

Electrochemical Investigation of the Photoelectrochemical Etching of GaN in H₃PO₄

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The rapid development of material and processing technology for nitride-based semiconductor devices in recent years has in some respects outpaced fundamental scientific understanding. Several groups^[1,2] have investigated the use of photo-electrochemical (PEC) etching and measurements of etch rate as a function of electrolyte pH have shown peaks in both the acidic and alkaline etching regimes. This behavior has not been satisfactorily explained. In this paper we present an electrochemical investigation into the PEC etching of n-GaN in H₃PO₄ as a function of pH.

Experiments were carried out on electrodes consisting of a 2 μm n-GaN ($n \sim 3 \times 10^{18} \text{ cm}^{-3}$) epitaxial layer on a sapphire substrate in a standard three-electrode electrochemical cell configuration. The n-GaN working electrode was uniformly illuminated by an expanded 5 mW HeCd laser beam giving an illumination intensity of $\sim 50 \text{ mW cm}^{-2}$. The electrolyte consisted of aqueous H₃PO₄ solutions ranging in concentration from $1 \times 10^{-3} \text{ mol dm}^{-3}$ - 5.0 mol dm^{-3} . Etch depths were measured using AFM and stylus profilometry.

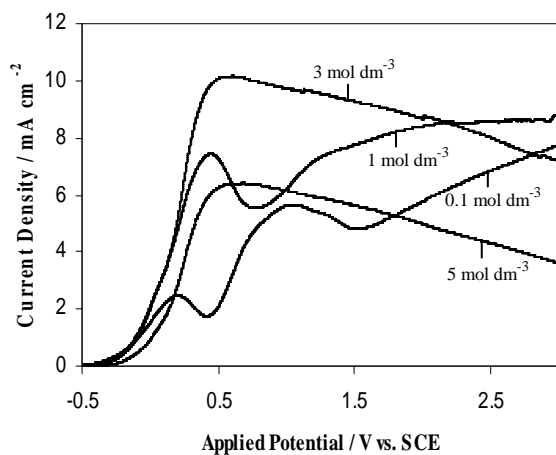


Fig. 1. Linear sweep voltammograms at 10 mV s^{-1} for n-GaN anodized in aqueous H₃PO₄ of various concentrations.

Fig. 1 shows linear sweep voltammograms for n-GaN anodized in aqueous H₃PO₄ of various concentrations ranging from 0.1 mol dm^{-3} - 5.0 mol dm^{-3} . It can be seen that, in all cases, etching occurs at potentials more positive than $\sim -0.4 \text{ V (SCE)}$. Initially the current increases sharply with potential. In the case of both 5 mol dm^{-3} and 3 mol dm^{-3} H₃PO₄, a current maximum is reached followed by a relatively slow decrease at more positive potentials. In the case of 1 mol dm^{-3} and 0.1 mol dm^{-3} H₃PO₄ the current reaches a maximum value and

then decreases relatively sharply. This appears to be a passivation effect due to the formation of a surface oxide in these lower concentration (higher pH) electrolytes. However the oxide is only partially passivating and at higher potentials the current again increases.

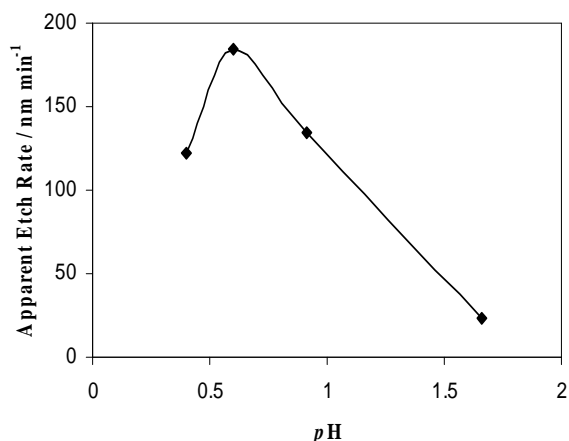


Fig. 2. pH dependence of the apparent PEC etch rate for n-GaN in aqueous H₃PO₄ with an illumination intensity of $\sim 50 \text{ mW cm}^{-2}$.

Apparent etch rates were experimentally obtained by measuring the step height on a partially masked electrode. Fig. 2 shows the results obtained in several concentrations of H₃PO₄ for electrodes that were anodized at potentials corresponding to half the peak current in Fig. 1. The experiments were carried out at constant potential for 100 s in the case of 1, 3 and 5 mol dm^{-3} H₃PO₄ and for 500 s in the case of 0.1 mol dm^{-3} H₃PO₄. A maximum apparent etch rate of $\sim 185 \text{ nm min}^{-1}$ is observed at an electrolyte pH of 0.6. Similar results have been reported by others^[1,2] in experiments in which the potential was not externally controlled. We believe that at lower pH, the etch rate is reduced due to mass transport effects in the higher viscosity H₃PO₄ electrolyte. At higher values of pH we believe that the etch rate is reduced due to the formation of a passivating oxide film.

REFERENCES

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