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# Growth of thick GaN layer on $ZnAl_2O_4$ spinel layer by HVPE

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ABSTRACT

Thick GaN film was grown by hydride vapor phase epitaxy (HVPE) on spinel covered ZnO layer. Single crystal ZnO was grown on *c*-plane sapphire by ultra high vacuum (UHV) DC sputtering. A thin Al layer was thermally deposited on it. A spinel layer was formed by a solid phase reaction of the Al and ZnO layers, and GaN thick film was grown on it. Structural and chemical properties of the spinel layer were studied by X-ray diffraction (XRD) and secondary ion mass spectroscopy (SIMS), respectively. The crystal quality of GaN was observed by atomic force microscope (AFM) and transmission electron microscope (TEM). We found that the spinel layer is helpful for the reduction of zinc and oxygen diffusion into GaN during the HVPE growth.



## 1. Introduction

GaN has become an important material system, with various commercial uses. One of the most important issues in this material system is how to prepare the GaN substrate since its quality is indispensable for the development of high performance optoelectronic devices. Among the various fabrication methods such as liquid phase epitaxy (LPE) [1], ammonothermal [2], and hydride vapor phase epitaxy (HVPE) [3], HVPE might be the best way to obtain cost effective substrates and templates. As is well known, the substrate fabrication process contains two important steps: one is the thick film growth on a substrate and the other is the separation of the thick film from the substrate. There have been a lot of successful results about the former issue, but the latter still has several unsolved problems. In the case of laser lift-off, not only cracks but also residual stress and bending degrade the film quality [4,5]. Other approaches involve complex fabrication processes [6,7]. Hence, a new (simple and easy) way for substrate removal is required. Chemical lift-off might be the best way of obtaining high crystal quality thick GaN layer with minimum damage.

HVPE of GaN on ZnO has been studied for a long time [8,9]. It has a lot of merits in terms of the HVPE growth and separation process. ZnO has the same crystal structure as GaN, and has a small lattice mismatch with GaN, 1.8% in *c*-axis and 0.4% in *a*-axis directions [10,11]. Also, ZnO can be easily etched by chemicals such as HCl, HF, $HNO_3$, and $NH_4Cl$ [12–16]. In spite of these merits, GaN on ZnO still suffers considerable deterioration of crystal quality due to the out-diffusion of both zinc and oxygen during the HVPE growth [16].

In this report, we propose to cover the ZnO layer with a spinel layer to reduce the out-diffusion of ZnO. We have investigated the feasibility of HVPE GaN on ZnO covered with spinel. The results showed that the spinel layer is helpful to reduce the diffusion and to obtain high quality GaN thick film.

## 2. Experimental

The growth of single crystal ZnO was carried out on *c*-plane sapphire by using an ultra high vacuum (UHV: $<1.5\times10^{-9}$ Torr) DC sputtering system. The sputtering condition of the ZnO film was optimized in terms of the structural properties. ZnO was grown at 900 °C with a plasma power of 50 W and a gas flow of 10.5 sccm ($Ar:O_2=10:0.5$). An Al layer (~150 nm) was deposited on the ZnO layer and annealed in air to obtain spinel.

GaN layer was grown by HVPE on the spinel layer. The growth was performed in two steps: a low-temperature (LT) GaN layer (thickness ~2.5 μm) was grown at 850 °C with the V/III ratio of ~50, and a high-temperature (HT) GaN layer (thickness ~40 μm) was grown at 1020 °C with the V/III ratio of ~20. The growth parameters have not been optimized yet. We prepared GaN layers on the ZnO buffer with and without the protection layer simultaneously to compare the effect of the spinel layer. Also, we have prepared two sets of samples. One-set (Set-A) includes the GaN layers grown by two steps (LT and HT GaN layers). The other set

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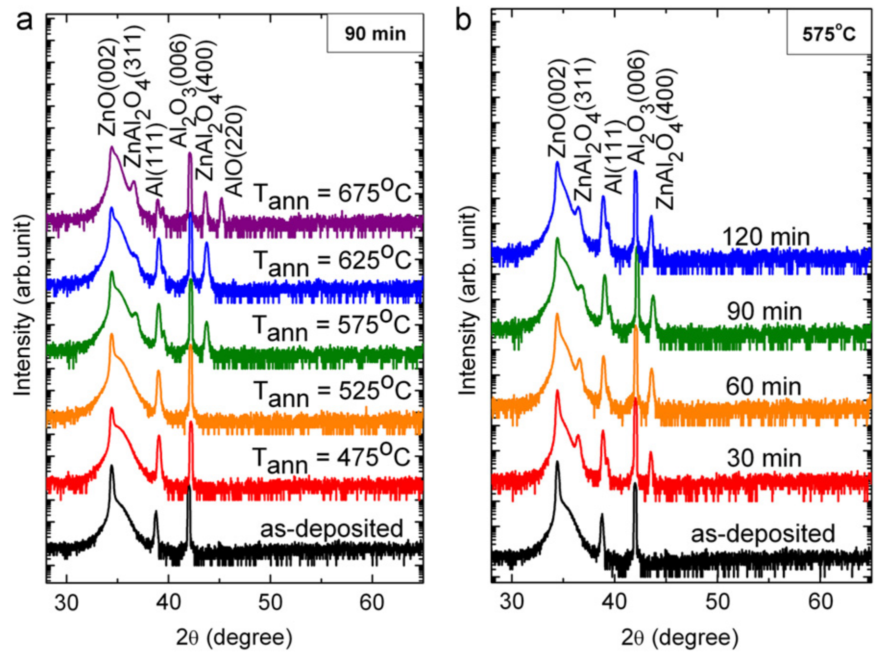


**Fig. 1.** X-ray diffraction of $Al/ZnO/Al_2O_3$ samples annealed at various (a) temperatures and (b) times.

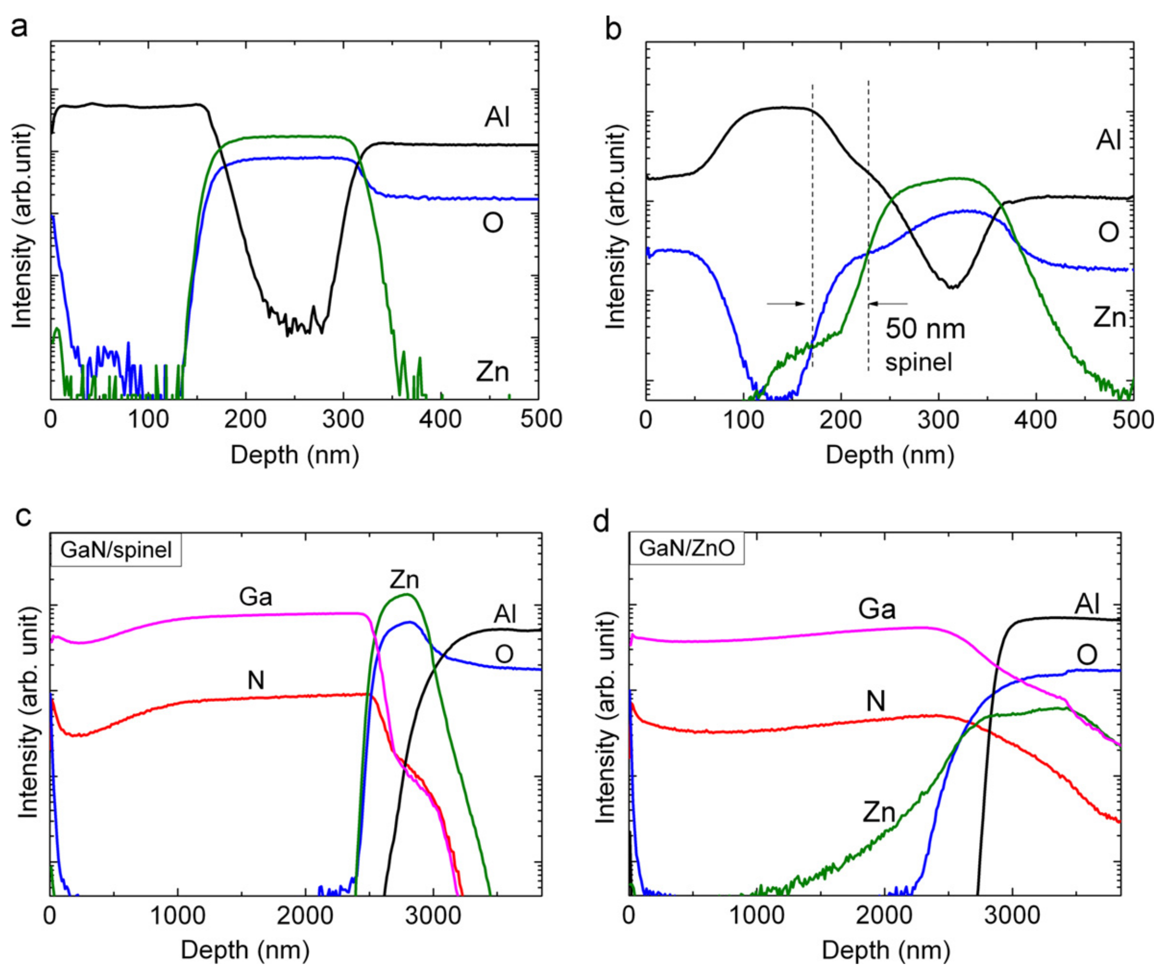


**Fig. 2.** SIMS depth profile of (a) as-deposited ($Al/ZnO/Al_2O_3$), (b) annealed samples, LT-GaN grown on (c) spinel and (d) ZnO.

(Set-B) has only a thin LT GaN layer that was prepared to observe a finger print of the out-diffusion of zinc and oxygen during the initial growth stage.

High-resolution X-ray diffraction (HRXRD) measurements were utilized to evaluate the crystallinity of the films. In this study, (002) and (101) omega scans and (101) pole figure scan