Marked substrate-surface dependence of In content included in high-temperature grown InN

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Indium nitride (InN) and its alloys with GaN or AlN have attracted attention for optoelectronic devices and high-power devices. Because of the low dissociation temperature for InN, growth of InN has not been widely studied compared with GaN or AlN. Understanding of growth behavior of InN, therefore, is essentially desired in order to prepare high quality InGaN or InAlN crystals as well as high quality InN itself. Recently, we found that high-temperature (～600°C) growth brought about enhanced 2-dimensional growth and good electrical property for MOVPE InN [1]. Higher temperature growth, however, newly causes a problem to be solved. This is inclusion of metallic indium into InN grown at about 600°C. Possibility of an appearance of metallic In was anticipated based on the analysis of structural stability for InN by molecular dynamics calculation [2]. Koukitu et.al. reported through the thermodynamic calculation [3] that a lower V/III ratio and a higher H_2 partial pressure are easy to bring about In drop generation during MOVPE growth of InN. In this paper, we report that In content included in high temperature grown InN is markedly dependent on substrate surface before the growth. Especially, it is found that amount of In included in an InN grown on a 1000°C-grown GaN layer is extremely high compared with that grown on a sapphire. This fact clearly states that substrate surface should be taken into consideration in the study of In inclusion in InN.

Using a conventional MOVPE apparatus with a horizontal reactor InN was grown. Trimethylindium (TMI) and ammonia (NH_3) were used as source materials and N_2 as a carrier gas. Growth temperature in the range of 500～650°C was employed. For substrates, α-Al_2O_3 (0001) nitrided in the flowing NH_3 at 900C for 30min, GaAs(111)B(just) and GaAs(111)A(2° off) nitrided in the flowing NH_3 at 650°C for 10min, and GaN layers grown on α-Al_2O_3 at 1000°C or 550°C were used.

X-ray diffraction intensity ratio In(101)/InN(0002) was used as a measure of In content in InN. Figure 1 shows growth temperature dependence of In content in InN grown on a different substrate surface. In the case of InN grown on nitrided α-Al_2O_3 surface, metallic In peak is not found at a temperature less than 550°C. When growth temperature is increased up to 600°C, In with an intensity ratio of a few % appears. Drops of In, however, are not found on the grown InN surface with SEM and AFM observations. In the case of 1000°C-grown GaN surface, on the other hand, metallic In begins to appear from 550°C and In content is higher by 2 or 3 orders of magnitude than that on nitrided α-Al_2O_3 surface. There are many In drops on the grown InN surface. Thus, it is clear that In is easy to be included in InN grown on 1000°C-grown GaN compared with nitrided α-Al_2O_3 surface.

Figure 2 shows substrate surface dependence of In content included in InN grown at 600°C with a different V/III ratio. Even on GaN surface, In content in InN is reduced to a similar level to the nitrided α-Al_2O_3 surface when the GaN is grown at a low temperature about 550°C. In the case of nitrided GaAs(111)A and (111)B surfaces, In content level is also similar to that of 550°C-grown GaN surface. The lowest In level is achieved on the nitrided GaAs(111)A surface. It is pointed out that V/III ratio dependence is hardly observed for the nitrided α-Al_2O_3 surface unlike GaN surfaces.

In summary, we found that substrate surface had a significant role in In inclusion in InN grown at a relatively high temperature (～600°C). Different behavior for In inclusion was found between nitrided α-Al_2O_3 surface and GaN surface. Even for InN on GaN, In content is different depending on GaN formation method and/or conditions. Practically, it was found that the lowest In level was achieved on the nitrided GaAs(111)A surface. The mechanism for the different level of In inclusion is not clear at present. Since In atom mobility on a Ga-terminated surface should be much higher than on a N-terminated or facet surface, In drops should grow much more rapidly on the Ga-face of GaN. Therefore, polarity of substrate surface may

be related to the mechanism for the different level of In inclusion.

REFERENCES

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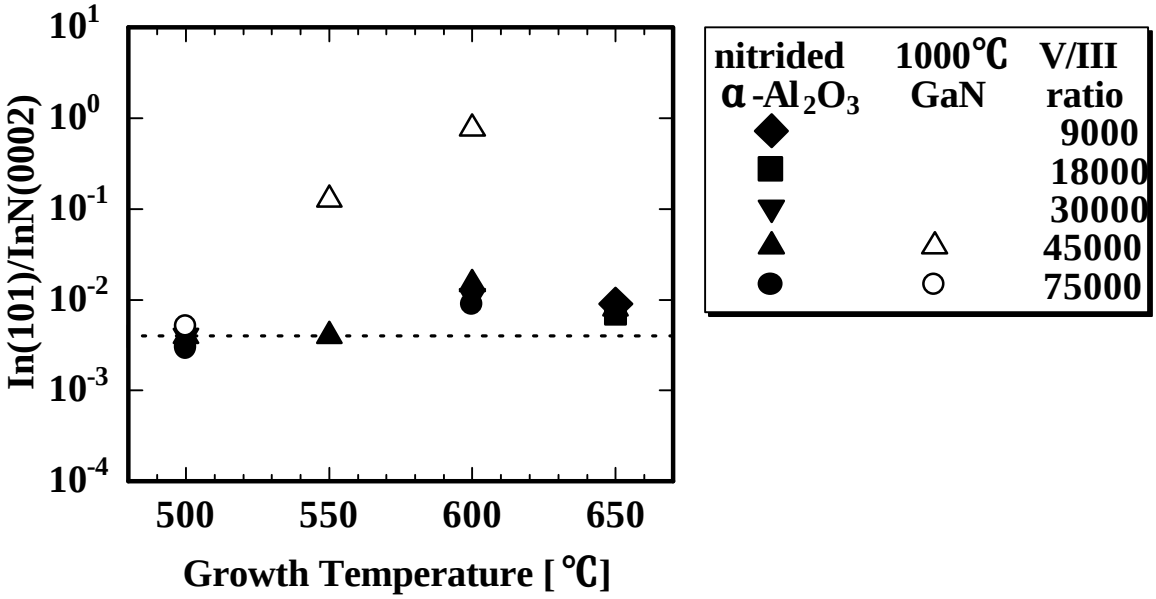

Figure 1. Growth temperature dependence of metallic In content included in InN grown on nitrided sapphire and 1000℃-grown GaN layer. X-ray diffraction intensity ratio In(101)/InN(0002) is used as a measure of In content.

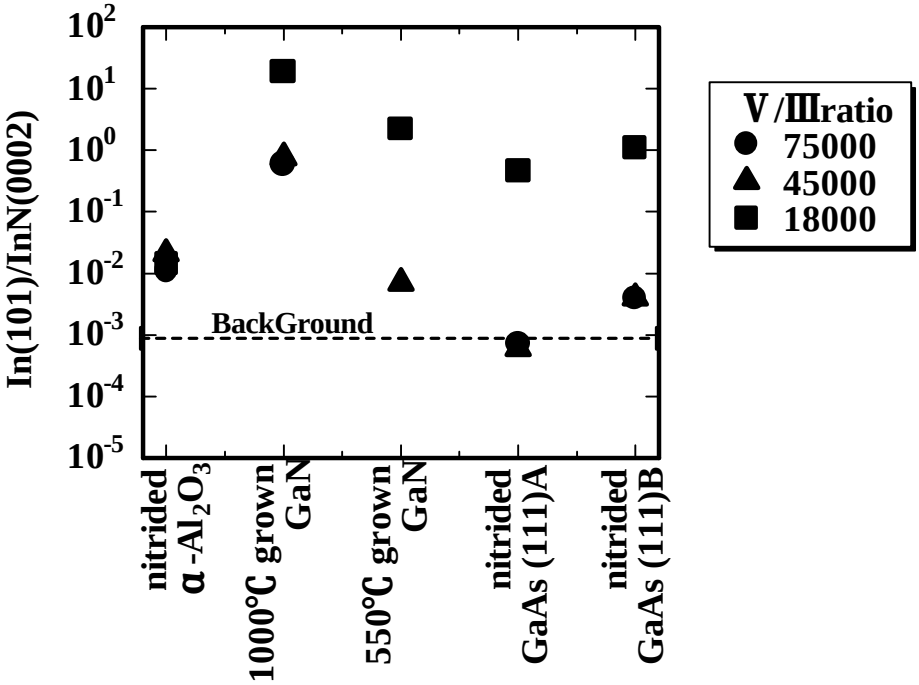

Figure 2. Metallic In content included in InN grown on a different substrate surface with a different V/III ratio.