Extended Abstracts of the 1998 International Conference on Solid State Devices and Materials, Hiroshima, 1998, pp. 466-467

High Temperature Reactive Ion Etching of GaN and AlGaN Using Cl_2 and CH_4 Plasma

Durga Basak*, Kenji Yamashita, Tomoya Sugahara, Daisuke Nakagawa, Tao Wang*, Katsushi Nishino and Shiro Sakai
*Satellite Venture Business Laboratory
Department of Electrical and Electronic Engineering
The University of Tokushima, 2-1 Minami-josanjima, Tokushima 770-8506, Japan
Phone :+81-886-56-9518, Fax: +81-886-56-9060
E-mail: basak@svbl.tokushima-u.ac.jp

1. Introduction

Reactive ion etching (RIE) is one of the promising techniques for pattern transfer in GaN and its ternary alloys using chlorine [1-3] and hydrogen [4,5] based plasmas. Mainly Cl_2-based plasma is used because group-III chlorides are volatile. Use of CH_4 in the plasma increase the etch rate of III-V nitrides since methyl derivatives are more volatile than that of chlorides. However, methane ratio in the gas mixture has to be controlled optimally to prevent polymerization. High etch rates are reported using $CH_4/Cl_2/H_2/Ar$ gas mixture in ECR-RIE system where high ion density (5×10^{11} cm^{-3}) is achieved at very low pressure (1 mTorr) [6,7]. However, in ordinary RIE system plasma density becomes very low below 1Pa. While high temperature and presence of reactive species in the gas mixture might increase the etch rate at the expense of high plasma density. Another important aspect of etching is in the selectivity which enables fabrication of complicated device structures. In this paper we report the etching characteristics of doped p-GaN and p-AlGaN using $Cl_2/CH_4/Ar$ at high temperature with low ion density and demonstrate high etching selectivity of 2.5 between GaN and AlGaN.

2. Experimental

GaN and $Al_{0.15}Ga_{0.85}N$ layers are grown on sapphire by three layer laminar flow gas injection MOCVD. Samples are patterned by $SiO_2/Cr/Ni$ mask. Etching experiments are carried out in Load-locked ANELVA (L-D201-L) RIE system. Prior to etching, the chamber is pumped to a base pressure of 1×10^{-4} Pa. Etch rates are measured by Dektak profilometer after removing the mask. Etched side wall and surface morphology is checked by Scanning Electron Microscope.

3. Results and Discussion

Figure-1 shows the variation of the etch rate with CH_4 flow. A maximum etch rate of about 220 nm/min and 170 nm/min are obtained for p-GaN

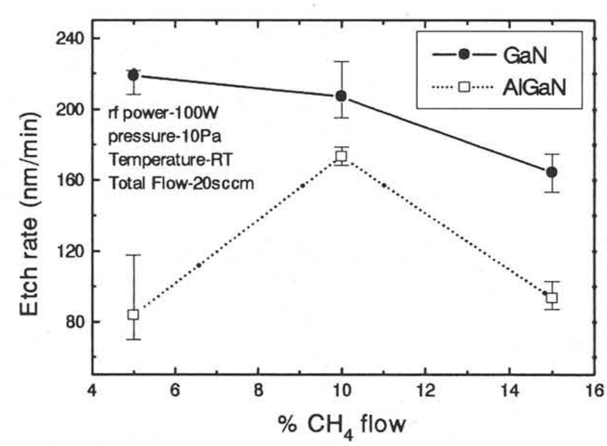

Fig.1 Variation of etch rates of p-GaN and p-AlGaN with CH_4 flow

and p-AlGaN respectively. It shows that with increase in methane flow from 5% to 15%, etch rate decreases for p-GaN and for p-$Al_{0.15}Ga_{0.85}N$, it increases and then decreases. Although methane produces more volatile etch product than chlorides, the decrease in etch rate with increase in methane flow may be attributed to the mechanism which is dominated by a competitive reaction kinetics between Cl_2 and CH_4. Variation of etch rates of p-GaN and p-AlGaN as a function of temperature (Figure-2) shows that etch rates in both cases increase above 100^0C. Considering the highest etch rates and easy removal of volatile etch products at higher temperature, the condition with gas flow $9Cl_2/1CH_4/10Ar$, 100W rf-power, 10Pa pressure and 200^0C cathode temperature is used to etch p-GaN and p-AlGaN to a depth of 1 μm and 0.5μm respectively and the etch rates are found to be 230nm/min and 94nm/min, respectively,

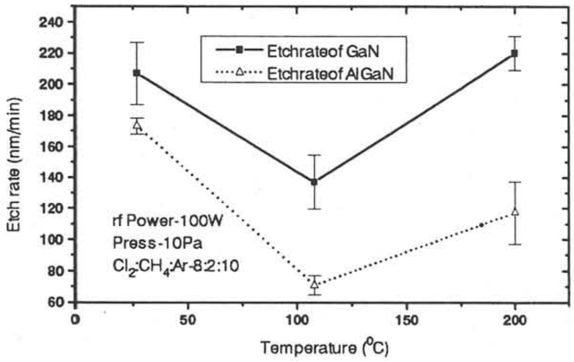

Fig.2 Variation of etch rates of p-GaN and p-AlGaN with temperature

indicating a selectivity of 2.5:1 which is higher than the value 1:1, reported by Humphreys et al. [8]. Figure-3 shows that highly anisotropic process is achieved with almost vertical wall. Vertical

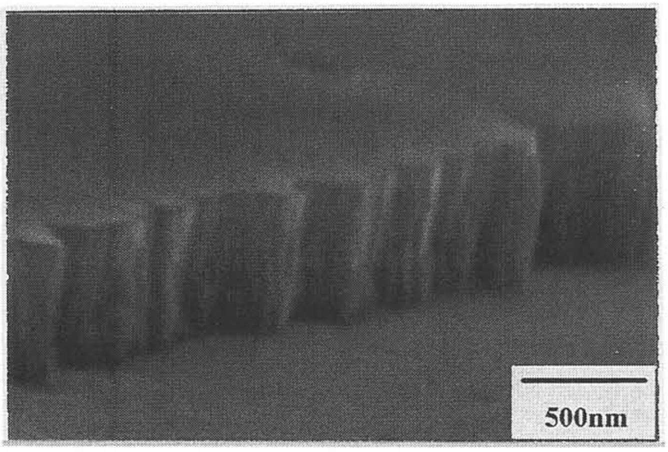

Fig.3 SEM picture of p-GaN etched in $9Cl_2/1CH_4/10Ar$ plasma at 100W rf-power, 10Pa pressure and 200^0C temperature.

striations are observed due to poor masking pattern. Etched surface is smooth with very few etch pits. However, p-AlGaN side wall is rough due to possible redeposition of the polymer etch product. ECR etching of AlN using Cl_2/H_2 plasma at low temperature [9] indicates that high temperature etching of AlGaN may be limited by CH_4 plasma chemistry.

Summary

A very high etch rate, anisotropic etch profile and a selectivity of 2.5:1 have been achieved for p-GaN and p-AlGaN using low density plasma RIE system with $Cl_2/CH_4/Ar$ gas mixture.

Acknowledgements

This work has been supported partly by the Grant-in-Aid from the Ministry of Education, Science, Sports and Culture.

References

1. I. Adesida et al., Appl Phys. Lett., 63, p-2777 (1993)
2. M. E. Lin et al., Appl Phys. Lett., 64, p-887 (1994)
3. S. J. Pearton et al., J. Vac. Sci. Technol.,11, p-1772 (1993)
4. S. J. Pearton et al.,Electron. Lett., 31, p-836 (1995)
5. S. J. Pearton et al., Appl Phys. Lett., 64, p-3643 (1994)
6. S. J. Pearton et al., Appl Phys. Lett., 67, p-2329 (1995)
7. S. J. Pearton et al., Appl Phys. Lett., 66, p-1761 (1995)
8. B. Humphreys et al., MRS Internet J. Nitride Semicon. Res., Vol 1, 28 (1996)
9. S. J. Pearton et al., Appl Phys. Lett., 64, p-2294 (1994)