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Polarity conversion of hydride vapor phase epitaxy growing GaN via growth interruption modulation

Benliang Lei [a,d], Guanghui Yu [a,*], Haohua Ye [a], Sheng Meng [a], Xinzhong Wang [a,d], Chaotong Lin [a,d], Ming Qi [a], Aizhen Li [a], Gérard Nouet [b], Pierre Ruterana [b], Jun Chen [c]

[a] State Key Laboratory of Functional Materials for Informatics, Shanghai Institute of Microsystem and Information Technology, Chinese Academy of Sciences, 865 Changning road, Shanghai 200050, People's Republic of China
[b] Laboratoire Structures des Interfaces et Fonctionnalité des Couches Minces, UMR CNRS 6176, ENSICAEN,6 Boulevard du Maréchal Juin, 14050 Caen Cedex, France
[c] Laboratoire de Recherche sur les Propriétés des Matériaux Nouveaux, IUT d'Alençon, 61250 Damigny, France
[d] Graduate School of the Chinese Academy of Sciences, Peking100039, People's Republic of China

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Abstract

GaN films were deposited by hydride vapor phase epitaxy with and without adopting growth interruption modulation (GIM). The surface morphologies of these samples were observed by atomic force microscopy. After chemical etching, the surface morphology of GaN film grown directly on sapphire changed greatly and turned out to be N-polarity, which could be changed into Ga-polarity when growing via interruption modulation. Photoluminescence spectra showed that optical property of Ga-polar film was better than that of N-polar film. High resolution X-ray diffraction revealed the high crystalline quality GaN film grown by using the GIM method. The polarity conversion was the result of surface reconstruction when adopting GIM method.

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1. Introduction

The wurtzite gallium nitride is a polar crystal and exhibits both spontaneous polarization and piezoelectric effect due to the uniaxial and non-centrosymmetric structure [1]. The polarization field in GaN grown on sapphire depends on the crystal direction as well as the growth sequence along the growth direction. The c-plane sapphire on which GaN layers are grown and GaN do not share the same atomic stacking order. Consequently, the crystal direction [0001] of a GaN film can either be parallel or antiparallel to the growth direction, leading to epilayers with two different polarities, Ga- and N-polar films [2]. The two polarities have very different structural and electronic properties [3]. A Ga-polar film has a relatively smoother and more stable surface [4–6], lower impurity contamination, donor and acceptor type impurities and also Ga vacancies [7,8], and is more favored for achieving *p*-type conductivity [9]. The Schottky barrier height on the Ga-surface is higher and the associated leakage current is lower [10,11]. The photoluminescence properties of Ga-polar films have been reported to be better than N-polar films [12,13]. Therefore it is obviously that the overall quality of the Ga-polar film is better than that of N-polar film and there are many reports about how to obtain Ga-polar GaN layers [14–16]. Also, there are some investigations about transformation of the polarity of GaN films by molecular beam epitaxy [17] and pulse laser deposition [18]. It is interesting to know how to change the polarity of GaN films from N-polar into Ga-polar by hydride vapor phase epitaxy (HVPE). In the following, we demonstrated a GIM mode of HVPE to change the polarity of GaN film from N-polar into Ga-polar, this method was previously used for relaxing strain and reducing dislocations when growing GaN films [19].

2. Experimental details

Thick GaN films were grown in a home-built HVPE reactor, where HCl was introduced into the Ga source region to produce

* Corresponding author.
E-mail address: ghyu@mail.sim.ac.cn (G. Yu).

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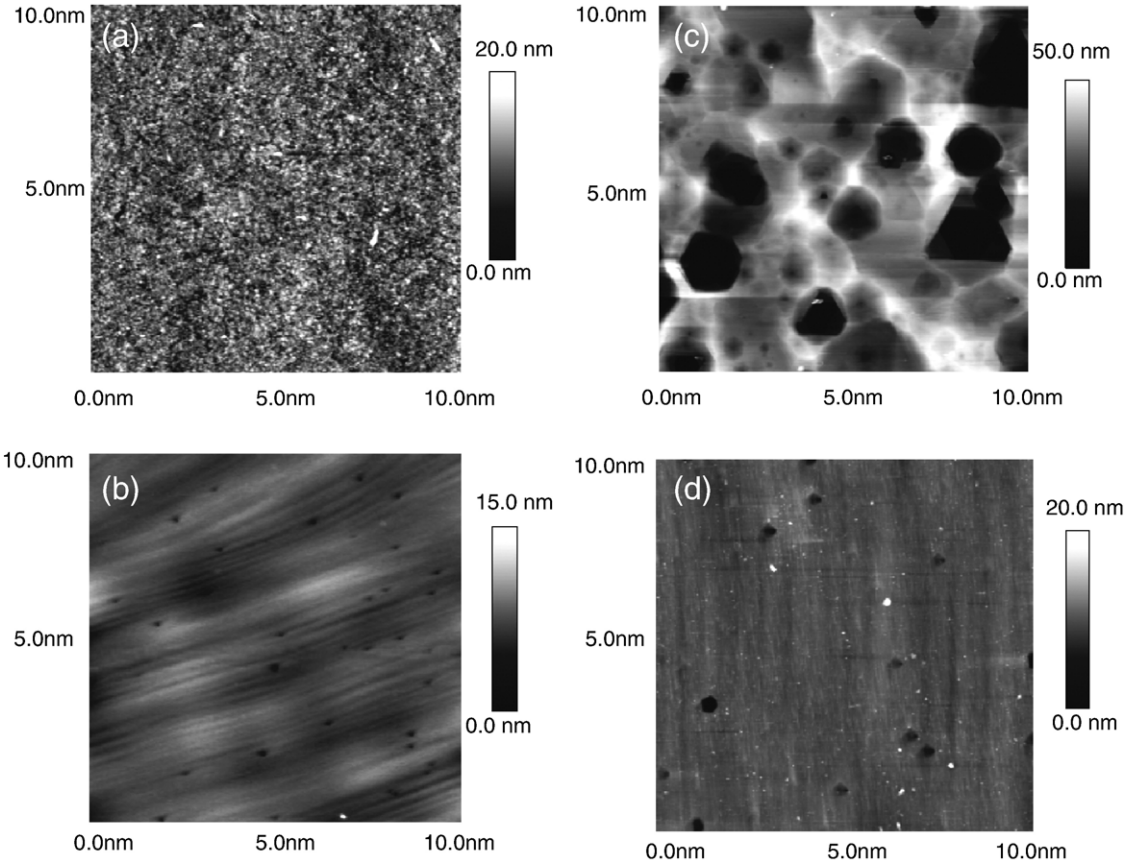

Fig. 1. Surface morphologies of As-grown GaN films (a, b) and etched GaN films (c, d) without and with adopting interruption modulation, respectively. All are given by AFM (10×10 μm).

GaCl gas as the group III precursor and NH_3 was introduced into the growth region as the group V precursor for GaN growth (1050 °C) with HCl and NH_3 flows of 0.01 and 0.7 slm, respectively. Nitrogen was used as a carrier gas and the total gas flow in the reactor was 3 slm. Sapphire substrates with (0001) orientation were degreased using organic solvents (trichloroethylene, acetone, and methanol) in an ultrasonic cleaner and rinsed with deionized water. The substrates were exposed to an ammonia flow of 0.7 slm at 1050 °C for 10 min before the main GaN layer were deposited at the same temperature. In the experiment, two samples were prepared on sapphire, with (sample B) and without (sample A) growth interruption. The NH_3 flow was kept constant at 0.7 slm for both growth conditions and the 0.01 slm HCl was interrupted three times for 20 min after 20 min of dual flow.

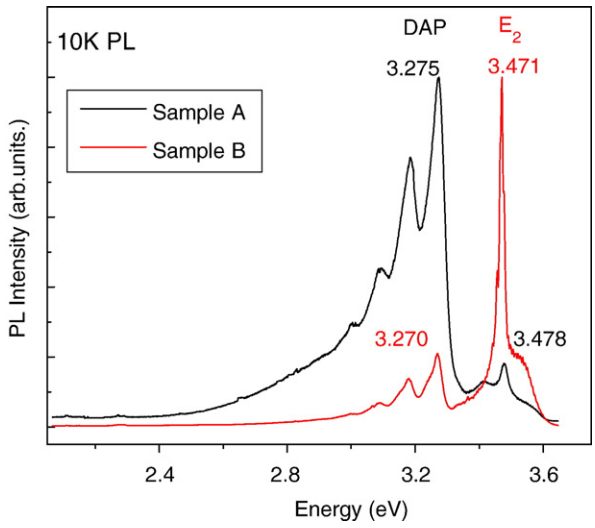

Fig. 2. Photoluminescence of GaN grown by HVPE with and without adopting interruption modulation at 10 K, respectively.

The crystalline quality of the HVPE layers was characterized by high resolution Philips X'pert MRD X-ray diffraction (XRD) using the GaN symmetrical (002) and asymmetrical (102) omega scan with a slit width of 1 mm, $K_{\alpha 1}$ line of Cu target was chosen as X-ray source. The morphology of the top surface of the HVPE GaN epitaxial layers were studied by atomic force

Table 1
Structural and photoluminescence characteristics as well as surface roughness of GaN layers grown by HVPE

Sample	XRD FWHM (arcsec)		RMS (nm)		PL	
	ω(002)	ω(102)	As-grown	Etched	FWHM (meV)	Peak position (eV)
A	436.0	397.0	2.1	35.5	52	3.478
B	494.2	198.4	0.5	1.1	19	3.471

Sample A is without and sample B is with growth interruption. The two samples A and B have thicknesses of 50 μm and 200 μm, respectively.