GaN-based Nano-pores and Nano-wires Fabricated Using Electroless Chemical Etching Process

B. S. Ooi*, A. Najar, A. B. Slimane, R. T. ElAfandy, A. Gasim, Q. Li, and T. K. Ng
Photonics Laboratory
King Abdullah University of Science and Technology (KAUST), Thuwal, 23955-6900, Saudi Arabia.
**email: boon.ooi@kaust.edu.sa*

Engineered nanostructures based on large bandgap nitride, such as GaN-related nano-pores (NPs) and nano-wires (NWs) have attracted intense research interest in recent years. The ability to control the morphology from porous-structure, to free-standing short-wires and ultra-long-wires structure may enable researchers to engineer and study the optical and electronic properties of the GaN-related nanostructures for potential applications in light emitting diodes (LEDs), photonics integrated circuits, piezoelectric devices, and photovoltaic. The free-standing direct bandgap GaN-related NWs can potentially offer efficient UV to green emission without suffering from efficiency drooping at high injection level. Moreover, having effective 1D carrier confinement, ultra-long NWs offer researchers an opportunity to further engineer the piezoelectric- or spontaneous-polarization effects, and light-photon interaction at nano-scale. Despite having high specific surface area, large bandgap GaN-related materials have high thermal stability and low reactivity with oxygen, rendering GaN-related NPs suitable for use in III-V photovoltaic, such as in reducing the surface reflectivity.

The samples used in this study consist of 30 µm GaN epitaxy grown on c-plane sapphire using metal-organic chemical vapor deposition (MOCVD). Using the Pt-assisted UV electrode-less chemical etching technique, we are able to prepare a port-folio of GaN-related nanostructures from NPs to standing NWs, and long lying NWs, as shown in Fig. 1(a)-(c).

In this talk, we discuss the use of Pt-assisted electro-less chemical etching method using the $HF/H_2O_2/CH_3OH$ solution for fabricating the nanostructures. Without external carrier injection, close-loop carriers (electrons and holes) transports are achieved across the electrolyte/Pt/n-GaN and electrolyte/n-GaN interfaces during UV lamp illumination. This injects holes into the semiconductor valence band, and facilitates etching through oxidization and dissolution of the surface atoms.

The NPs shown in Fig. 1(a) were etched for 60 mins in the above-mentioned solutions. Fig. 2(a) and (b) shows the PL peak shift and Raman scattering trend with increasing etching duration. The corresponding Raman scattering peak shifts are tabulated in Table 1. The blueshift of PL peaks were attributed to 0.35 GPa uniaxial compressive stress relaxation for the sample etched for 90 min. This is deduced from the E_2 peak shift, calculated using the proportionality factor of 4.2 cm^{-1}/GPa for hexagonal GaN.

The average length of the NWs in Fig. 1(b) and Fig. 1(c) are 2.5 µm and > 7 µm, respectively. The non-facetted NWs have diameters between 20-40 nm depending on HF concentrations. The fact that anisotropic etching process proceeds with such large aspect ratio is peculiar and warrant further investigations.

In Fig. 3, the n-GaN/sapphire sample was illuminated with a focused UV Gaussian beam, instead of the flat-top beam used for samples in Fig. 1(a) - (c). On the same sample, we observe regions without nanostructure formation, indicating the presence of a threshold photon density for initiating NPs formation. The trench in Fig. 3(a) reviews the underlying pores, indicating simultaneous NPs and NWs formation. In addition, Fig. 3(a) and (b) show low and high density NWs formation due to the effect of low and high photon density, respectively.

Our results indicate the close relationship between the mechanisms of formation for both NPs and NWs nanostructures. A carrier transport model for the nanostructures formation will be presented.

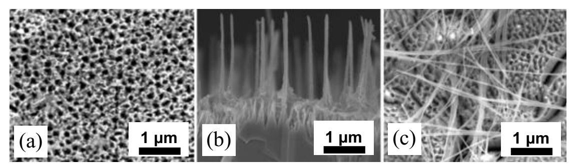

Fig. 1 (a) NPs, (b) standing NWs, and (c) long lying NWs.

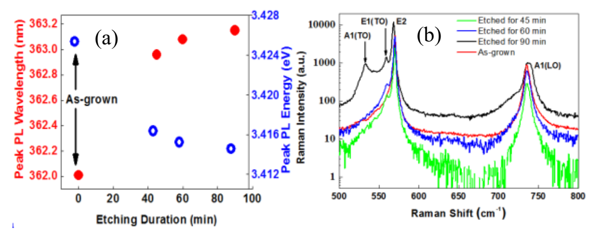

Fig. 2 (a) PL plots, and (b) Raman scattering plots.

Table 1 Raman scattering peak positions.

	E_2 (cm^{-1})	A_1(TO) (cm^{-1})	E_1(TO) (cm^{-1})	A_1(LO) (cm^{-1})
45min	570.0	-	560.0	736.1
60min	569.9	-	560.1	735.7
90min	568.5	533.3	559.4	736.6
As-grown	570.0	-	-	735.6

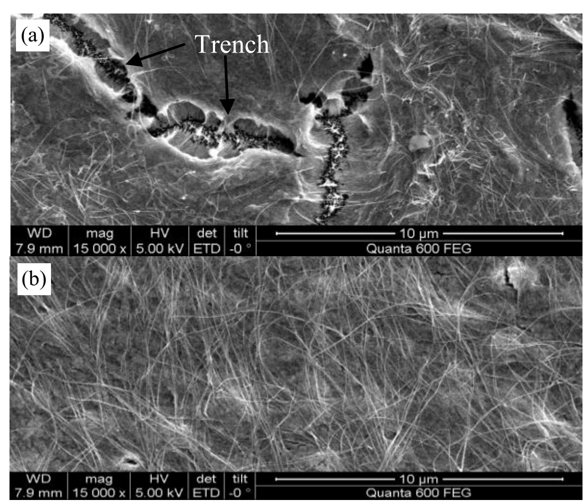

Fig. 3 (a) Low, and (b) high photon density NWs formation.