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Epitaxial Growth of $Al_xGa_{1-x}N$ by MOVPE

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Wide band gap semiconductor GaN and AlN have attracted much attention as the materials for optical devices in short wave length region. However, very little work on the solid solution $Al_xGa_{1-x}N$ has been reported. This is almost an ideal alloy system because both Ga and Al have nearly the same covalent radius. In this paper, we report the epitaxial films of $Al_xGa_{1-x}N$ grown on sapphire(0001) and Si(111) substrates by MOVPE using TMG, TMA and NH_3 as source materials with an ambient H_2 gas of normal pressure. These organometallic compounds react with NH_3 at room temperature and form complex addition compounds [1],[2], which make this method much complicated. In order to reduce these parasitic reactions, as shown figure 1, organometallic compounds and NH_3 were mixed just before the reactor and were fed through the delivery tube to the substrate with the velocity of the gas stream being 110cm/sec. This enabled us to control the solid composition of $Al_xGa_{1-x}N$ fairly well. Figure 2 shows a plot of the alloy composition x versus X^v ; where X^v=[TMA]/([TMG]+[TMA]) i.e. the ratio of the TMA to total group 111 input. The Al distribution coefficient defined as x/X^v, was found to be near to unity and was insensitive to the substrate temperature and the kinds of substrates

Figure 3 shows the RHEED patterns of $Al_{0.1}Ga_{0.9}N$ grown on (0001)sapphire for the azimuth $[1\bar{2}10]$(fig.3a) and $[10\bar{1}0]$(fig. 3b). The RHEED patterns showed that single crystal films had been obtained with alloy composition $0 \leqq x \leqq 0.4$ at substrate temperature 1020°C on sapphire and 1050°C on Si substrate: the crystals were of wurtzite type as expected and c-axis was aligned normal to the substrate surface.

The lattice constant of $Al_xGa_{1-x}N$ films grown on sapphire, was measured double crystal X-ray diffraction for the (0006) planes. Figure 4 shows the lattice constant C as a function of alloy composition x. From the figure, it is clear that C decreases linearly with the alloy composition satisfying Vegard's law, which holds in many 111-V alloys but contradicts the results for samples prepared by MBE [3]. This contradiction will be considered to be concerned with the difference of the growth method.

In conclusion, epitaxial layers of $Al_xGa_{1-x}N$ were grown on sapphire(0001) and Si(111) substrate by MOVPE. By reducing the parasitic reactions of organometallic compounds with NH_3, the alloy composition of $Al_xGa_{1-x}N$ layers could be controlled fairly well. Single crystal films were obtained up to x=0.4 at substrate temperature 1020°C on sapphire and 1050°C on Si substrate. The change of the lattice constant was proportional to the alloy composition.

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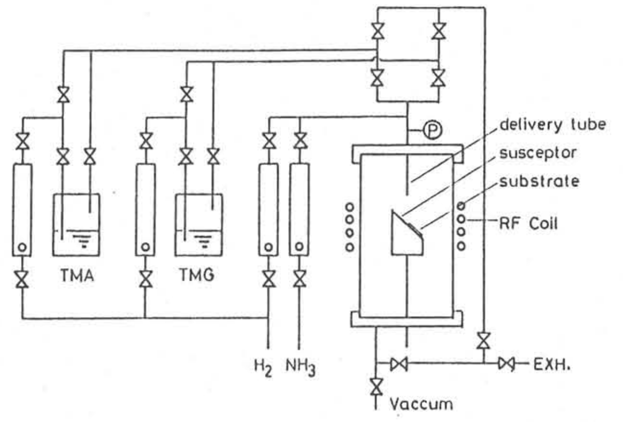

Figure 1 Schematic diagram of growth apparatus.

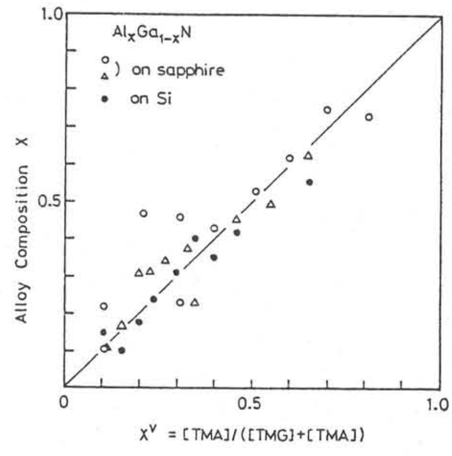

Figure 2 The alloy composition of $Al_xGa_{1-x}N$ layer versus vapor composition X^V, at different temperature. (o:1020°C, ▵:1120°C on sapphire, •: 1050°C on Si)

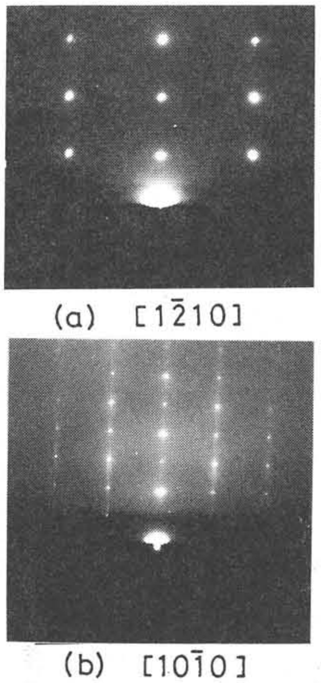

Figure 3 RHEED patterns of $Al_{0.1}Ga_{0.9}N$ film on (0001)sapphire substrate for the azimuth [1$\bar{2}$10](a) and [10$\bar{1}$0](b).

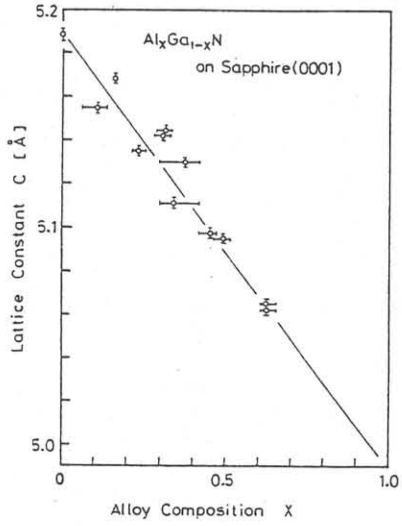

Figure 4 Change of the lattice constant C with the alloy composition x of $Al_xGa_{1-x}N$ films grown on sapphire at 1120°C.