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Structural and Optical Characterization of GaN Porous Structures Formed by Photo-assisted Electrochemical Process

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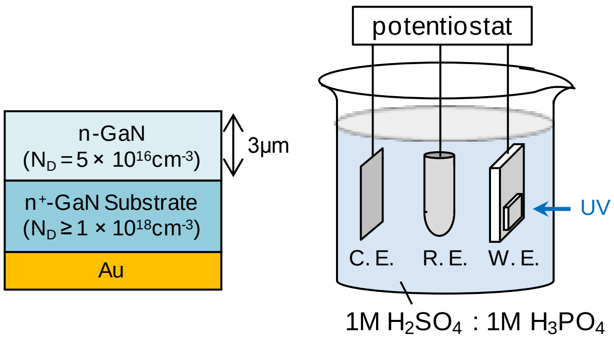
The GaN porous structures were formed by the photo-assisted electrochemical process and their structural and optical properties were investigated in view of the application to optoelectrical devices. The sample structures are schematically shown in **Fig. 1(a)**. n-type GaN epitaxial layers ($N_D = 5 \times 10^{16}$ cm^{-3}) grown on free-standing GaN substrates ($N_D \geqq 1 \times 10^{18}$ cm^{-3}) were used for the porous formation. The Au-ohmic contact was first made on the backside of the GaN substrate to supply the electrochemical current. The electrochemical process was performed using a standard cell with three electrodes in electrolyte which is a mixture of 1M H_2SO_4 and 1M H_3PO_4 as shown in **Fig. 1(b)**. Photo-assisted anodization was carried out during 5 min under UV irradiation.

The porous structures were formed at V_a = 0.5 V (sample A) and at V_a = 1.0 V (sample B), whose SEM images are shown in **Figs. 2 (a) and (b)**, respectively. The arrays of pores were formed on both samples, however, the morphologies are drastically changed with V_a. Pore diameter of sample B is larger than that of sample A. It is also noted that pores of sample B is more uniform and straight in the depth direction, as shown in the cross-sectional images. Such dependence of pore morphology on anodization conditions would be caused by deference in the reaction velocity at the semiconductor surface. In the case that the larger bias was applied, the pore straightly formed along the direction of electric filed which is producing holes required for reaction. This tendency is quite similar to the pore formation on InP [1].

Figure 3 shows the reflectance spectrum of sample A, sample B and planar sample measured as a reference. First, the reflectance of the planar sample was higher than 30 % over the measurement range. Typical peaks were observed around 3.4 eV and 5.0 eV, which were attributed to the interband transitions. The reflectance obtained from sample A was 10–20 % lower than that obtained from the reference sample, as shown in **Fig. 3**. On the other hand, the reflectance of sample B drastically decreased compared with the other two samples. A possible explanation for the low reflectance observed on sample B is that the straight nanopores with enlarged openings appeared on the surface. This kind of air-dielectric composite has a small *n* close to unity leading to the low reflectance on the air interface.

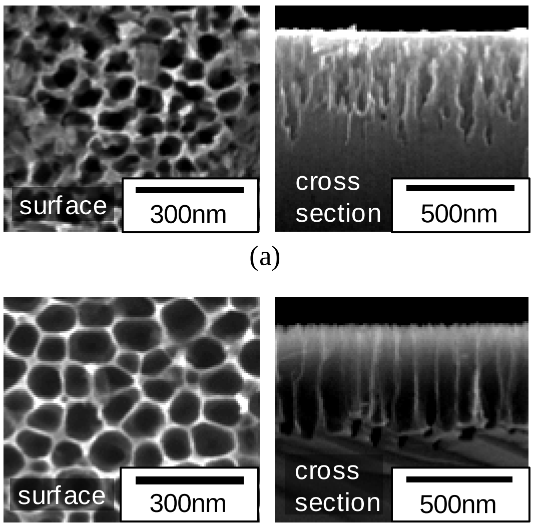
Figure 4 shows the *I-V* characteristics in electrolyte under various UV intensity such as 5, 20 and 40mW. As shown in **Fig. 4**, the cathodic currents changed little as the light power changed. However, the anodic currents increased systematically as the light power increased where the dark current showed good blocking behavior. These results indicate that the basic photovoltaic property of n-type semiconductors remained on the porous GaN electrode. Furthermore, photocurrents of porous sample increased by about 2000 times (at 0 V, 40 mW) as compared to that of planar sample. These results indicate that porous structures are very useful for the photoelectric conversion devices such as solar cells and photo-detectors.

[1] T. Sato et al.: Appl. Surf. Sci. 252 (2006) 5457.



(a) (b)

Fig. 1. Schematic illustration of (a) sample structure, and (b) experimental setup.



(a)

(b)

Fig. 2. SEM images of (a) sample A formed at V_a = 0.5 V, and (b) sample B formed at V_a = 1.0 V.

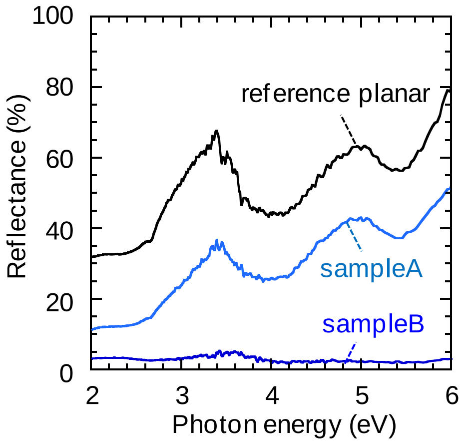


Fig. 3. Reflectance properties of three samples.

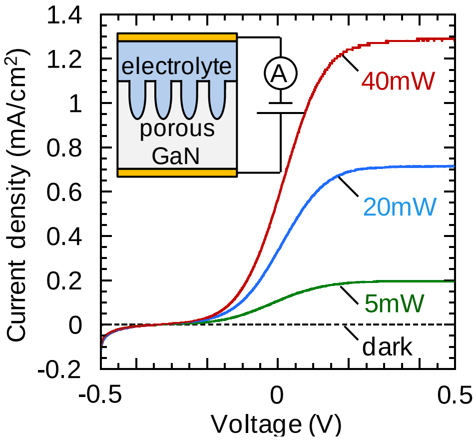


Fig. 4. Photocurrent vs. voltage characteristics measured in the electrolyte.