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High electron mobility InSb films grown on Si (111) substrate via √7×√3-In and 2×2-In surface reconstructions

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1. Introduction

Due to its excellent electronic characteristics such as the high electron mobility and the narrow band gap, InSb has received a great deal of attention as a good candidate for infrared detectors, high-speed devices and magnetic sensors[1]. However, the heteroepitaxy of InSb on Si is difficult to achieve because of the large lattice mismatch of about 19.3% between them. Previous reports illustrated that InSb bi-layer, prepared by adsorption of 1 monolayer (ML) Sb onto In-induced surface reconstruction, can be a good solution of the lattice mismatch problem [2-4]. The InSb films synthesized on the InSb bi-layer were rotated by 30^o with respect to Si(111) surface. In this case, the lattice mismatch between InSb and Si nominally improved down to about 3.3%. Some groups [5-7] reported that the two step growth method is a successful way for the growth of highly mismatched systems, such as InSb/GaAs and InSb/Si [5-7]. This growth method consists of an initial low-temperature InSb layer growth (180-240 ^{o}C) and a following high-temperature InSb layer growth (350-440 ^{o}C). In our previous reports we showed that the electron mobility values of InSb films synthesized with two step growth procedure via InSb bi-layer range from 18000-20000 cm^2/Vs [8, 9]. In order to grow the InSb films with higher electron mobility, it is necessary to increase the growth temperature for the improvement of crystal quality. However, since there is a critical temperature (between 200-250^{o}C) for degradation of InSb bi-layer, high temperature growth of the InSb first layer (T_{s1}>250^{o}C) is not possible. Moreover, big temperature gap between the InSb first/second layers leads to the deterioration of the first layer. Accordingly, in current study we tried to increase the growth temperature of the first layer and decrease the temperature gap between InSb first/second layers with gradually increase of the growth temperature during the deposition of each layer. Moreover, in order to improve the crystalline quality of the InSb films, the thickness of InSb first layer decreased compare to our previous reports. Finally epitaxial growth of InSb films on √7×√3-In and 2×2-In surface reconstructions are compared.

2. Experimental procedures and results

All the depositions were carried out in an OMICRON molecular beam epitaxy (MBE) chamber. The InSb bi-layer was prepared by the following process. First, 0.33ML-In atoms were deposited at 450^{o}C on the clean 7 × 7 surface to make √3 ×√3-In surface reconstruction. After cooling down the T_s to RT, the √7 ×√3-In and 2×2-In surface reconstructions were prepared by adsorption of additional In atoms onto the √3 ×√3-In surface. Then 1ML-Sb atoms were evaporated at 180^{o}C onto the √7 ×√3-In and 2×2-In surface reconstructions to prepare the InSb bi-layer. The InSb films were grown by the two-step growth procedure. In this procedure, the 3nm-thick InSb layer was grown on the InSb bi-layer at starting temperature of 200^{o}C. The growth temperature rose gradually up to 320^{o}C during deposition. The second layer was then deposited at starting growth temperature of 380^{o}C when gradually increased to 440^{o}C during deposition. The total film thickness of the samples in this work was about 1.1μm. The grown InSb films were characterized by X-ray diffraction (XRD) and Hall measurement.

The XRD analysis ($2\theta/\omega$ scan) of the InSb films grown via √7 ×√3-In and 2×2-In surface reconstructions showed that samples were heteroepitaxially grown and had no polycrystalline nature. The FWHM of InSb (111) peaks of both samples was about 160 arcsec, indicating good crystal quality of the films. The room temperature electron mobility of the samples grown via √7 ×√3-In and 2×2-In surface reconstructions was about 38,000 and 28,000 cm^2/Vs respectively. These values are high as for the 1.1μm-thick InSb film grown on Si substrate without any buffer layer. The high temperature growth of the InSb first layer, small temperature gap between the InSb first/second layers and low thickness of first layer, seems to improve the crystalline quality which in turn enhances electron mobility of the InSb films. However, InSb films prepared via √7 ×√3-In surface reconstruction showed higher electron mobility values which results from the higher In coverage of √7 ×√3-In surface reconstruction in comparison with 2 ×2-In surface reconstruction.

3. Conclusions

The InSb films prepared with two-step growth procedure via InSb bi-layer. The heteroepitaxial growth of InSb films with high electron mobility achieved by increasing the growth temperature of the first layer and decreasing the temperature gaps between first/second InSb layers. The InSb films showed the electron mobility values of 38,000 and 28,000 cm^2/Vs for √7 ×√3-In and 2×2-In surface reconstructions which is higher than previously reported values. This might be due to the improvement of crystalline quality of the first and second layers. These results show the efficiency of the two-step growth procedure and InSb bi-layer for the improvement of the electrical property of the InSb films.

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