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Properties of GaN Films Obtained by Nitridation of Porous GaP (001)

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With the help of nitridation of porous GaP (001) in nitrogen plasma thin films of cubic-GaN were obtained. The conclusion was made that the quality of the GaN films is dependent on the degree of porosity of the GaP substrate. XPS spectra were used to investigate the chemical composition of porous GaP substrates, obtained by electrochemical etching. From XPS measurement we determined that the annealing in atomic nitrogen leads to the formation of GaN films. X-ray diffraction measurements show that cubic GaN on porous GaP substrate has no tensile strain

Keywords: Nitridation of Porous GaP, Films of Cubic-GaN, XPS Spectra.

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1. INTRODUCTION

Wide-band-gap semiconductors based on GaN are promising materials for laser diodes (LDs) and light-emitting diodes (LEDs) in the blue and violet regions. GaN usually has a hexagonal structure and high-quality hexagonal GaN (h-GaN) epilayers have been obtained on sapphire (α-Al_2,O_3) substrates using a thin AlN [1] intermediate films or low-temperature-grown GaN buffer layer [2]. However, cubic phase GaN has an advantage over the hexagonal one. Cubic GaN is believed to have higher mobility and show higher activation of acceptors, resulting from its reduced phonon scattering in a higher crystallographic symmetry and smaller effective mass. Moreover, easy cleavage and lack of columnar growth makes it suitable for laser structures. Cubic GaN can be grown on GaP. One of the advantages of GaP substrate over sapphire is that its thermal expansion coefficient is closer to GaN than is that of sapphire.

But the presence of significant lattice mismatch and the difference of thermal expansion coefficient between GaN and GaP leads to numerous defects in the GaN films and stacking faults in epilayers. One of the possible ways to solve this problem is using a "soft" substrate that could take up the elastic strains (appearing in a heterostructures during its formation and subsequent cooling).

With the help of X-ray photoelectron spectroscopy (XPS) the presence of oxides on the surface of porous substrate was determined. We propose removing the oxide layers by annealing of GaP substrate in hydrogen plasma. The morphology of porous substrate was investigated with the help of a scanning electron microscope (SEM).

The properties of GaN films obtained by nitridation of porous substrate were characterised by double-crystal X-ray diffraction analyses and photoluminescence (PL) measurement using a laser (325 nm).

2. EXPERIMENTAL SETUP AND RESULTS

Porous GaP layers where formed by anoding n-type GaP substrates in an HF electrolyte under a constant current density of 400 mA/cm^2. In Fig. 1 the scanning electron microscopy (SEM) image of the surface of porous GaP substrate is presented. X-ray photoelectron spectroscopy (XPS) measurements were used for investigation of chemical compositions.

For the purpose of removing the oxides from the surface an etching process of porous GaP substrate in a flow of pure H_2 at the temperature of 550 °C was used. The etching time was about 15 min.

With the aim of obtaining GaN films, the process of nitridation of porous GaP was carried out in a flow of atomic nitrogen at 400 °C, and subsequent annealing in the vacuum at 600 °C during 30 min. The plasma was generated by applying RF (the frequency was 40 MHz) power to the helical antenna around the chamber. For the prevention of GaN surface damage the ionic components were separated by magnetic fields. The chamber pressure during nitridation was around 10^{-5} Torr. Pure NH_3 was used as a nitrogen source.

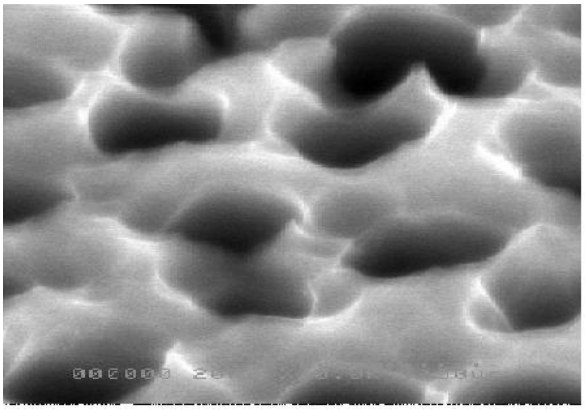

Fig.1 – SEM image of the surface of porous GaP substrate

Thus, the atoms of nitrogen (due to the small covalent radius 0.07 nm) during the nitridation process penetrate into the bulk of GaP and substitute the P atoms. This can be explained by the large difference in binding energy Ga-N and Ga-P, and consequently, P atoms are widely replaced by N atoms on the surface, forming the Ga-N bonds .

The subsequent annealing in vacuum at a temperature of 600°C during 5 min leads to adsorption of P from the surface and re-crystallisation of the disorder of the GaPN phase with formation of GaN.

All of the spectra (room-temperature PL) are normalised by peaks from their band-edge emission. In all the spectra two common peaks are observed: the band edge emission peak and emission in the visible regions. On the samples with a porosity of 25 % two peaks are observed: strong band emission at 361.5 nm and a weak peak in the visible region. The full width at half maximum (FWHM) of the band-edge emission PL spectra has a minimal value for the GaN films obtained on the porous GaP substrates with porosity of 25 %. This allows us to make the assumption that the quality of GaN films is dependent on the morphology of the porous GaP substrates.

The emission in the visible regions is relative to the defects in the interface between the GaN films and porous GaP substrate. From Fig. 2 it is clear that the intensity of PL of GaN films is dependent on the porosity of GaP substrate.

X-ray diffraction measurement shows two peaks, one at 40°, which corresponds to the reflection of (200) plane of cubic GaN, and another peak at 31,7°, that corresponds to the reflection from the porous GaP.

The FWHM value of the X-ray peak and PL spectra shows that high-quality GaN films are obtained on porous GaP substrate with a porosity of 25 %.

3. CONCLUSION

From XPS measurement it was determined that the annealing of porous GaP substrate in atomic nitrogen leads to formation of GaN films. The quality of the GaN films was characterised by PL and X-ray diffraction measurement. So, using porous GaP as a substrate it is possible to obtain a new type of hetero-transition on the basis of materials with a significant difference in lattice constant and a different coefficient of thermal expansion.

REFERENCES

1. H. Amano, I.A. Kasaki, K. Hiramatsu, and N. Sawaki, *Thin Solid Films* **63**, 145 (1989).
2. S. Nakamura, T. Mukai, and M. Senoh, *Appl. Phys. Lett.* **64**, 1687 (1994).