C — 4 — 8* Film Growth of GaN onto c-axis Oriented ZnO Films using R-ICB Technique and its Application to Thin Film Devices

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An attempt to grow good crystalline films of GaN onto a ZnO film preferentially oriented along the c-axis on a glass as a substrate has been made by using the reactive ionized-cluster beam (R-ICB) deposition[1,2,3], which is promising as a technique for growing good quality thin films at relatively low substrate temperatures. The ZnO film serves as an adequate nucleating seed for a growth procedure of GaN film, because the lattice misfit between the both is as low as 0.46%.

In this paper, measurements of X-ray diffraction patterns, optical and electrical properties of grown GaN films are performed, from which their crystallinities are evaluated by comparison with those prepared by the conventional CVD technique.

High purity gallium (99.999% up) is used as a source material, and heated at about 900°C in a crucible with a small nozzle (1 mm ϕ). Ga-clusters are formed by the super condensation phenomena due to the adiabatic expansion of the vapour and are reached with nitrogen flowed through a controlled leak valve into a vacuum chember by ionization of electron bombardment. Pressure in the chamber during deposition was kept to 10^{-4} Torr range.

In Fig.1, X-ray diffraction of ZnO and sapphire substrates as a function of the scanning angles (2θ) are compared with that of GaN. The lattice constant of GaN (a ≃ 3.189 Å) differs considerably from that of sapphire substrate (2.742 Å), which corresponds to the distance between nearest-neighbor bonding atoms on sapphire (0001) plane, and the misfit is about 16.3%.

Figures 2(a) and (b) show the fractured edges of two GaN films deposited on ZnO substrates at different temperatures (a) T_S ≃ 300°C and (b) T_S ≃ 450°C, with keeping constant I_e = 300 mA (cluster ions are contained as much as 30 per cent in total clusters) and V_a = 0 (only ejection velocity of cluster beam). The crystallinity of these GaN films varies from an amorphous structure to a columnar structure with increasing substrate temperatures. The resason why the epitaxial growth of GaN on a Zn film could be achived at substrate temperatures as low as 450°C can be attributed to the presence of ions and the kinetic energies of clusters, besides a small misfit between the lattice constants of GaN

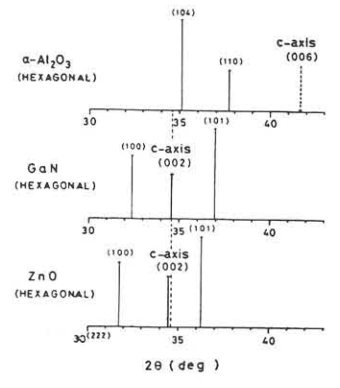

Fig. 1 X-ray diffraction patterns of powdered α - Al_2O_3, GaN and ZnO, indicating the relative lattice misfit among them.

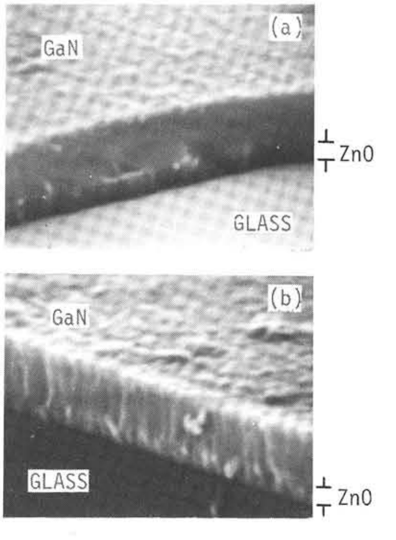

Fig. 2 Fractured edges of two GaN/ZnO films grown at different substrate temperatures: (a) T_S≃ 300°C and (b) T_S≃ 450°C.

and ZnO used as a substrate.

Measurements of optical absorption coefficients of GaN/ZnO films were made in the wavelength region from 0.36μm to 0.74μm using a dual beam spectrometer. Figure 3 shows the result of the optical absorption coefficient (α) of a GaN/ZnO film as a function of incident photon energies ($h\nu$) in comparison with the results of GaN films epitaxially grown on sapphire substrates by rf-sputtering (sample 2)[4] and by CVD with $GaBr_3$ and NH_3 (sample 3)[5] and HCl, NH_3 and H_2 (sample 4)[6]. The fundamental absorption edge of the GaN/ZnO film obtained was found to be about 3.2ev, which is somewhat smaller than those in the GaN/sapphire curves.

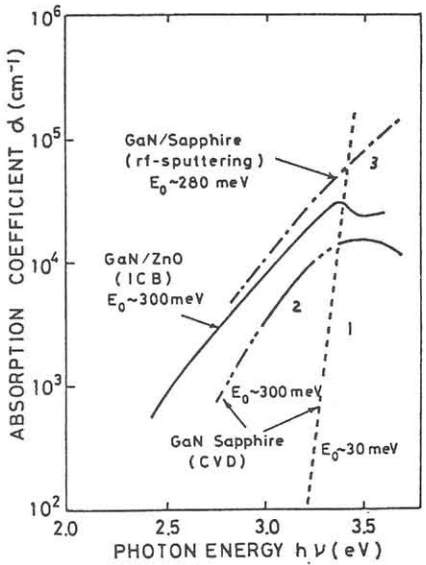

Fig.3 Optical absorption coefficient $\alpha$of grown films as a function of incident photon energies $h\nu$ near the fundermental absorption edge.

The crystallinity of the GaN/ZnO film can be also evaluated from the value of a structural parameter E_0, which is related to crystal imperfections such as defects or impurities. The values of E_0 obtained from the slopes of the curves near the band tail are written in this figure. For the GaN/ZnO film obtained, E_0 was of the order of 280 ∿ 300meV, and was comparable order with the values of epitaxial films except for the sample 4.

With the GaN/ZnO films a possibility of low cost blue light-emitting diodes (LED's) was examined. Figure 4 shows the current-voltage characteristics of three diodes. The current transport mechanism in GaN LED's of the MIS structure was found to be due to the space charge limited current (*SCLC*), in which the relation $I \propto V^2$ is satisfied, rather than the tunneling of electrons through the insulating layer, which obeys the Fowler-Nordheim expession $I \propto V\,exp\,(-b/V^{1/2})$.

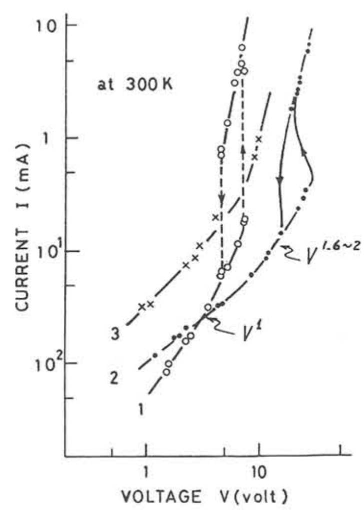

Fig.4 Typical cuurent-voltage characteristics of fabricated MIS structures.

With the fabricated MIS structures, when a voltage as high as 10V was applied between the terminals, whitish-blue light was emitted near the negatively biased ternimal, although the external quantum efficiency is lower than 10^{-5} at the present stage.

In view of the results obtained here, it may be concluded with some degree of confidence that there is a possibility of applications of GaN/ZnO films to various kinds of thin film devices.

1) T.Takagi *et.al.*: Thin Solid Films, 63,41(1979).
2) K.Matsubara *et.al.*: Surf. Sci. 86, 290(1979).
3) T.Takagi *et.al.*: J.Appl.Phys., 51,5419(1980).
4) J.A.Van Vechten: Phys. Rev., 187,1007(1969).
5) Y.Morimoto *et.al.*: Jap.J.Appl.Phys., 12,1820 (1973).
6) J.I.Pankove *et.al.*: J.Appl.Phys., 45,1280 (1974).