Morphology Dependent Growth Kinetics of Ga-polar GaN(0001)

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Striking morphology dependencies are observed in the growth of GaN on Ga-polar GaN(0001) surfaces that depend sensitively on growth conditions and surface termination. In particular the growth rate depends on morphology, decreasing as the surface smoothens. Under some conditions pits can be formed or overgrown. In these experiments the growth was by molecular beam epitaxy used Ga and NH_3 sources. The morphology of the films was characterized by atomic force microscopy (AFM)and reflection high-energy electron diffraction (RHEED); growth and decomposition rates were determined using desorption mass spectroscopy (DMS).

MOCVD GaN templates, grown on low temperature GaN buffers, were used as the starting substrates. These surfaces were atomically smooth, exhibiting atomic steps and large terraces as shown in Fig. 1. After degreasing and outgassing at 500°C, they were annealed in NH_3 at a background pressure of of 1×10^{-7} Torr at 785°C for 1 min. Then a Ga flux was introduced and the growth rate measured as a function of time using DMS. Growth conditions were established that were excess Ga. Growth was performed between 730 and 780°C at several NH_3 fluxes.

Approximately 100 Å of GaN was grown by ammonia MBE at 780°C on the initial surface of Fig. 1 under a III/V ratio of about 2:1. The growth rate was observed to decrease by about 50% over the several minutes required for this short deposition. Then they were quenched at about 200°/min in a low NH_3 background of 1×10^{-7} to 1×10^{-8} Torr. The AFM of the resulting surface, shown in Fig. 2, shows steps that are no longer straight and pits at a density of about 1×10^{10} cm^{-2}. The pits are observed both at step edges and on terraces. The absence of pits on the starting sur-

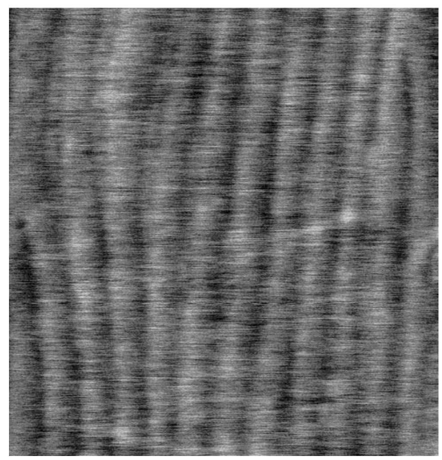

Fig. 1: AFM image showing a 2μm scan of the starting MOCVD GaN(0001) template. The steps are quite straight without evidence of pit defects or significant pinning.

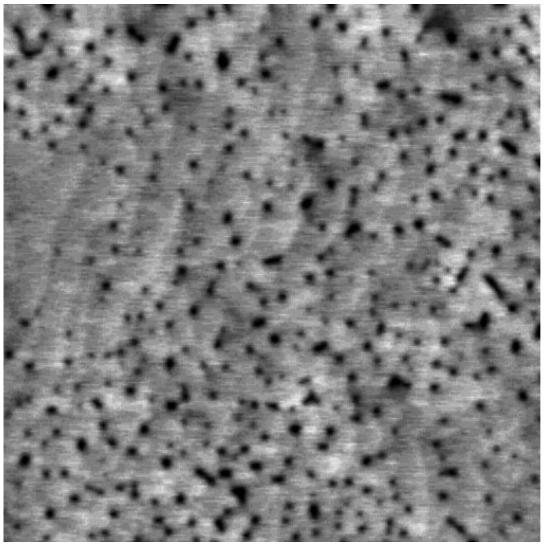

Fig. 2: A 2 μm AFM scan of a surface on which a thin 100 Å film was grown by MBE under excess Ga conditions at 735°C.

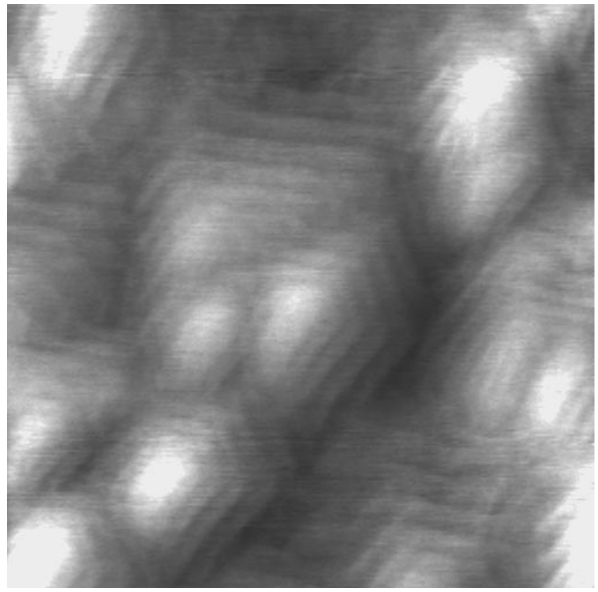

Fig. 3: A 2 μm AFM image of the hillocks grown on the surface of Fig. 2 after 300 Å of growth. The hillock density is about 20 times less than the pit density.

face and the small amount of growth suggests that their appearance results from NH_3 etching. This is consistent with RHEED examination of other surfaces, in which the diffraction changes from a smooth c(2×2) to a rough surface, after only about 5 min of annealing in NH_3. At the temperature and conditions of this growth, no hillocks are observed. The distribution of pit diameters for this sample was a gaussian with a mean of 300 Å and a standard deviation of 150 Å. This suggests that only one type of defect is exposed by the etching.

On the surface of Fig. 2, a 300 Å film of GaN was then deposited at 730°C under a III/V ratio of 2:1. This sample was then quenched, but after first reducing the NH_3 flux. The resulting AFM image of the surface, shown in Fig. 3, shows a surface covered with hexagonal hillocks without pits. The rms roughness is 0.65 nm. The density of hillocks is about 5% of the pit density, suggesting that the sources are of unequal activity. The size of the hillocks depends on the growth fluxes — a III/V ratio of about 1:1 produces a higher density of hillocks and an approximately 50% reduction in hillock diameter. This flux dependence is in contrast to a previous report[1].

For all of the films examined there was a significant reduction in growth rate with time, as the films smoothened. The rates were about a factor of 2 higher than on N-polar GaN$(000\bar{1})$ films. The latter also exhibit a much higher hillock density.

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[1]B. Heying, E.J. Tarsa, C.R. Elsass, P. Fini, S.P. DenBaars, and J.S. Speck, J. Appl. Phys., **85**, 6470 (1999).