Vapor Phase Epitaxy of Cubic Gallium Nitride Using a Single Source

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Epitaxial films of cubic gallium nitride (*c*-GaN) have been deposited on Si(001) substrates (4°-off toward the [110] direction) using the single source diethylazidogallium methylhydrazine adduct [$Et_2(N_3)Ga{\cdot}MeHNNH_2$] by employing cubic silicon carbide (3C-SiC) as a buffer layer. The 3C-SiC buffer layer could be easily deposited on Si(001) using the single source 1,3-disilabutane. The deposition temperatures of the buffer layer and the GaN film were ~950 °C and ~750 °C, respectively. It should also be pointed out that a low temperature (~600 °C) self-buffer of GaN was necessary to avoid mixing of a small amount of the hexagonal phase in the cubic GaN films. All deposition experiments were carried out in an ultrahigh vacuum chamber (base pressure ~1 x 10^{-9} torr) equipped with reflection high energy electron diffraction (RHEED) and a residual gas analyzer (RGA). The films deposited were characterized by RHEED, x-ray photoelectron spectroscopy (XPS), x-ray diffraction (XRD), scanning electron microscopy (SEM), and photoluminescence (PL).

It has been known for some time that cubic silicon carbide can be used as a buffer layer for the deposition of cubic gallium nitride on Si(001) substrates.[1)] The lattice mismatch of *c*-GaN with 3C-SiC is less than 4 %, and this is a good indication that *c*-GaN will grow epitaxially on 3C-SiC. To make the 3C-SiC buffer layer, one either carbonizes the silicon substrate or deposits silicon carbide usually using two compounds as separate sources for silicon and carbon.[2)] In our laboratory, we have successfully deposited 3C-SiC,[3)] 4H-SiC, and 6H-SiC[4)] films on Si, 4H-SiC, and 6H-SiC single crystal substrates, respectively, using the single source 1,3-disilabutane. The use of this compound as a source for SiC films has the effect of lowering the deposition temperature by at least 300 °C. Parallel to this development, we have synthesized a new single precursor for gallium nitride, namely, diethylazidogallium methylhydrazine adduct (Fig. 1). It is a colorless liquid at room temperature and shows reasonable volatility for chemical vapor deposition. This precursor was maintained at 65 °C during the deposition of *c*-GaN.

The RHEED pattern of the 3C-SiC buffer layer (Fig. 2) deposited on Si(001) at 950 °C using 1,3-disilabutane clearly shows that epitaxial growth of the film has taken place on the Si substrate. The 3C-SiC buffer layer was deposited at ~7 x 10^{-7} Torr using the precursor only. On top of this buffer layer, a GaN film was deposited using diethylazidogallium methylhydrazine adduct. The deposition of the GaN film was carried out in two steps. A low temperature (600 °C) self-buffer of *c*-GaN was first deposited on the 3C-SiC buffer layer, and then after raising the substrate temperature up to 750 °C, a thick layer of *c*-GaN was deposited. The pressure during the deposition was 2 x 10^{-6} Torr. This reaction pressure was achieved by introducing hydrogen with the precursor into the deposition chamber, each having the partial pressure of about 1 x 10^{-6} Torr. It was found that adding hydrogen to the deposition process greatly improves the crystallinity of the GaN films. Fig. 3 shows the RHEED pattern of the

final *c*-GaN film. It can be seen that a diffraction pattern for *c*-GaN has clearly developed indicating the formation of the *c*-GaN film on the 3C-SiC buffer layer. The XRD pattern of the film (Fig. 4) shows only the characteristic (002) and (004) peaks of *c*-GaN other than those for the substrate peaks. The peaks corresponding to 3C-SiC were not detectable probably because the buffer layer was very thin. XPS elemental analysis of the film gave the same ratio of Ga:N as a *h*-GaN film deposited on sapphire by the conventional MOCVD method. The surface of the film was examined by SEM, which is shown in Fig. 5. In this figure, intertwined flake-like shapes can be seen but the general structure is similar to those obtained previously by other investigators. Although not shown here, photoluminescence study also yielded a spectrum that is typical of a *c*-GaN film.

The successful epitaxial growth of *c*-GaN on Si(001) suggests the possibility of using Si(001) wafers as substrate instead of sapphire, hopefully leading to large area deposition of GaN.

References

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Figures

Fig. 1. The precursor.

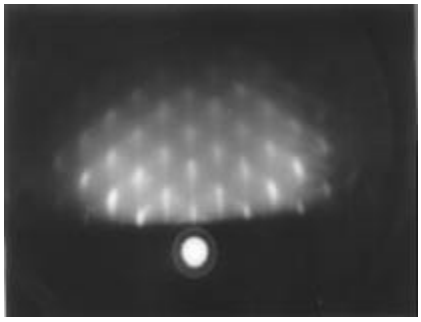

Fig. 2. RHEED pattern of the 3C-SiC buffer.

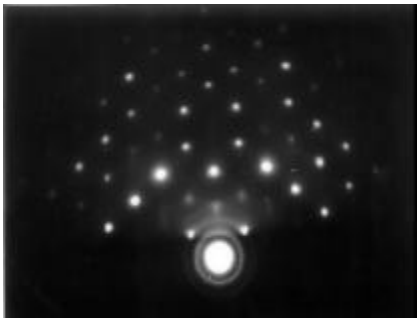

Fig. 3. RHEED pattern of the *c*-GaN film.

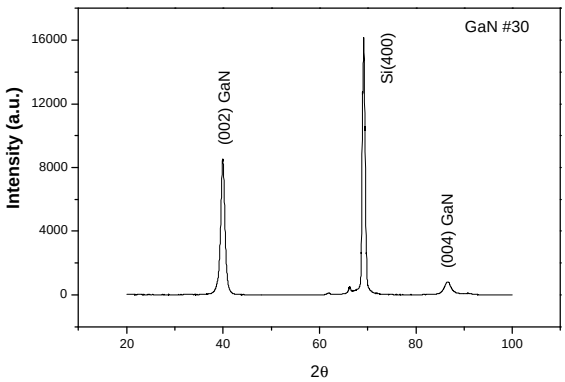

Fig. 4. XRD pattern of the *c*-GaN film.

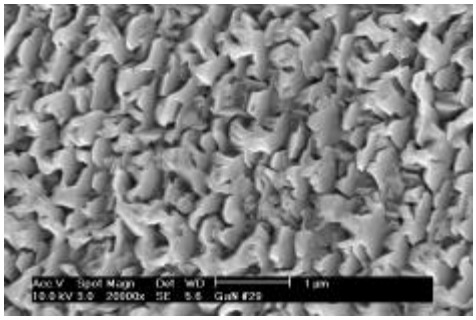

Fig. 5. SEM image of the *c*-GaN film.