Element Distributions in Aluminum Nitride Thin Films

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The wurtzitic polytype of the semiconductor material aluminum nitride has a wide electronic band gap of 6.2 eV. This makes AlN ideal for high power electronic devices and optoelectronic applications in the ultraviolet spectral region. A high acoustic wave velocity opens the field for the use of AlN as base material in surface acoustic wave filters working in the GHz range. Another advantageous property of AlN is the high wear resistance. This opens the possibility to furnish an aluminum workpiece with a surface layer of better mechanical properties. Here, the pulsed laser deposition (PLD) from a sintered AlN target was applied to deposit thin AlN layers. It is shown how ERDA measurements helped to characterize the ablation target, to reduce the oxygen content and to optimize the process parameters. Secondly, as another possibility to form AlN the nitridation of bulk aluminum by nitrogen plasma immersion ion implantation (PIII) was investigated. The resulting nitrogen depth distributions were evaluated by ERDA and this was the first step to clarify both the diffusion mechanisms of nitrogen in aluminum during the nitridation process and the AlN formation. The ERDA measurements were performed with the position sensitive ionization chamber in the ERDA beam line using 200 or 210 MeV Au ions [1].

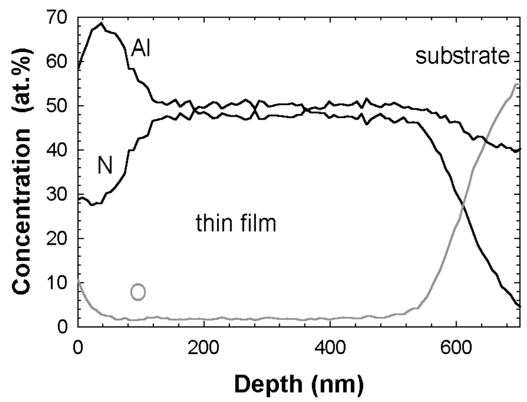

Fig. 1: Concentration depth profiles of an AlN film deposited on sapphire by pulsed laser deposition

1. Pulsed laser deposition

Thin epitaxial aluminum nitride films were grown on c-plane sapphire by pulsed laser deposition [2]. In the first experiment the degradation of the sintered AlN ablation target after continuous laser ablation was investigated by ERDA. For this purpose, the ablation target itself was measured before and after ablation. Additionally, the concentration depth profiles of the deposited AlN films were determined. The results show that an oxygen concentration of up to 4 at.% is present in the target. This is due to the fact that AlN can only be sintered if certain additives like yttrium oxide are used. Moreover, it is observed that the AlN ablation target drastically degrades after a distinct amount of laser pulses in such a way that it is depleted of nitrogen. This can be seen in fig.1 showing the depth profiles of an AlN film where the degradation of the target occurred during the last quarter of the deposition process. The surplus aluminum oxidized due to the high affinity of aluminum to environmental oxygen gas. ERDA measurements were also performed to investigate the influence of the deposition process parameters on the stoichiometry of the AlN films and on the impurity content. The results show that the desired 1:1-stoichiometry is nearly obtained with little surplus aluminum. The lack of nitrogen to fulfill exact stoichiometry is compensated by the existent oxygen impurity which originates from the oxidic additive in the ablation target.

2. Plasma immersion ion implantation

Nitrogen ions were implanted into aluminum at different temperatures ranging from 250 to 485 °C to investigate the nitride formation under diffusional conditions [3]. The implantation acceleration voltage was 30 kV, the incident dose 1.5x1018 atoms/cm^2 and the retained dose was up to 7x1017 atoms/cm^2. To clarify the mechanisms of phase formation a distinct knowledge of the depth distribution of implanted nitrogen as well as of the diffusion of nitrogen was necessary. Additionally, the incorporation and diffusion behavior of contaminating oxygen was of interest.

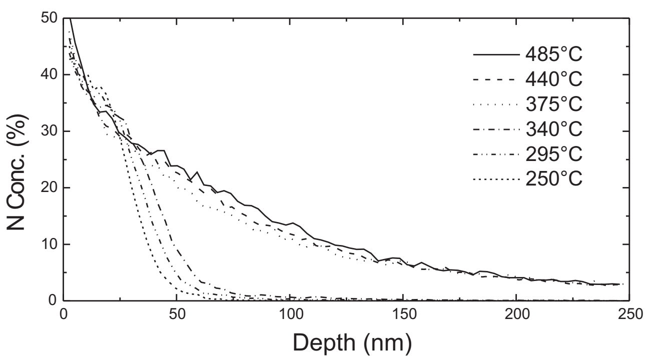

Fig. 2: Nitrogen concentration depth profiles of AlN films formed by plasma immersion ion implantation at different target temperatures

The evaluated nitrogen depth profiles of the implanted aluminum samples exhibit a half-Gaussian shape for temperatures below 340 °C (see fig.2). Above this temperature diffusion of nitrogen takes place resulting in penetration depths of more than 250 nm which exceeds the projected ion range of 40 nm by far. Interestingly, the incorporated oxygen seemed to follow the diffused nitrogen enforcing the demand of reducing the oxygen incorporation during the implantation.

References

[1] W. Assmann *et al.*, Nucl. Instr. and Meth. **B89** (1994) 131
[2] S. Six *et al.*, Thin Solid Films **370** (2000) 1
[3] D. Manova *et al.*, Nucl. Instr. and Meth. **B148** (1999) 851