growth mechanisms and the interface dynamics involved in this process. This work presents a dynamic observation of the nucleation and growth mechanisms of GaN nanowires which were formed by direct reaction of ammonia (NH_3) with gold (Au) – gallium (Ga) liquid droplets.

An environmental scanning/transmission electron microscope (ESTEM), Tecnai F20, was used for in situ observations. Au was deposited on silicon-perforated membrane TEM ready grids by sputtering. These silicon grids were introduced into the ESTEM column and heated up to 400C using a heating holder. Next, 60 mTorr of Trimethylgallium (TMG) was introduced in to the column for 5 minutes. Subsequently, the sample temperature was increased to 800C and 70 mTorr of NH_3 was introduced into the ESTEM column. Low and high magnification images and digital videos (15fps) were recorded using Gatan Orious 600SC camera. JEOL 2010F TEM/STEM was used for ex-situ characterization of the samples.

GaN nanowires grew at 800 C after 40 mTorr of NH_3 was introduced. Several nanowires with different length and diameter were observed over the whole substrate, therefore growth due to electron beam effects are discarded. A growth sequence under 70 mTorr of NH_3 (Figure 1A-C) gives us different growth rates for different diameters of the Au-Ga droplet. Fig. 1A was taken 51 minutes after opening the NH_3 valve and Fig 1B-C were taken 46 minutes after Fig. 1A. Direct observations revealed that the growth rate of the nanowires is directly proportional to the NH_3 pressure introduced and indirectly proportional to the diameter of the Au-Ga droplet.

In addition, ex-situ analytical and structural studies were performed on the nanowires. Figure 2 shows an energy dispersive X-ray spectrum (EDS) of a nanowire, showing the presence of Ga in the body of the nanowire, and the respective STEM image of the nanowire. Electron loss energy spectroscopy (EELS) was also performed showing the presence of nitrogen as well as Gallium in the body of the wire.

References
[1] F.A. Ponce, D.P. Bour, *Nature.* 386 (1997) 351.
[2] S. Nakamura, *Science.* 281 (1998) 956.
[3] K. Pakula, R. Bozek, J.M. Baranowski et al., *J. Crys. Growth*. 267 (2004) 1.
[4] Y. Xia, P. Yang, *Adv. Mater.* 15 (2003) 353.
[5] Wagner, R.S, Ellis, W.C., Appl. Phys. Letters. 4 (1964) 89.
[6] T. Kuykedall, P. Pauzauskie, Sangkwon Lee, Y. Zhang, *Nano Lett.* 3 (2003) 1063
[7] Zhang, L. Zhang, J. Vac. Sci. Technol. B 21(2003) 2415.
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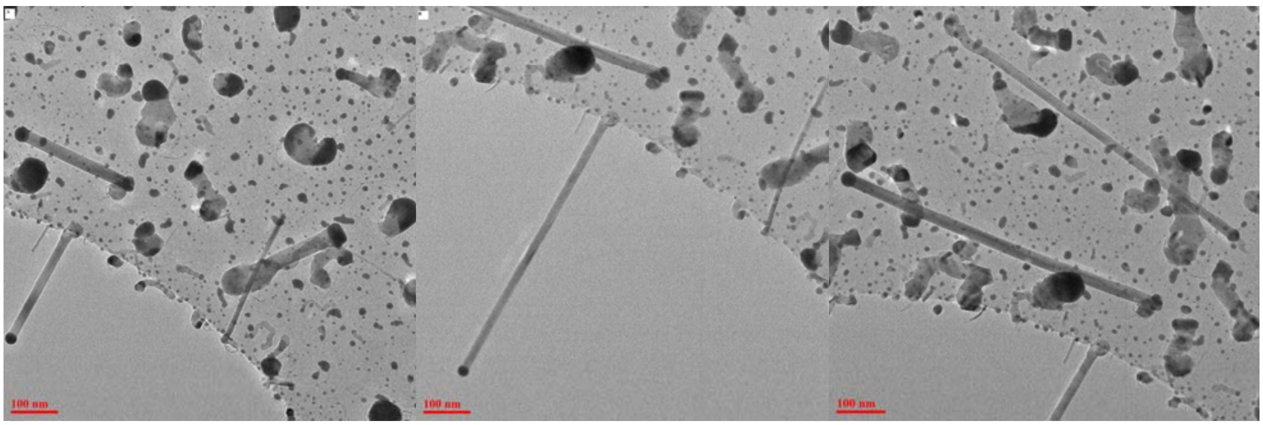

FIG. 1. A) Low magnification TEM image of GaN nanowires on Si membranes. B,C) Low magnification TEM image of the same area as A.

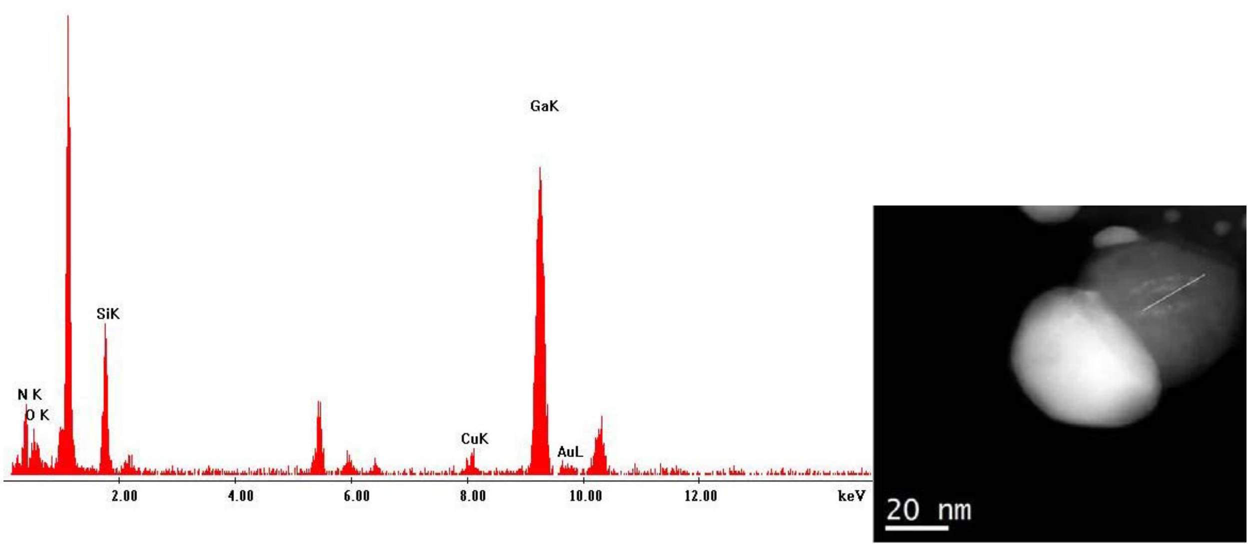

FIG. 2. STEM image of a wire with a respective energy-dispersive x ray spectra of the wire body.

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