FEATURES OF REACTIVE ION-BEAM ETCHING OF GaN USING O_2 + Ar WORKING GAS

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Dry etching techniques of GaN are necessary to obtain vertical and smooth sidewall profiles for optoelectronic device applications. A number of methods have been employed in order to solve this problem, including chemically assisted ion beam etching, reactive ion etching and reactive ion-beam etching (RIBE). These methods usually use aggressive halogen-based working gas. The etching rates from 10 to 1000 nm/min were reported. However there are a few studies of the etching-induced degradation of the optical properties of the etching surfaces [1,2]. A RIBE process of the GaN epitaxial layers using O_2 + Ar gas and influence of the etching on luminescence of the GaN layers were investigated. An uniform ion beam was extracted from an ion source with a cold hollow cathode [3]. The ion beam current density was varied from 0.1 to 0.3 mA/cm^2, the ion beam energy was varied from 0.1 to 1.0 keV, the O_2 content was varied from 0 % to 100 %. The substrate temperature during etching was about 50 ^{0}C. Vacuum conditions of 0.4 mTorr working pressure and 5 sccm gas flow rate was employed. The GaN layers were nominally undoped 1.5-3 μm thick epitaxial layers grown in AIXTRON `MOVPE reactors. Photoluminescence experiments were performed at room temperature using N_2-laser radiation and at T=18K using He-Cd laser radiation for excitation.

Anisotropy sidewall and good surface morphology of etching region was achieved. The surface roughness of the GaN layer increases after etching using 90 % Ar + 10 % O_2 (Fig. 1b) and decreases after etching by RIBE using pure O_2 gas (Fig.1c). The photoluminescence (PL) intensity after etching decreases owing to a creation of a near surface damage layer. The PL intensity increases with decreasing the ion beam energy and with increasing the O_2 content which may be attributed to a decrease of the damage layer thickness (according to a simulation by SRIM-99 method). The PL spectra shape of the etching samples is similar to the spectra shape of the as grown samples.

The use of the Ar + O_2 working gas provides higher etching rates than the pure O_2 (Fig.2). The last one should be used as a post-etching stage for the PL efficiency recovery (Fig.3). The RIBE based on the Ar+O_2 gas mixture allows to avoid organic impurities on the layer surface and to refuse the halogen-based gases.

In conclusion, the above mentioned etching process allows to obtain good verticality profile with a satisfactory smoothness and low decrease of PL of etched surface.

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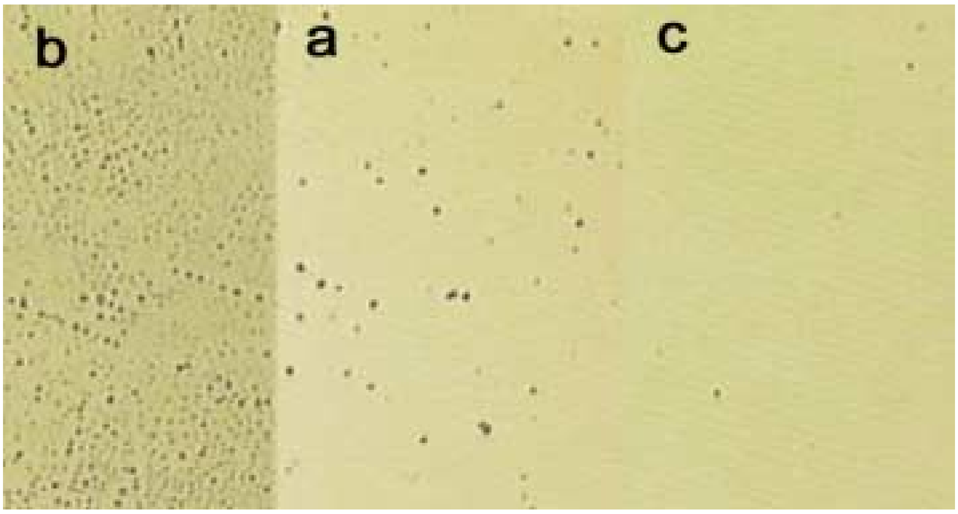

Fig. 1 Micrograph (1000x) of GaN: as grown (a); etched surface using 90 % Ar + 10 % O_2 (b); etched surface using pure O_2 (c) (E = 0.5 keV, J = 0.15 mA/cm^2, t = 30 min).

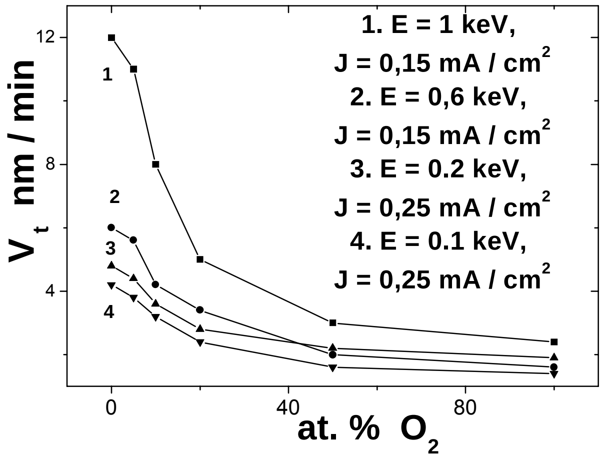

Fig. 2. Etching rate as a function of working gas composition at different ion energies and current densities.

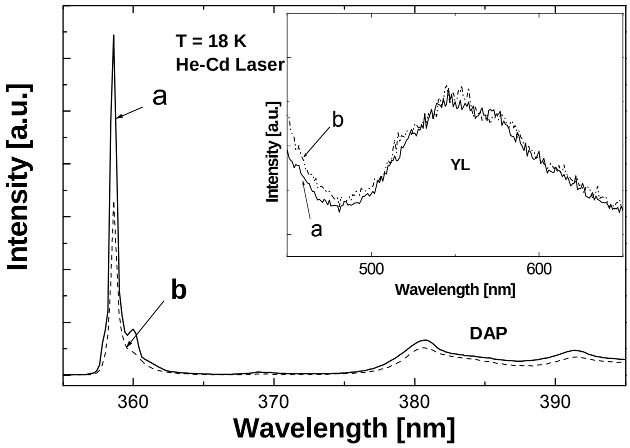

Fig. 3. PL spectra of GaN of as grown (a) and after RIBE by pure O_2 with E = 0.2 keV, J = 0.15 mA/cm^2 (b).

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