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Vertical High Quality Mirrorlike Facet of GaN-Based Device by Reactive Ion Etching

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Abstract

Due to the excellent chemical and thermal stabilities of GaN, wet etching has proven difficult.[1] Wet chemical etching of GaN shows isotropic etching profiles and slower etching rates than the dry etching technique.[2] Therefore, in order to fabricate GaN-based device such as light emitting diodes and laser diodes, the development of GaN dry etching techniques with high etch rates, high selectively over mask materials, highly anisotropic etch profiles, and smooth sidewalls are required.[3-5] The facets of GaN using dry etching techniques requires not only high GaN etch rates and high selectivities over mask layers but also a vertical etch profile with a smooth sidewall because the quality of the etched mirrors is often a limiting factor for the performance of the laser.[6] Consequently, the manufacture of vertical high quality mirrorlike facet in III-V semiconductors is one of the key issues when optoelectronic devices are integrated monolithically. The four primary dry techniques that have been employed to etch GaN are reactive ion etching (RIE), electron cyclotron resonance etching (ECR), magnetron reactive ion etching (MIE), and inductively coupled plasma etching(ICP). Chlorine-based gases such as BCl_3, $SiCl_4$, and Cl_2 were the primary reagents that have been employed to etch the III-Nitrides.[7] Etching rates and surface morphologies are sensitive to process parameters, such as RF power, chamber pressure, and etchants flow rate. In this letter we report the results of RIE etching of GaN using a $BCl_3/Ar/CH_4/N_2$ chemistry to form the vertical high quality mirrorlike facet for fabricating GaN-based device. The ability of BCl_3 was used to reduce the native oxide on compound semiconductors, and the ability of CH_4 to protect the facet against the etching of plasma etchants.

Fig. 1 shows the etching rate as a function of BCl_3/Ar gas composition at a total gas flow rate of 40 sccm with a fixed RF power of 200 W. The GaN samples used in this study were grown on c-face sapphire substrates by metalorganic chemical vapor deposition (MOCVD). For both n- and p-GaN, the etching rate was found to increase with BCl_3 flow rate. The highest etching rate, 505Å/min and 448Å/min, were obtained for n- and P-GaN, respectively. The increase of etching rate with BCl_3 flow rate was attributed to the increase of Cl radicals to act with GaN. Fig. 2 shows SEM micrographs of PECVD-SiO_2 masked GaN etch profiles; the etch anisotropy (a) for $BCl_3/Ar/5sccmCH_4$, and the etch anisotropy (b) for $BCl_3/Ar/30sccmCH_4$. When the CH_4 flow flux was as small as 5sccm, some pillars appear at the bottom due to the CH_4 can protect some sections of GaN from RIE etching. Similarly, When the CH_4 flow flux increase as 30sccm, some small hollows emerge at the bottom due to only small areas was etched and the others will protect by CH_4 .The performance of sidewall in Fig. 2 is not perfect. The SEM micrographs of PECVD-SiO_2 masked GaN etch profiles is showed as Fig. 3, including the etch anisotropy (a) for $BCl_3/Ar/CH_4$, and the etch anisotropy (b) for $BCl_3/Ar/CH_4/10sccmN_2$. When 10sccm N_2 were added in plasma gas, the roughness of GaN in the bottom could become smaller due to the N_2 can inactive the etching ability of BCl_3 against GaN. The SEM micrograph of mirrorlike facet of GaN using $BCl_3/Ar/CH_4/N_2$ by reactive ion etching is showed as Fig. 4. Further studies on etch parameters and on fabrication of device are now under way.

Acknowledgments

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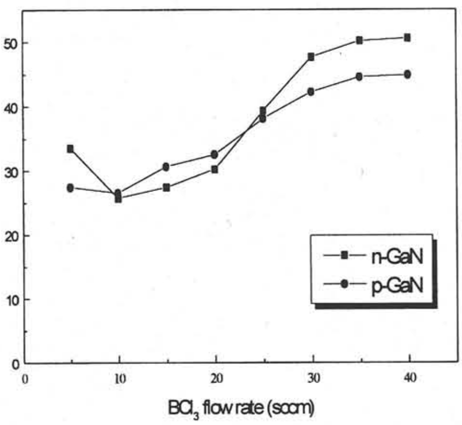
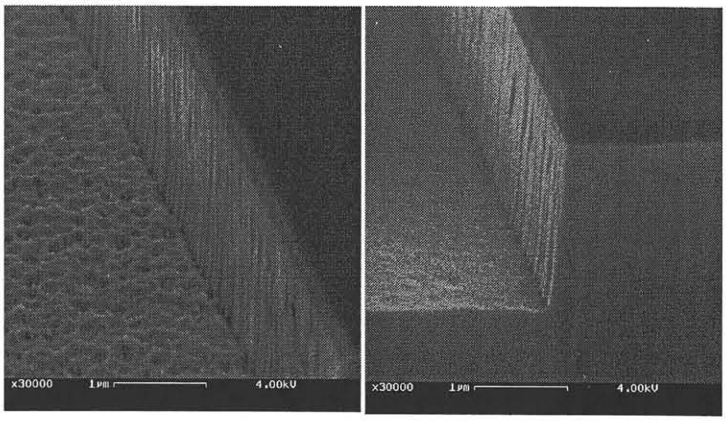
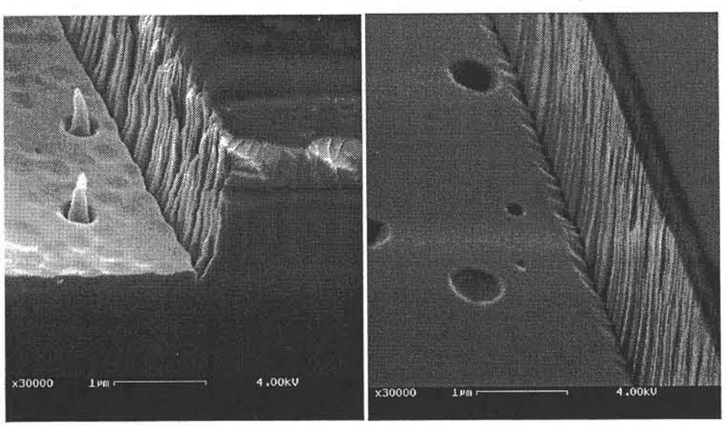


Fig. 1 The etch rate as a function of BCl3/Ar gas composition at a total gas flow rate of 40 sccm with a fixed gas pressure 60 mTorr and a fixed RF power of 200W.



(a) (b)

Fig. 3 SEM micrographs of PECVD-SiO_2 masked GaN etch profiles; the etch anisotropy (a) for $BCl_3/Ar/CH_4$, and the etch anisotropy (b) for $BCl_3/Ar/CH_4/10sccmN_2$ ..



(a) (b)

Fig. 2 SEM micrographs of PECVD-SiO_2 masked GaN etch profiles; the etch anisotropy (a) for $BCl_3/Ar/5sccmCH_4$, and the etch anisotropy (b) for $BCl_3/Ar/30sccmCH_4$.

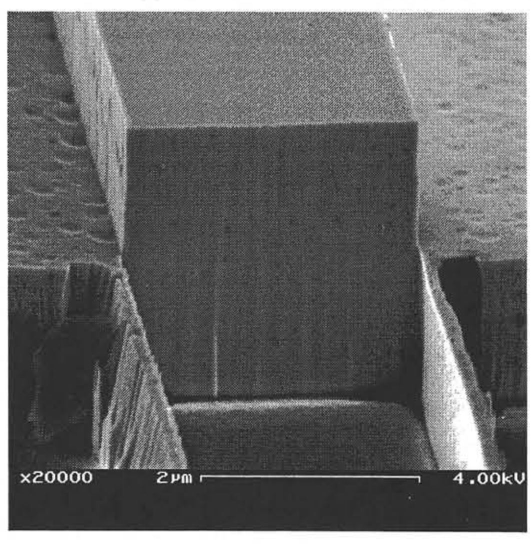


Fig. 4 SEM micrograph of mirrorlike facet of GaN using $BCl_3/Ar/CH_4/N_2$ by reactive ion etching.