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Initial Growth Prismatic Domains in Cyclotron Assisted MBE of GaN/SiC

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Abstract

In N-rich growth conditions, prismatic domains were formed in the initial stage of a cyclotron assisted MBE of GaN over 6H-SiC (0001). They exhibit {10$\bar{1}$ 0} facets and are either voids or amorphous phase. Their density is of a few 10^9 cm^{-2} and they are located in a 50 nm layer closest to the substrate surface.

1. Introduction

A great interest is given to III-nitride materials since few years for their optoelectronic potential [1].

Progress have been made on growth process and monocrystalline films deposited by MBE or MOVPE are now available on a variety of substrates. However, a high density of growth defects are still present in the films. They are mainly threading dislocations and planar defects. Dislocations are reported to have **a**, **c**, or **a** + **c** Burgers vector [2] [3] and to form low angle grain boundaries which result from the coalescence of islands [2].

Different kinds of planar defects have also been reported: stacking faults [4] parallel to the film/substrate interface, and planar faults perpendicular to the interface. Some of them have been identified as Double Positioning Boundaries (DPBs) by Smith et al. [5] in GaN layers grown on SiC by ECR-MBE, and later named Stacking Mismatch Boundaries (SMBs) by the same authors [6]. According to Tanaka et al. [7], such defects were reported to be generated by interface steps which disrupt the 2D growth mode of AlN on SiC. Similar defects in AlN grown on SiC have also been identified as prismatic stacking faults for which an atomic model was given [8] [9]. Such defects are also presumed to limit inversion domains [10]. Recently, a third kind of defects named nanopipes has been observed in GaN grown on sapphire by OMVPE [11], and they have been characterized as open core screw dislocations [12].

In the present paper, new defects observed in a GaN film grown under N-rich conditions are analyzed.

2. Experimental details

SiC-6H wafers are cut 3.5° off the basal plane towards <11$\bar{2}$ 0>. The $(0001)_{Si}$ surface is treated using the classical way followed by a hydrogen plasma step in order to reduce the amount of oxygen-carbon bonds below the X-ray photoemission limit. The details of this procedure were reported by Lin et al. [13]. Growth of the GaN layers was performed by an Electron Cyclotron Resonance plasma enhanced Molecular Beam Epitaxy, at a rate of 40 nm /h with a substrate temperature of 750 °C and a microwave power of 180 W. A nitrogen flow of 17 standard cubic centimeters per minute is used. The obtained layers are monocrystalline and have the hexagonal wurtzite structure.

Transmission Electron Microscopy (TEM) cross section and planar view samples were thinned down to 100 μm by mechanical grinding and dimpled down to 10 μm. Electron transparency was achieved by ion milling with a LN_2 cold stage at 5 kV. A final stage at 3 kV was used to remove possible ion damage. In the case of planar view samples, dimpling and ion thinning were performed only from the substrate side. HREM observations were made along the $<11\bar{2}0>$ and <0001> directions in a Topcon 002B electron microscope operating at 200 kV with a point to point resolution of 0.18 nm (Cs=0.4 mm).

3. Results

A series of different samples were prepared with similar growth conditions. However, for one of them (A1205), a lower temperature of the Ga cell were used (895° instead of 925°C normally used) leading to a lower Ga flux. Thus, more N-rich growth conditions were reached for this specific deposited layer.

Each sample has been observed by cross section transmission electron microscopy . In all of them, threading dislocations and stacking faults are observed. However, only for the A1205 sample, when the GaN/SiC interface is observed by using $g = 0002$ or $11\bar{2}0$, and slightly under focused, numerous domains appear underlined in the image (Figure 1). They extend along the growth direction but none was observed to reach the film surface. The large majority of them starts from the interface. Their size ranges from a few to 250 nm height with a width of 10 to 20 nm.

Two shapes are mainly encountered. For some, the width is constant (Figure 2a), whereas for others, it increases at the top and decreases close to the interface, giving rise to a "nail-like" shape (Figure 2b). The surfaces limiting the domain seem to be observed edge on, along the planes. In some areas, the HREM image pattern is unchanged when the domain boundary is crossed (Figure 3). Only an abrupt variation of the spot intensity is observed.

Planar view observations (Figure 4) reveal that such domains have actually facets and are either voids or amorphous material. Since the amorphous phase may come from the ion thinning stage, no conclusion can be drawn. A Burgers circuit drawn around the defect presents a closure failure which corresponds to an a component dislocation (Figure 4). This dislocation character is observed in approximately one case over two.

A bright field planar view image of the GaN/SiC interface is shown Figure 5. The reflection used is $g = 11\bar{2}0$, and the observed moiré fringes result from the lattice mismatch between GaN and SiC, and density of the domains is about 10^9 cm^{-2}. In addition to the domains, numerous planar defects, which links them one to another, are visible. Their structure has been determined and published elsewhere [14].

4. Discussion and conclusion

Nanopipes with facets have been already reported by Qian et al. [11] and later identified as open core screw dislocations by the same authors [12]. They result from a spiral growth mode and are observed to reach the layer surface. The domains observed in the present study do not correspond to such defects, since they are buried inside the layer close to the interface with the substrate. In addition, they frequently present an a component dislocation character which is not observed for nanopipes.

Such domains may result from an uncompleted coalescence of the islands which have facets. This growth mode is probably related to the N-rich condition at the beginning of the deposition process which may have modified the growth rates in the different directions.

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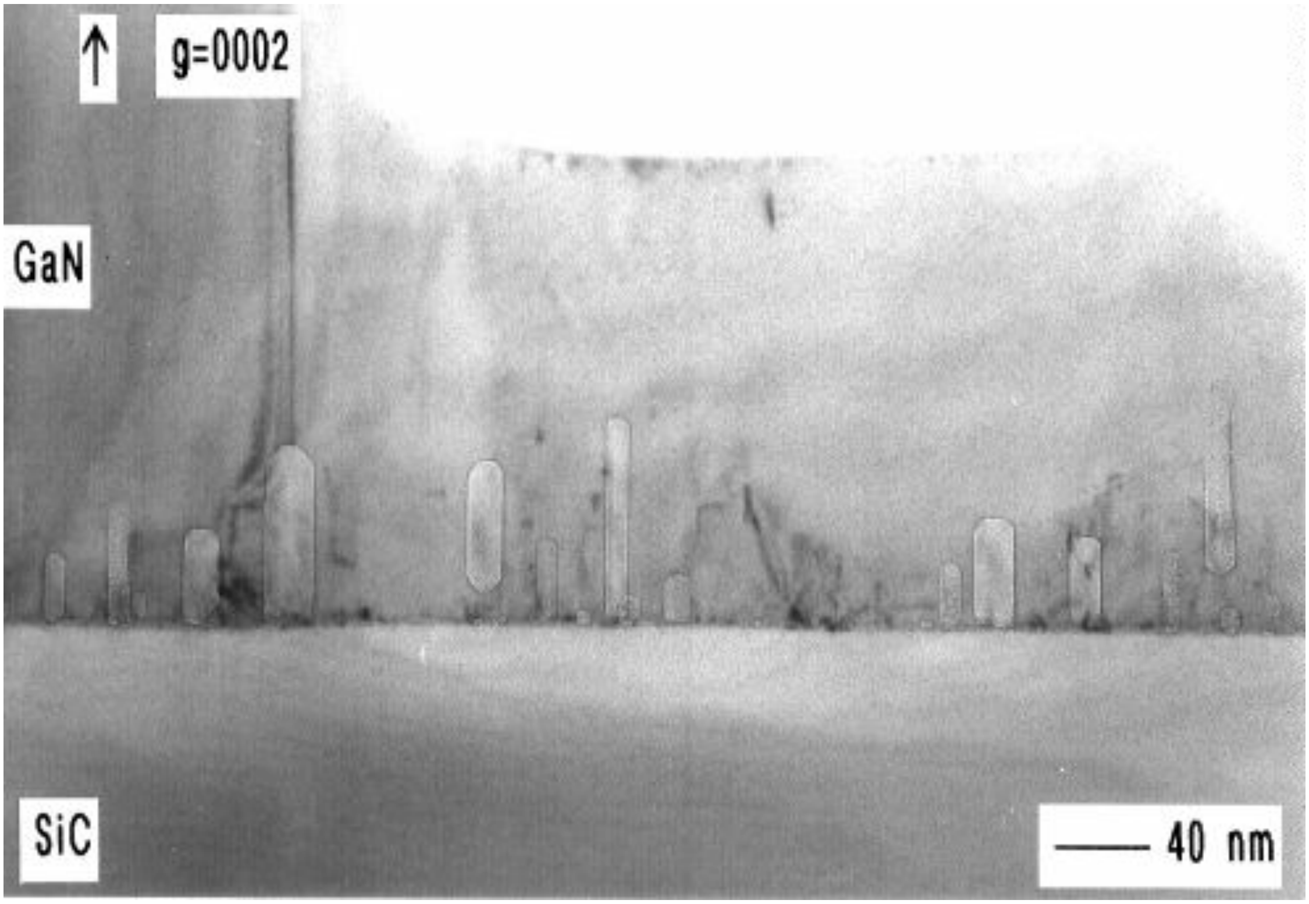

Figure 1. Bright field cross section image of the GaN/SiC interface showing domains elongated along the growth direction.

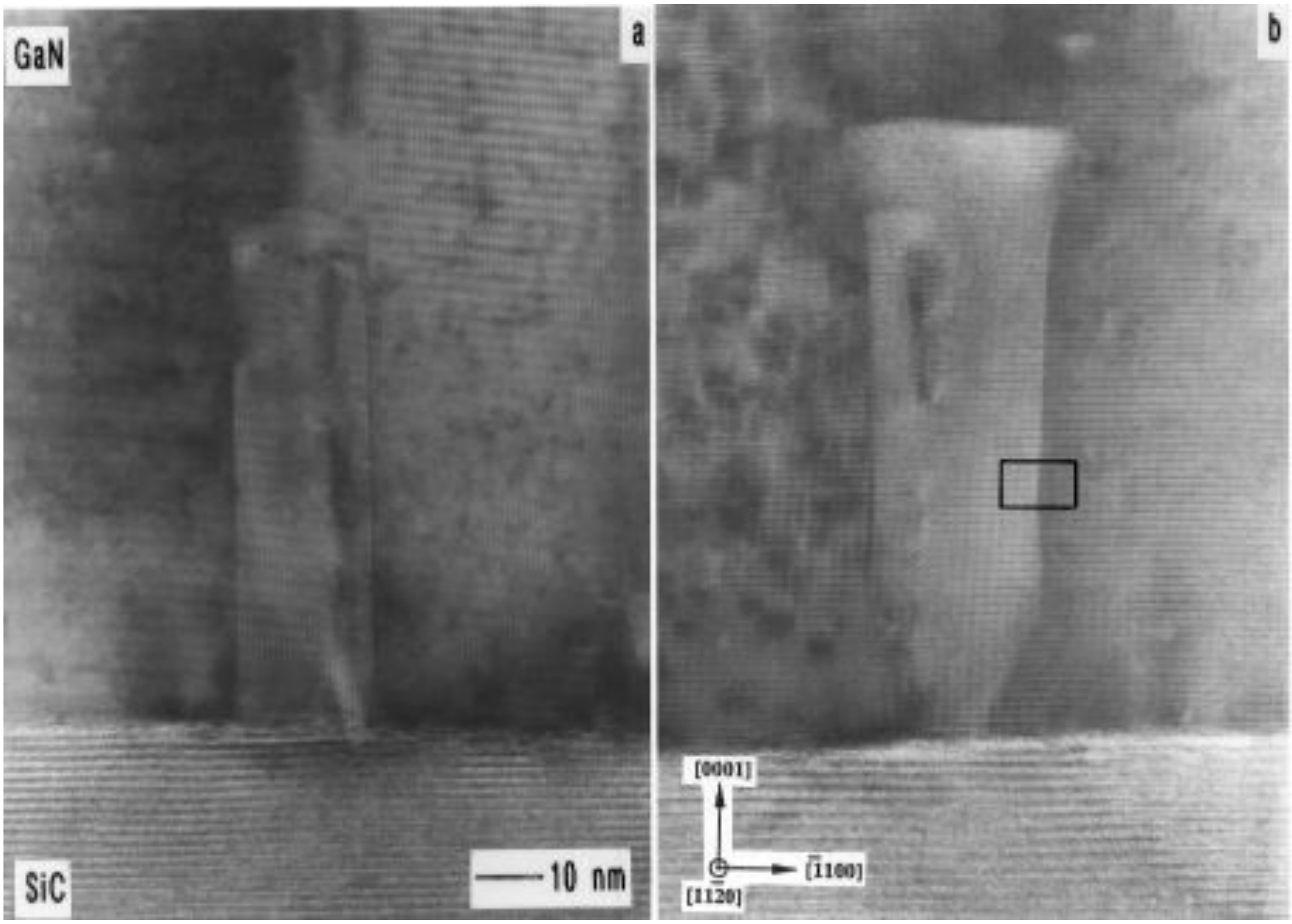

Figure 2. HREM image of two typical domain shapes: a) prismatic, b) "nail-like " .

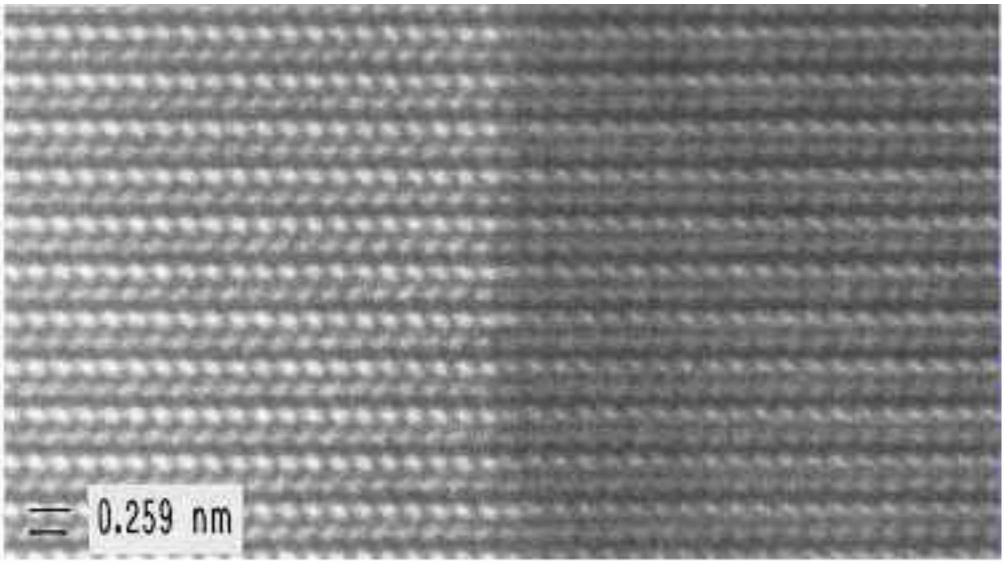

fig.3

Figure 3. Detail of the HREM image contrast of a domain boundary (inset Figure 2b). The pattern is unchanged whereas the intensity increases abruptly.

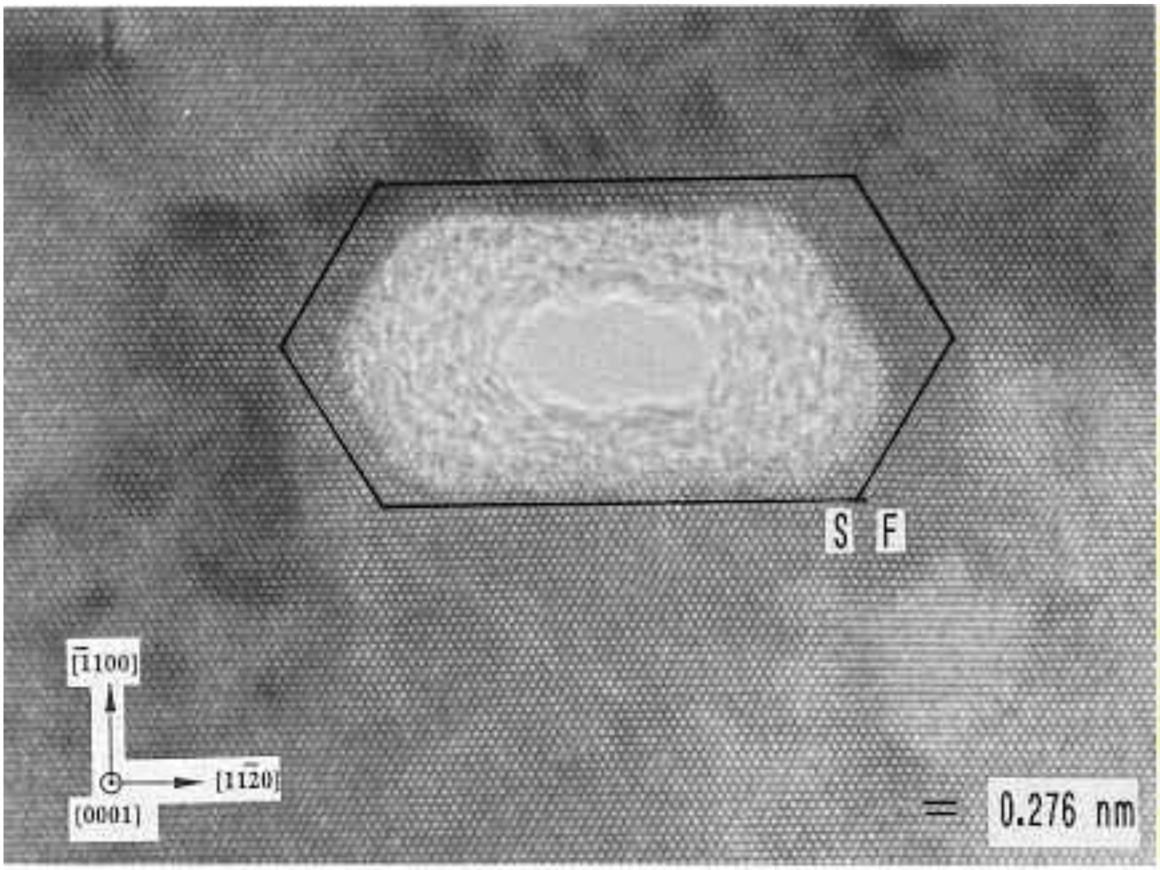

fig.4

Figure 4. HREM planar view image of a domain filled of amorphous material, and showing an a component dislocation.

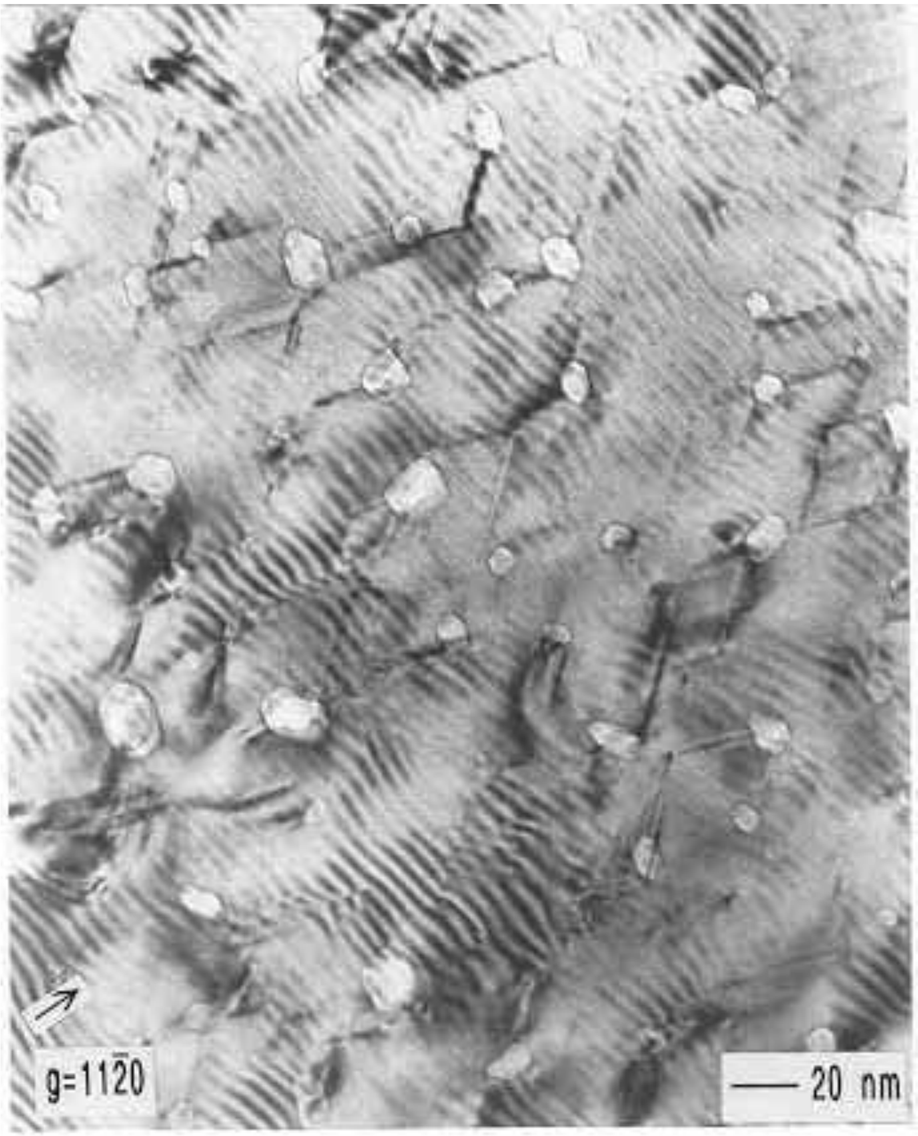

fig.5

Figure 5. Bright field planar view image of the GaN/SiC interface, the main part of the domains are linked by planar prismatic defects.

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