Growth of High-quality GaN Template from Nanometer-size Lattice Channels by Hydride Vapor Phase Epitaxy

A.Usui[1], H. Goto[1], T. Matsueda[1], H. Sunakawa[1], T. Nakagawa[1], A. Okada[2], J. Mizuno[2], A. A. Yamaguchi[3], H. Shinohara[4] and H. Goto[4]

[1]Nitride Semiconductor Department, Furukawa Co., Ltd., Oyama, Tochigi, Japan
[2]Institute for Nanoscience and Nanotechnology, Waseda University, Shinjuku, Tokyo, Japan
[3]Optoelectronic Device System R&D Center, Kanazawa Institute of Technology, Nonoichi, Ishikawa, Japan
[4]Nano Processing System Division, Toshiba Machine Co., Ltd., Numazu, Shizuoka, Japan
*E-mail: a-usui@furukawakk.co.jp

Wide bandgap semiconductors such as SiC and GaN in power devices are attractive for energy-saving measures in consumer products, automobiles, and industrial machines. In particular, the on-resistance of GaN is expected to be 1/1000 of that of Si, and when GaN is used together with related materials, such as AlGaN and InGaN, device design capabilities can be increased by exploiting their heterostructures. To realize such GaN devices, however, high-quality GaN substrates are indispensable. In this paper, we describe the growth of high-crystalline-quality GaN template by HVPE, focusing on the reduction to reduce the dislocation density in the grown layer.

As a method to reduce dislocations in GaN crystal, we have proposed facet-initiated epitaxial lateral overgrowth (FIELO) [1]. The basic concept of FIELO is the growth of a high-quality layer by overgrowing crystals generated from small channels that are opened on a dielectric mask such as SiO_2. In particular, structures with facet planes appeared in the open channels were found to reduce the threading dislocation density by enhancing the bending of the dislocations. However, when micrometer-size channels are used, it is inevitable that many dislocations will propagate from the GaN template through the channels. Furthermore, due to the formation of micrometer-size facets, a relatively thick layer growth (~30 μm) was required to recover a flat (0001) surface; a uniform dislocation distribution, regardless of the mask pattern, was not achieved until the layer was about 100 μm thick. To overcome these problems, we adopt the nano-FIELO technique, which is based on nanometer-size channels. A nanoimprinting technique [19] is applied followed by dry etching to form these channels.

In this method, GaN growth has started by forming nanometer-size facet structures on stripe channels of 50nm-width which were opened on SiO_2 layer deposited on GaN/sapphire substrate. As a result, uniform GaN layer has grown with the dislocation density as low as $5x10^7$ cm^{-2} at the thickness of about 20 μm. However, the crystalline quality of the samples grown using the stripe mask pattern was anisotropic in nature. Accordingly, in an attempt to correct the anisotropy, a sample using the grid mask pattern, consisting of 500 nm × 500 nm square masks surrounded by 80-nm-wide channels, was grown. Figure 1(a) shows a top-view SEM image of the initial growth stage, and facet structures can be seen clearly to have developed from every opening. The facet structures were found to be completely buried at a thickness of ~0.9μm and the development of flat (0001) surface was confirmed, as shown in Fig. 1(b). The FWHMs of the XRC for a 20-μm-thick sample were 214'' and 226'' for (11−20) and (10−10) incident conditions, respectively. These results indicate that the anisotropy diminished by using the grid mask pattern. The dislocation behavior for a sample grown with the gird mask pattern was investigated using cross-sectional TEM observations, and a bright-field image is shown in Fig. 2. Although a large dislocation density (~ 1×10^9 cm^{-2}) was found for the MOCVD GaN template, the density in the HVPE GaN on the mask pattern was significantly lower. Both the mask covering the propagation end of the threading dislocations and the narrow channels work effectively in nano-FIELO. The optical properties of the nano-FIELO GaN layers were characterized by photoluminescence (PL) measurements. The PL intensity of the nano-FIELO GaN sample lies between those of the MOCVD GaN template and HVPE GaN substrate. Since the HPVE GaN substrate has a high crystal quality with a low dislocation density (3×10^6 cm^{-2}), the best performance can be expected from this sample. The optical quality of the MOCVD GaN template, however, is considered to be inferior to the nano-FIELO GaN due to the higher dislocation density.

Such high-quality GaN templates will make it easier to fabricate high-performance light-emitting diodes and electron devices.

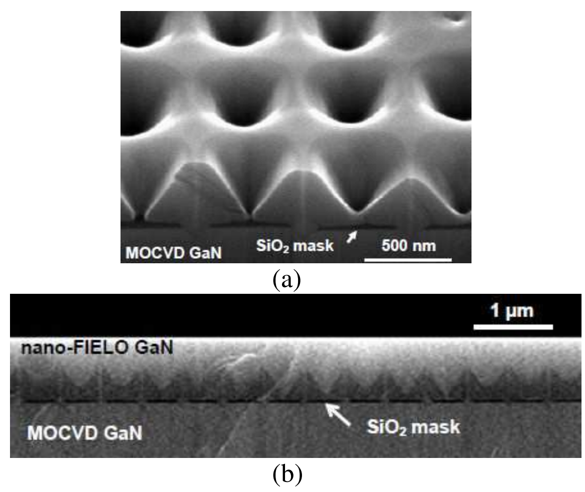

Fig. 1 (a) Top-view SEM image of the initial growth stage and (b) cross-sectional SEM image of a sample with a thickness of about 0.9 μm grown with nano-FIELO with the grid mask pattern.

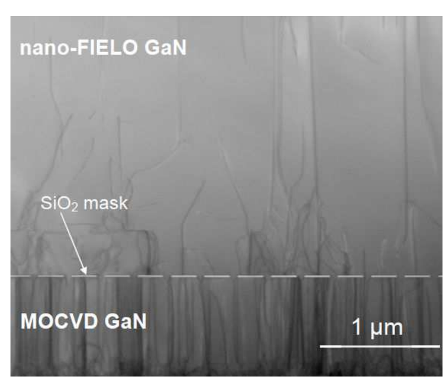

Fig. 2 Cross-sectional TEM bright-field image of a nano-FIELO GaN sample grown with the gird mask pattern.

Refernces:
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