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Investigation of V-defects formation in InGaN/GaN multiple quantum well grown on sapphire

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Abstract

In the growth of InGaN multiple quantum well structure, V-pits has been observed to be initiated at the threading dislocations which propagate to the quantum well layers with high indium composition and substantially thick InGaN well. A set of samples with varying indium well thickness (3–7.6 nm) and composition (10–30%) are grown and characterized by photoluminescence (PL), X-ray diffraction, transmission electron microscopy and atomic force microscopy. The indium content and the layer thicknesses in InGaN/GaN quantum well are determined by high-resolution X-ray diffraction (XRD) and TEM imaging. With indium composition exceeding 10%, strain at the InGaN/GaN interface leads to the generation of V-pits at the interlayers of the MQW. Higher indium composition and increase in thickness of a period (InGaN well plus the GaN barrier) appear to enhance pits generation. With thicker InGaN well and reduction in thickness of GaN to InGaN (or the *R* ratio), pit density is substantially reduced, but it results in greater inhomogeneity in the distribution of indium in the InGaN well. This leads to a broadened PL emission and affect the PL emission intensity.

Keywords: V-defects; Multiple quantum wells; InGaN/GaN heterostructures; Photoluminescence

1. Introduction

InGaN/GaN heterostructures and quantum well (QW) structures have a wide range of applications such as the active layers in GaN-based light-emitting diodes [1,2] as it is possible to tune the optical band gap from visible to ultraviolet spectral range by controlling the In composition [3,4]. The GaN layer is usually grown on lattice mismatched sapphire substrate which leads to the generation of a high density of threading dislocations [5,6], typically in the order of 10^8–10^{10} cm^{-2}. This can disrupt the InGaN MQW through inverted hexagonal pits formation [7,8] as these pits are found to be initiated at threading dislocations and extend along the *c*-axis growth direction in the InGaN layer [9,10]. Furthermore, the lattice mismatch between the InGaN/GaN layers also constitutes to composition pulling effect where indium atoms are excluded from the InGaN to reduce the deformation energy during the film growth [11]. As a result, indium composition and the extent of relaxation in the InGaN film progressively increases with the film thickness [12]. This anomalous composition pulling affects the emission mechanism in the MQWs structure and its luminescence efficiency.

2. Experimental details

In this paper, the effect of varying indium composition and well thickness in the MQW structures on the luminescence efficiency is studied. The In well thickness and the number of periods are determined from high-resolution X-ray diffraction (HRXRD) and transmission electron microscopy (TEM). The generation of V-pits by dislocation propagation and its effect on its surface morphology is determined from TEM and atomic force microscopy (AFM), respectively. The InGaN/GaN MQW structures were grown by metalorganic chemical vapor deposition (MOCVD) using Emcore D180 on *c*-plane sapphire substrate. After thermal cleaning of the sample at 1100 °C, a GaN buffer of 35 nm thick was grown at 530 °C. The reactor temperature was then further

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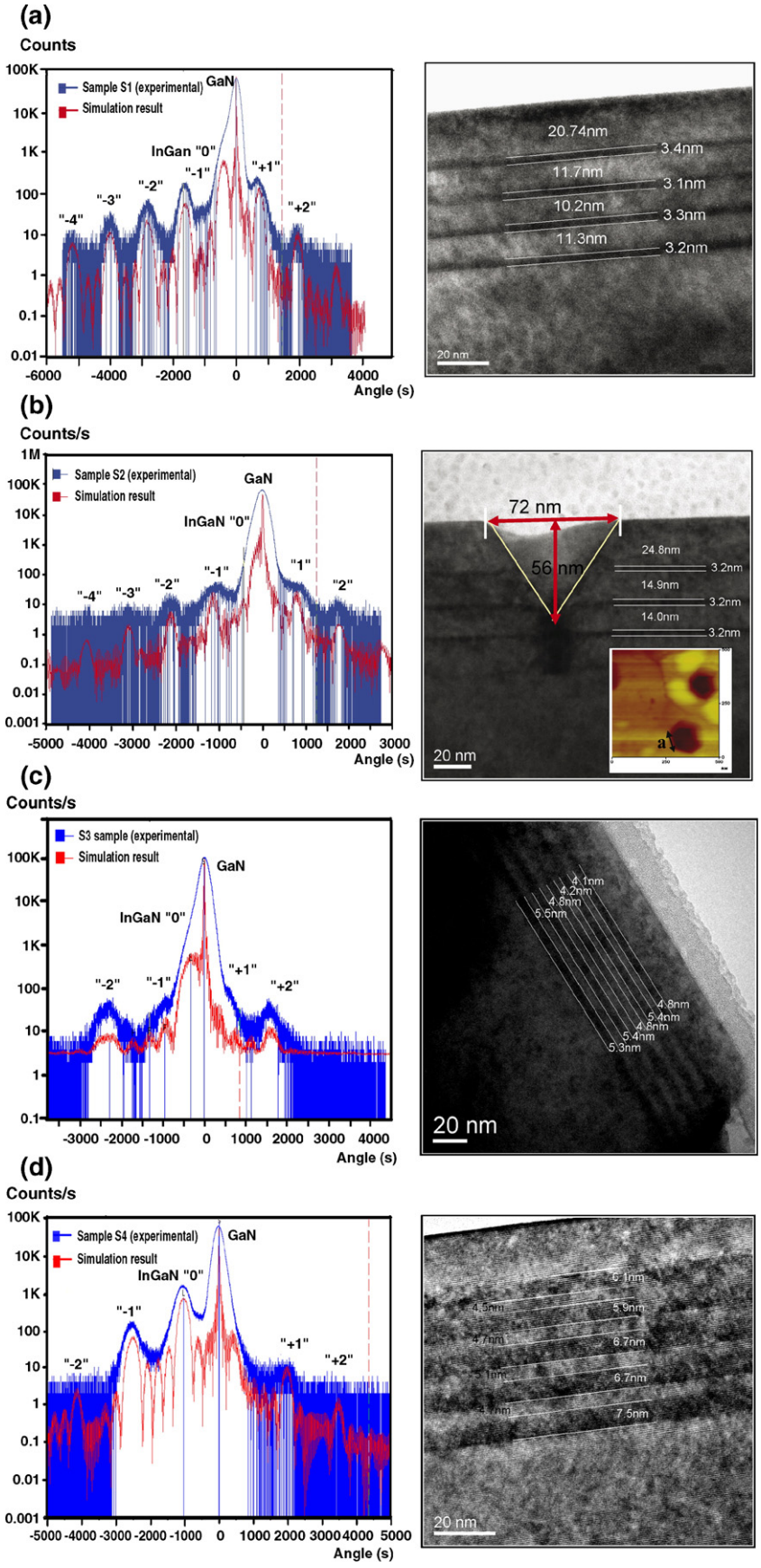

Fig. 1. (002) XRD diffraction pattern with simulated pattern obtained using $\omega/2\theta$ scan (left) and cross-sectional TEM image (right) for the InGaN/GaN MQW structures (a) S1, (b) S2, (c) S3, and (d) S4. The inset in Fig. 2b shows the plane view AFM images for a V-pits region.