Photo-enhanced wet oxidation and etching of GaN

L. -H. Peng and H. -M. Wu
Institute of Electro-optical Engineering
National Taiwan University
Taipei, Taiwan 106, R. O. C.

C. -C. Chuo and J. -I. Chyi
Department of Electrical Engineering
National Central University
Chung-Li, Taiwan 320, R. O. C.

The wide bandgap III-V nitrides have long been recognized as the material of choice for realizing short wavelength emitters, high temperature and power electronics. The chemical stability of III-V nitrides, however, prevents the use of cost-effective wet methods in device processing. In this work, we report the use of photoelectrochemical (PEC) method to achieve wet oxidation, etching, and MOS action on n-type GaN and enhanced photo-response on oxidized InGaN QW.

The PEC set-up was similar to that originally designed by Haisty [1] in which the galvanic cell consisting of a GaN working and a Pt counter electrode immersed in an electrolyte. Activation of the PEC process was initiated by a 254 nm mercury line source at an intensity ~ 10 mW/cm^2. The reaction is accredited to the UV-excited hot carriers at the GaN/electrolyte interface to access the H^+/H_2 and OH^-/O_2 redox levels and to enhance the oxidative dissolution of GaN. [2]

Shown in Fig. 1 is the PEC response from n-type GaN grown on sapphire. Wet oxidation of GaN is found to take place in H_3PO_4 solutions with pH values ranging from 3 to 4, whereas etching can occur at a larger window from −1 to 2 in H_3PO_4 and 11 to 15 in KOH solution. At room temperature, the PEC process is found reaction-rate limited and has a peak value of 224 nm/hr at pH = 3.5 for oxidation and 125 nm/min at pH = 0.75 for etching.

Illustrated in Fig. 2 are the SEM micrographs taken on the PEC oxidized GaN with an oxide thickness of (a) 100 nm and (b) 450 nm. The thin-oxidized sample A has a purple-bluish color whereas cracks appear on the thick sample B due to strain relief during the oxide growth. The missing N signal in the Auger spectra of Fig. 2 (c) suggests a complete surface coverage by an oxide layer, whereas the up shifting of the Ga $2P_{3/2}$ binding energy of the oxidized GaN to 1119 eV in Fig. 2 (d) represents a typical signal from Ga_2O_3. [3]

The spectral photo-current (PC) response of Fig. 3 reveals an optical enhancement by a factor of (a) 3 and (b) 40% in the oxidized GaN and InGaN MQW, respectively. These observations suggest that the PEC oxide can be used as an efficient surface passivation layer on the GaN-based opto-electronic devices.

In Fig 4 we depict the high frequency (1 MHz) C-V characteristics of a GaN MOS with a 50 nm-thick PEC-grown Ga_2O_3 and a size of ~ 1.7×10^{-4} cm^2. The data reveals a sharp transition between the depletion and accumulation regimes, and has a minimum interface trap density estimated to be $D_{it,\,min} < 2 \times 10^{12}$ cm^{-2} eV^{-1}.

In summary, we report a PEC wet oxidation and etching process on GaN and demonstrate their promising use as the surface passivation layer to the GaN-based opto- and electronic devices.

This research was supported by the National Science Council under Grant No. 90-2215-E-002-017 and 90-2215-E-002-023.

Reference:

[1] R. W. Haisty, J. Electrochem. Soc. **108**, 790 (1960).
[2] L. -H. Peng, C. -W. Chuang, J. -K. Ho, C. –N. Huang, and C. –Y. Chen, Appl. Phys. Lett. **72**, 939 (1998), ibid **76**, 511 (2000).
[3] I. Shalish, Y. Shapira, L. Burstien, and J. Salzman, J. Appl. Phys. **89**, 390 (2001).

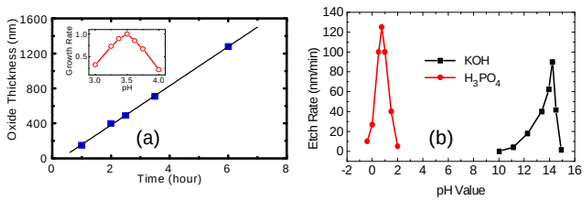

Fig. 1 PEC (a) oxidation, and (b) etch rate of n-GaN

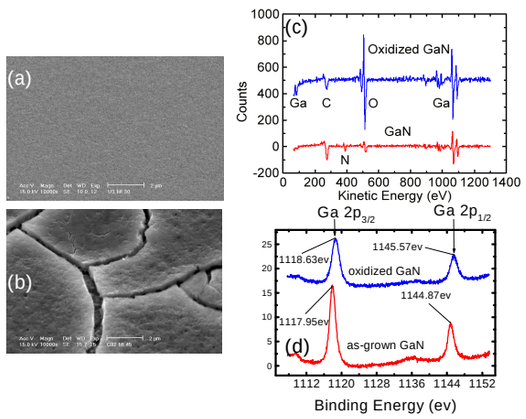

Fig. 2 (a), (b): SEM micrograph, (c) Auger, (d) XPS spectra of PEC-grown Ga_2O_3 on GaN.

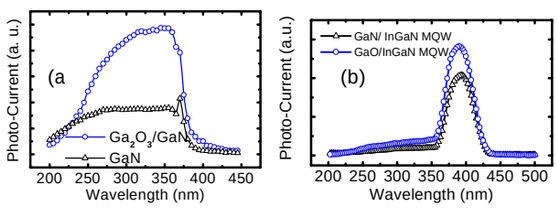

Fig. 3 Oxidation enhanced photo-current response on GaN, and (b) InGaN MQW

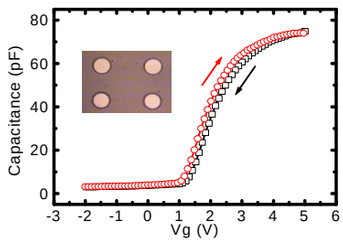

Fig. 4 High frequency (1 MHz) C-V data of Ga_2O_3/GaN