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Selective Area Growth of Widegap II-VI Semiconductors on Patterned Substrates

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1.Introduction

In recent years, the performance of computers has been improving, but the chip surfaces are predominantly covered by electrical wiring and signal delay caused by parasitic capacitance becomes serious. One solution to this problem will be the use of the optical interconnections replacing long-distance electronic interconnections [1]. To fabricate the optical interconnections, the low temperature selective area growth of optoelectronic devices and optical waveguides are necessary, which will prevent the problems of interface diffusion, damage on Al electrical wiring (about 500°C), and degradation of already integrated electronic devices. The growth temperature of II-VI semiconductors is usually lower than other semiconductors [2], so the selective growth of II-VI optical devices will encourage the development of the above issues with the improvement of device reliability.

In this paper, the selective growth of ZnSe and ZnS was investigated and will be demonstrated at much lower temperature of 350°C~450°C than previous works above 600°C [3]. Electron beam patterning of masks for the selective growth is also demonstrated. Selective area growth of ZnSe and ZnS in this work was studied using metal-organic molecular beam epitaxy (MOMBE). The precursors used for the growth were diethyl-zinc (DEZn), ditertiarybutyl-selenide (DtBSe), and ditertiarybutyl-sulfide (DtBS). Semi-insulating GaAs (001) substrates partially covered with SiO_x mask and C mask were used for selective growth.

2.Results

The growth temperature dependences of ZnS and ZnSe growth rates on GaAs and SiO_x are shown in Figs. 1 and 2, respectively. The growth on SiO_x was suppressed by raising the growth temperature. This was caused by promoting the desorption of the precursors on SiO_x. The selective growth of ZnS was achieved at and above 450°C. On the other hand, the selective growth of ZnSe was observed at and above 500°C, and the selective growth of both ZnSe and ZnS at the same growth temperature was difficult. To overcome this

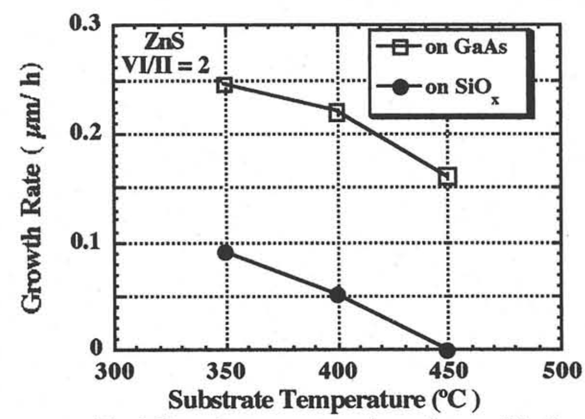

Fig.1 Growth temperature dependence of ZnS. Selective growth was observed at 450°C.

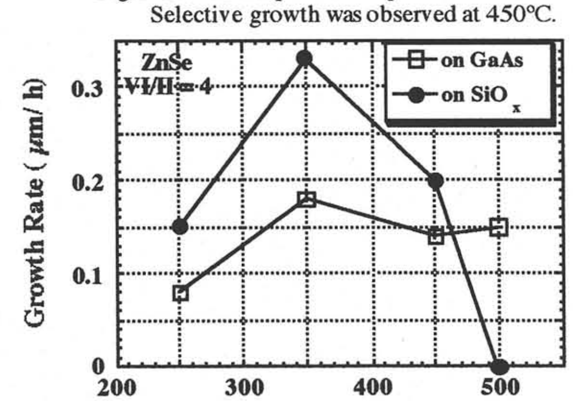

Fig.2 Growth temperature dependence of ZnSe. Selective growth was observed at 500°C.

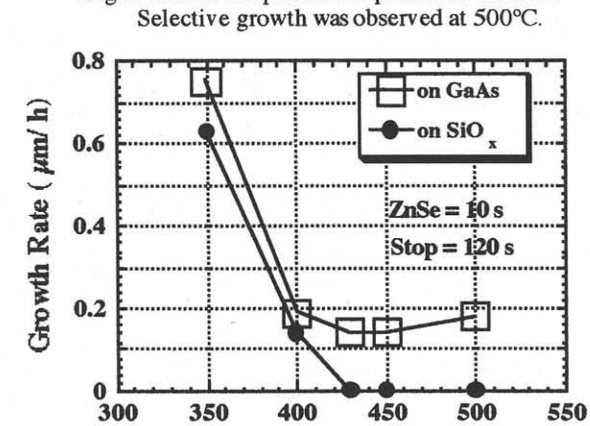

Fig.3 Growth temperature dependence of ZnSe using periodic supply epitaxy. Selective growth was observed at 450°C.

problem, we tried a periodic supply epitaxy to lower the selective growth temperature of ZnSe. Figure 3 shows the growth temperature dependence of ZnSe growth rate on GaAs and SiO_x by the periodic supply epitaxy. Growth interruption of 120 s after 10 s growth of ZnSe enhances the desorption of precursors especially on SiO_x surfaces and this makes it difficult to nucleate ZnSe on SiO_x. For the periodic supply epitaxy of ZnSe, the growth of ZnSe on SiO_x was perfectly suppressed at and over 450°C. On the other hand, ZnSe islands appeared on some parts of SiO_x at 430°C. However, the lower VI/II ratio suppresses the nucleation of ZnSe on SiO_x. Figure 4 shows the VI/II ratio dependence of the density and size of ZnSe islands. At the VI/II ratio of 1, the minimum distance from the boundary between the masked area and the unmasked area to the ZnSe islands where no ZnSe was deposited was extended to over 100 μm. From above results, we prepared the ZnSe/ZnS single quantum well at 450°C under the selective growth condition of ZnSe and ZnS. Figure 5 shows the photoluminescence spectrum of the ZnSe/ZnS single quantum well at 13K. The bright band edge emission from the ZnSe well were observed.

Electron beam writing of C masks and selective growth were examined. Figure 6 shows the SEM picture of ZnS selectively grown on the surface. Good selectivity and (111) facets were observed. In this case, the growth temperature of ZnS was lower than that of SiO_x masks and was 390°C. This shows that the carbon masks deposited by electron-beam irradiation can be a suitable mask for low-temperature selective growth.

3.Conclusion

Selective growth of ZnSe and ZnS on (001) GaAs substrates partially covered with SiO_x and C was examined by metalorganic molecular-beam epitaxy. In the case of SiO_x mask, the minimum growth temperature of ZnS to achieve selective growth was 450°C. On the other hand, the minimum growth temperature of ZnSe was 500°C, but it was reduced to 430°C using a periodic supply epitaxy. In the case of C mask deposited by electron beam irradiation, lower growth temperature of 390°C was possible in the ZnS selective growth.

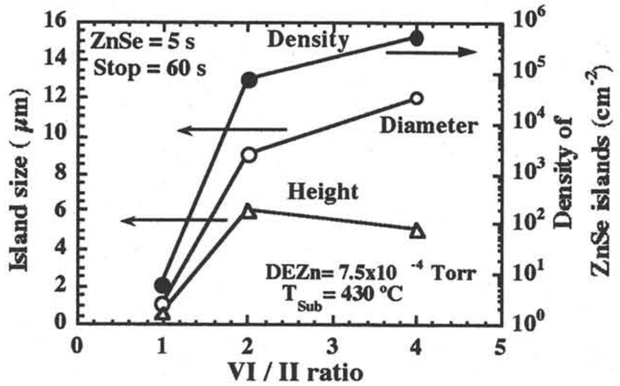

Fig.4 VI/II ratio dependence of ZnSe islands. Lower VI/II ratio suppressed the islands of ZnSe.

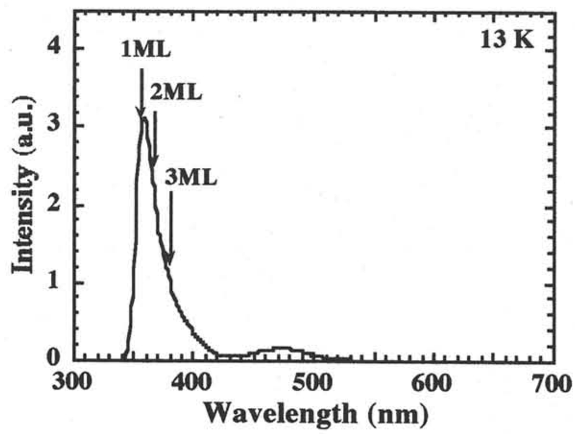

Fig.5 Photoluminescence spectrum of ZnSe/ZnS SQW at 13K. Arrows shows the optical transition wavelength calculated for the ZnSe well width of 1, 2, and 3 monolayer.The bright band edge emission from the ZnSe well was observed.

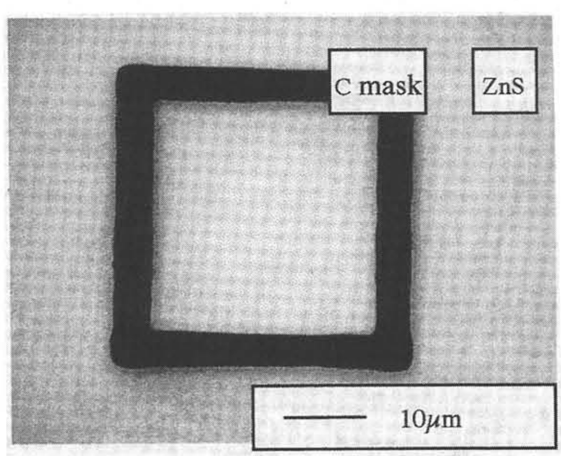

Fig.6 SEM picture of ZnS selective growth using C mask. Good selectivity was observed at 390°C.

References

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