MOVPEによる高速成長：In(AlGa)P表面における成長パラメータの影響
Impacts of growth parameters on the morphology of In(AlGa)P grown by high speed MOCVD

ソダーバンル・ハッサネット [1]，生方映徳 [2]，渡辺健太郎 [1]，菅谷武芳 [3]，中野義昭 [4]，杉山正和 [1]
H. Sodabanlu[1], A. Ubukata[2], K. Watanabe[1], T. Sugaya[3], Y. Nakano[4], M. Sugiyama[1]
[1] 東大先端研 RCAST, The Univ. of Tokyo，[2] 大陽日酸(株) Taiyo Nippon Sanso Corp.，[3] 産総研 AIST，[4] 東大院工 School of Engineering, The Univ. of Tokyo
E-mail: sodabanlu@hotaka.t.u-tokyo.ac.jp

1 Introduction

Recent years, we have reported the success in high speed MOCVD growth of GaAs and InGaP with the growth rates of 120 and 30 μm/h, respectively [1,2]. In case of InGaP growth, a high growth temperature is indeed neccesary to realize InGaP layers with low background impurities and good crystal quality [2]. However, such a high growth temperature leads to rough InGaP surfaces as a drawback. It is very promising that the performance of high-speed grown InGaP solar cells can further be improved with better surface morphology and interface roughness. Hence, in this work, we further investigate impacts of other growth parameters, including V/III ratio, substrate mis-orientation and Al composition on the surface morphology of $In_{0.5}(AlGa)_{0.5}P$ grown by high speed MOCVD.

2 Experimental details, results and discussion

With the optimized growth temperature of 650 °C and reactor pressure of 15 kPa [2], 1-μm thick In(AlGa)P layers were grown on (100) GaAs substrates with 3 different mis-orientations; exact, 5° toward (110) and 5° toward (111)B, notated as just, 5(110) and 5B from now on, respectively. Figure 1 shows the AFM images of InGaP grown at 10 μm/h using different V/III ratios. Step bunching along [011] and [010] directions was observed from samples grown on just and 5(110) GaAs, respectively. The step width was clearly narrower for InGaP grown on 5(110) substrates. The explanation is most likely the terrace width which is narrower for 5(110) than just substrates. These bunching steps could not be found on InGaP grown on 5B GaAs with As-terminated structure. Hence, it could be considered that the step bunching was related to the atomic structure of GaAs surface. A decrease in V/III ratio during InGaP growth increased step width for InGaP on just GaAs, but had opposite effect on InGaP on 5(110) substrates. In contrast, 10-μm/h grown InAlP on all GaAs orientation did not exhibit step bunching feature. By increasing the Al composition in $In_{0.5}(AlGa)_{0.5}P$ grown on just and 5(110) substrates, we could observe the transition from step bunching of InGaP to flat surface of InAlP when the Al:Ga ratio in gas phase was 1:30. It is most likely that Al adatoms work as surface surfactant that reduce the step bunching of In(AlGa)P. There is a potential for engineering the surface roughness of InGaP by introducing a small amount of Al and tailoring growth parameters to realize an abrupt interface between InGaP and the following epitaxial layer.

3 Summary

The impacts of V/III ratio, substrate mis-orientation and Al composition on the surface morphology of $In_{0.5}(AlGa)_{0.5}P$ grown by high speed MOCVD were studied. Atomic structures on GaAs surface play an important role to induce surface bunching on InGaP. Al adatoms could reduce step bunching by functioning as surface surfactant. Surface engineering can potentially improve the interface roughness and the performance of InGaP solar cells.

[1] H. Sodabanlu et al, J. Phys. D: Appl. Phys. 52, 105501 (2018).
[2] H. Sodabanlu et al, J. Photovolt. 10, 480 (2020).

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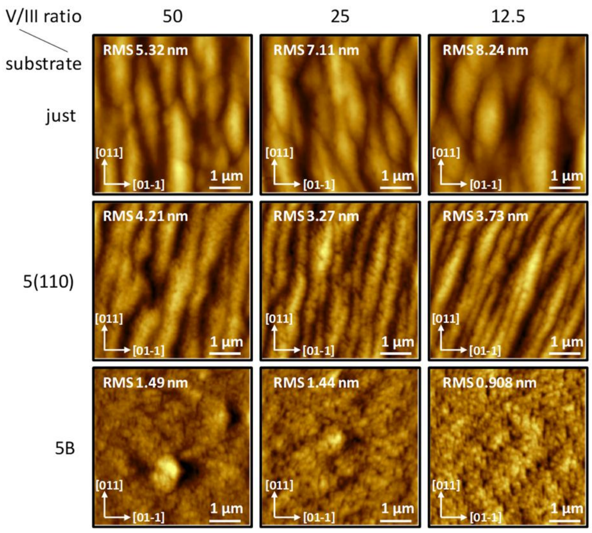

Fig. 1 AFM images of InGaP grown with a growth rate of 10 μm/h on just, 5(110) and 5B GaAs substrates using various V/III ratio.