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Fabrication of actinomorphic GaN nanowires by sputtering and ammoniating progress

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Abstract

Actinomorphic GaN nanowires clusters have been achieved by ammoniating Ga_2O_3 thin films deposited on the Mg layer on the Si (1 1 1) substrate. The resulting materials were characterized by X-ray diffraction (XRD), scanning electron microscopy (SEM), high resolution transmission electron microscopy (HRTEM) and selected-area electron diffraction (SAED). SEM images show that the resulting materials are actinomorphic nanowires clusters with the glazed surface. XRD, HRTEM and SAED indicate that the nanowires are single-crystal hexagonal GaN with a wurtzite structure.

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Keywords: A1. Actinomorphic nanowires; A3. Magnetic sputtering; B2. Gallium nitride

1. Introduction

In the past few years, one-dimensional nanostructures have attracted intensive interest due to their potential uses in optoelectronic devices and their fundamental importance to the study of size-dependent chemical and physical phenomena [1–5]. GaN-based semiconductors have a direct band gap that is suitable for blue light-emitting devices, and the band gap energy of the GaN-based semiconductors varies between 6.2 and 2.0 eV at room temperature depending on their composition. Thus, by using these semiconductors, red- to ultraviolet-emitting devices can be fabricated. They have attracted much attention after the successful fabrication of high-efficiency blue light-emitting diodes and laser diodes [6–8]. These studies have primarily focused on two dimensional quantum well structures. Recently, one-dimensional GaN materials have attracted much attention due to their potential uses in fundamental and applied research [9,10]. In this paper, we report an efficient approach for the synthesis of actinomorphic GaN nanowires by ammoniating Ga_2O_3 thin films deposited on the Mg layer on the Si (1 1 1) substrate.

2. Experimental details

In our experiment, actinomorphic GaN nanowires clusters were prepared by self-assembling of Ga_2O_3 films in their reaction with NH_3. GaN nanowires were prepared by a two-step method. The first step was to deposit Ga_2O_3/Mg films on the Si (1 1 1) substrate using a JCK-500 A magnetron sputtering system. The distance between the target and the substrate was 8 cm. The background pressure of the sputtering chamber was of about 6.4×10^{-4} Pa and Ar (99.99%) was introduced into the chamber with a pressure of 2 Pa during the sputtering process. When Mg was deposited, the output voltage of WLY steady current device was 160 V and the output current was 140 mA. It was different when Ga_2O_3 films were deposited by radio frequency magnetron sputtering. The sputtering power was 150 W and the frequency was 13.56 MHz. The sputtering process was maintained at room temperature by using the cooling system.

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Subsequently, the Ga_2O_3/Mg films were ammoniated with a flow rate of 500 ml/min in a horizontal tube furnace. The temperature and the duration of the ammoniating were 950 °C and 15 min, respectively.

3. Results and discussion

3.1. XRD analysis

The X-ray diffraction (XRD) patterns of the products were measured with Rigaku D/max-rB X-ray diffractometer. (Fig. 1). Peaks are found at 32.4°, 34.6°, 36.8° and 48.1° in correspondence with the hexagonal wurtzite GaN. They are due to the (1 0 0), (0 0 2), (1 0 1) and (1 0 2) diffraction peaks of hexagonal GaN, respectively. In the pattern, the diffraction peak of Mg is not found. One of the reasons is that the Mg film likely volatilized at 950 °C, as a result of its low melting point (648.8 °C). Besides, the diffraction peaks of Mg (lattice constants $a = 0.3200$ nm, $c = 0.5200$ nm) are very close to the relevant diffraction peaks of GaN (lattice constants $a = 0.3189$ nm, $c = 0.5185$ nm). It might be possible that the peaks of Mg are covered by the corresponding ones of GaN. A peak is found at 35.6°, which is due to the (4 0 0) diffraction peak of Ga_2O_3. That indicates that Ga_2O_3 films have not been completely ammoniated under the above conditions.

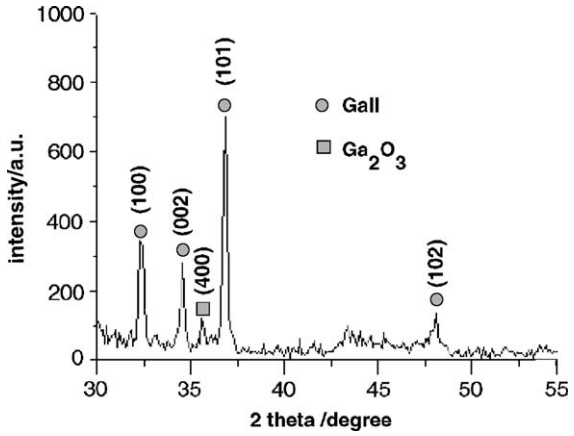

Fig. 1. XRD of the sample achieved at 950 °C.

3.2. SEM analysis

The morphology of the products was characterized using a Hitachi S-570 scanning electron microscopy (SEM) at room temperature. The SEM images (Fig. 2) show that the clusters are composed of nanowires, which take on an actinomorphic structure. These nanowires lie parallel to the surface of the substrates and come out of the same site. Fig. 2(a) is the SEM image of a cluster. It indicates that every nanowire has a cosh with dentate structures at the bottom, and other parts of the nanowires are very smooth. And that the diameters of the nanowires are not even and decrescent, which is consistent with what Ref. [11] reported. The length of the nanowires varies from 20 to 50 μm. Most of the nanowires are straight, although several ones are curved. Except for the cluster, there are a large number of crystal grains on the surface of the substrate,

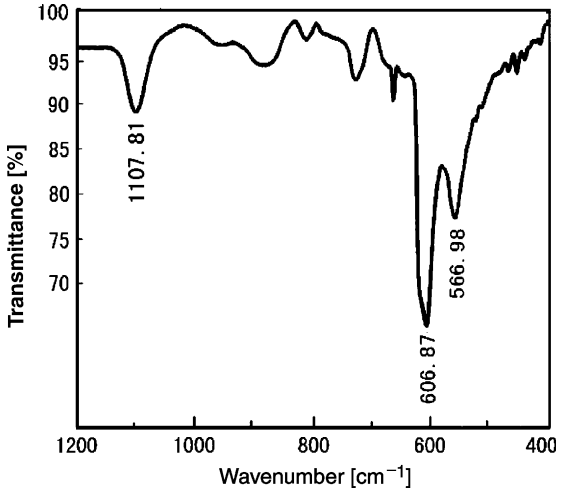

Fig. 3. FTIR image of the sample measured from 400 to 1200 cm^{-1}.

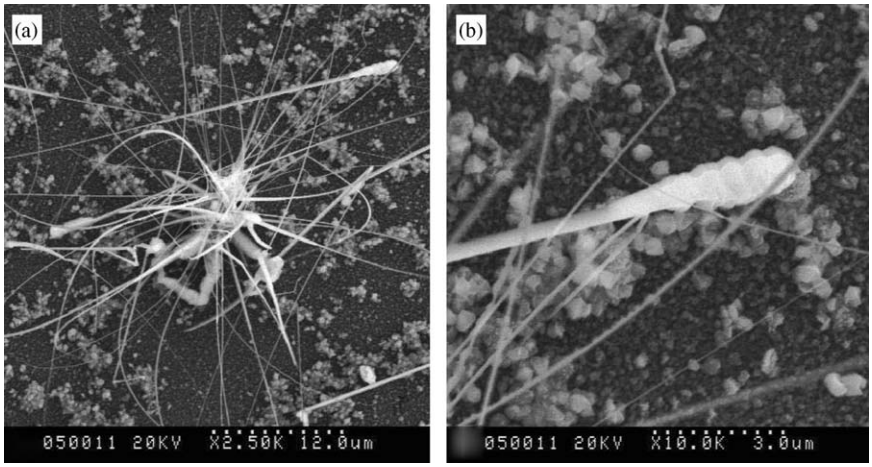

Fig. 2. (a) The image of nanowires cluster obtained at 950 °C, and (b) the amplified image of a part of cluster.