Development of SiC Substrate with Buried OxideLayer for Electron-Photon Merged Devices

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INTRODUCTION

Based on Silicon-on-Insulator (SOI) technology, we have a plan to develop electron-photon-merged devices. In this idea, a combined structure of CMOS-LSI/SOI and LED-array/GaN is monolithically fabricated on one chip, as shown in Figure 1. One of the key points of this work is to form a GaN layer with a good crystal quality using a Si substrate despite the significant lattice mismatch between Si and GaN. One possibility for solving the problem is to employ 3C-SiC as a buffer layer between the Si and GaN [1], since the lattice constant and the thermal expansion coefficients between 3C-SiC and GaN are much closer than those of Si and GaN.

Previously, we reported that an SOI substrate was carbonized using an electric furnace without any vacuum system, resulting in a uniform and flat 3C-SiC monocrystalline layer with a thickness of 4 nm being successfully formed on the top Si layer of the SOI substrate [2]. However, further carbonization to completely metamorphose the top Si layer of the SOI substrate into SiC layer results in crystal grain growth due to the growth mode transferring from two-dimensional to three-dimensional (3D). In addition, surface roughness drastically increased. Considering the next stage, GaN epitaxial growth on the SiC layer, it is necessary to obtain a flat monocrystalline SiC/OI structure. Therefore, an SOI substrate with an ultrathin top Si layer is fabricated to prevent 3D growth, and a flat, ultrathin SiC layer is formed by carbonization of the ultrathin Si layer.

EXPERIMENTAL

An SOI substrate with a structure of 100nm-Si(111)/200nm-SiO_2/bulk-Si(100) was used. Sacrificial oxidization was performed at about 1100°C to form an SOI substrate with an ultrathin top Si layer. After removing the surface SiO_2 layer by a buffered HF solution, the substrate was carbonized in a hydrogen and propane atmosphere at about 1250°C using an electric furnace. A detailed carbonization process has been described elsewhere [2].

A laser microscope and X-ray diffraction were used to observe the surface morphology and estimate the crystallinity of the formed SiC layer, respectively. The thicknesses of the ultrathin top Si and SiC layers were measured using spectroscopic ellipsometry. A cross-sectional transmission electron microscope (XTEM) and transmission electron diffraction (TED) were employed for a nano-scale analysis of the ultrathin top Si and SiC layers.

RESULTS AND DISCUSSION

Figure 2 shows an XTEM image of the top Si layer after sacrificial oxidization. An ultrathin top Si layer with a thickness of about 5 nm can be observed in the figure, fluctuating by less than a few monolayers. Using the SOI substrate with the ultrathin top Si layer, the 3D growth of SiC is suppressed even when the top Si layer is completely metamorphosed into SiC.

Figure 3 shows an XTEM image of a SiC layer formed by carbonization of the ultrathin top Si layer. An approximately 3nm thick SiC layer with no grains is formed on the buried oxide. Judging from the obtained TED pattern, the formed SiC layer is monocrystalline, and has a cubic (3C) structure, not a hexagonal one such as 6H. In the image, a Si island is also visible in the upper region of the buried oxide. It is thought that unreacted Si sinks into a softened buried oxide during carbonization (1250°C), and is encapsulated by the formed SiC layer. It is expected, therefore, that the ultrathin top Si layer of SOI substrate can be completely metamorphosed into a uniform SiC layer without unreacted Si islands by optimizing the carbonization condition.

SUMMARY

We attempted to form a SiC layer on a buried oxide layer for use as a substrate for electron-photon-merged devices. An ultrathin top Si layer formed by sacrificial oxidization was carbonized, and an ultrathin monocrystalline 3C-SiC layer was successfully fabricated on the buried oxide, although unreacted Si islands existed locally in the upper region of the buried oxide.

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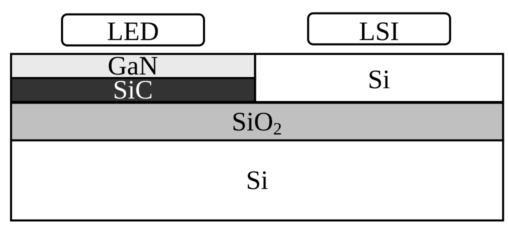

Figure 1. Substrate for electron-photon-merged devices.

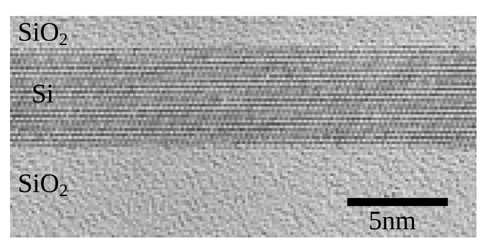

Figure 2. XTEM image of top Si layer after sacrificial oxidization.

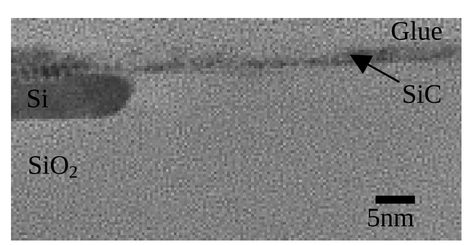

Figure 3. XTEM image of SiC layer formed by carbonizing ultrathin top Si layer.