Role of In on the Formation of Wire Structures on GaNAs Surfaces Grown by MOMBE

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III-V-N alloy semiconductors such as Ga(In)NAs grown on GaAs is promising for the demonstration of improved performances of long-wavelength semiconductor lasers for optical-fiber communications, especially the higher temperature stability with the higher band offsets in the heterostructures based on this materials system[1]. The increase of the N composition in GaNAs makes it possible to have lattice-matching to Si or GaP, which is also another unique feature of this materials system. However the increase of the N composition usually degrades both the surface morphologies and luminescence efficiencies. In this regards, there have been two interesting relevant reports: One is the formation of wire-like surfaces and the related lateral compositional modulation observed in GaNAs films grown by metalorganic molecular-beam epitaxy (MOMBE) [2], the properties of which were dependent on the N compositions. The example of the AFM image of the surface wire structure and the relevant lateral compositional modulation observed by TEM are shown in Figs. 1 and 2, respectively. Another is that the N composition is substantially modulated by the introduction of In, i.e., the decrease[3] or increase [4] of the N compositions. The understanding of these phenomena is important to fully utilize this new III-V-N alloy semiconductors in the higher compositional range of N for the above-mentioned future applications. In this paper, the role of In on the formation of the wire structures on GaNAs surfaces is studied and the main findings are summarized as follows: The N composition increases with the In supply, but the surface roughness is reduced in spite of the increase of the N composition. This apparent In surfactant effect reported also in the growth of GaN [5] will be discussed in detail.

The GaNAs samples were grown on (001) GaAs substrates with MOMBE at the growth temperature of 600°C. The source precursors used are TEGa (7×10^{-4} Torr), TDMAAs (1×10^{-3} Torr), MMHy (5×10^{-3} Torr), and TEIn ($0.5 \sim 1.8 \times 10^{-4}$ Torr), and they were supplied without thermal cracking. The typical growth rate of GaNAs is ~1μm/h. For the purpose of studying the growth kinematic effect of In on the growth surfaces, TEIn was supplied just during the growth interruptions. The growth sequence to study the In effect is as follows: growth of GaAs buffer [1min]→growth of GaNAs [10min]→TEIn supply[5~15s] →growth of GaNAs[10min]. In this growth sequence, it was confirmed that the incorporation of In in the film grown at 600°C is negligibly small [4]. The N composition was measured with X-ray diffraction measurements [6].

Firstly, TEIn beam pressure was fixed to 7×10^{-5}Torr and the period of the TEIn supply was changed from 5s to 15s. Figure 3 shows the AFM images of the GaNAs surfaces grown with the different TEIn supply periods. The reduced intervals of the surface wires will be evident for the longer TEIn supply. The N composition is increased but the RMS value of the surface roughness was reduced for the longer TEIn purge time as shown in Fig. 4. The same tendency was observed for the increase of the TEIn supply with the duration of the TEIn purge fixed to 10s. As shown in Fig. 5, the N composition was increased but the surface roughness RMS value was reduced for the increased TEIn supply.

The main role of the In purge will be attributed to the increase of the N composition. In this respect, the In effect shows the tendency similar to the previous study on the N composition dependence of the surface wire structures [2], where the (11n)A facets were changed with the N composition but the height of the wire or the surface RMS value was not much dependent on the N composition. The last point, however, is different in the present case and the surface RMS value was drasticaly reduced with the TEIn purge. The more details will be discussed during the conference.

References

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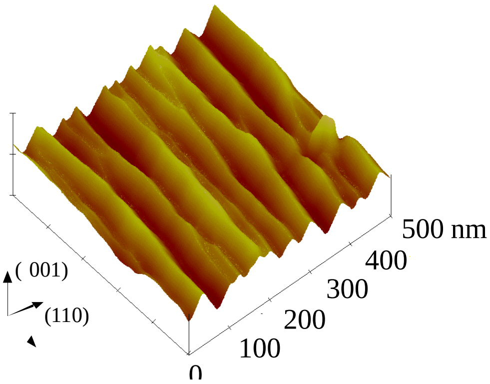


Fig. 1. Surface wire structures of GaNAs facetted with (113)A crystal plane (N=3.1%).

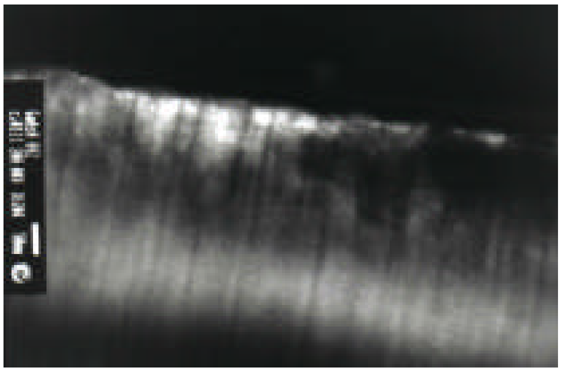
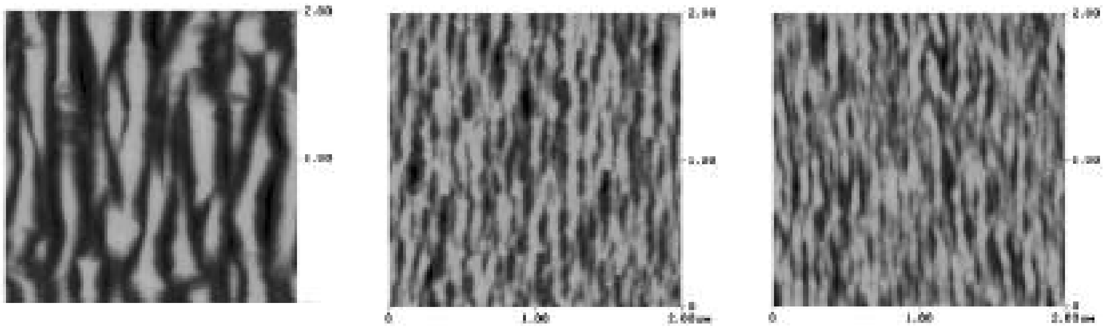


Fig. 2. TEM cross sectional viewof GaNAs (N=2.8%) in the <-110> direction. The dark stripes are the region with less N composition.



(a) N=1.1%, RMS=42nm (b) N=1.2%, RMS=8.8nm (c) N=2.8%, RMS=9.7nm

Fig. 3. AFM images of GaNAs with the TEIn purging time of (a) 5s, (b) 10 s, and (c) 15 s.

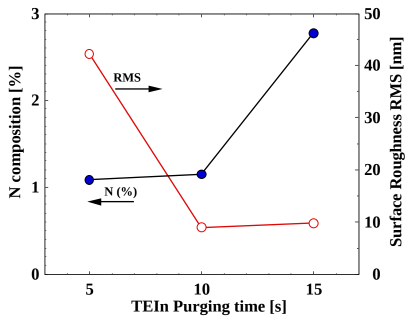


Fig. 4. TEIn purging time dependence of the N composition and the surface roughness RMS.

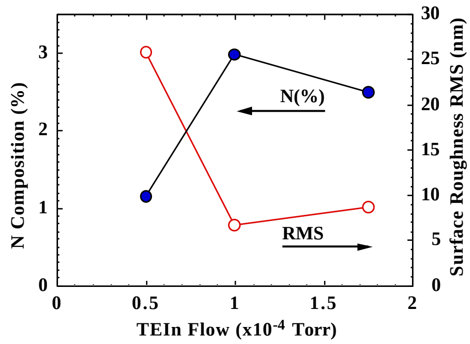


Fig. 5. TEIn flow rate dependence of the N composition and the surface roughness RMS.