Growth and Characteristics for $ZnGa_2Se_4$ thin film

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Abstract: The stochiometric mix of evaporating materials for the $ZnGa_2Se_4$ single crystal thin films were prepared from horizental furnace. To obtains the single crystal thin films, $ZnGa_2Se_4$ mixed crystal were deposited on throughly etched Si(100) by the Hot Wall Epitaxy (HWE) system. The temperates of the source and the substrate were 590℃ and 450℃, respectively. The crystalline structure of single crystal thin films was investigated by the double crystal X-ray diffraction(DCXD). Hall effect on this sample was measured by the method of van der Pauw and studied on carrier density and mobility dependence on temperature.

1. INTRODUCTION

The ternary semiconducting compound $ZnGa_2Se_4$ single crystal thin film, which is a wide-gap[1] material with an optical energy gap of 2.17eV, has the defect chalcopyrite structure with space group $S^2_4(I\bar{}_4)$ or $D^{11}_{2d}(I\bar{}_{42}m)$.

In this paper, $ZnGa_2Se_4$ single crystal thin films were deposited on throughly etched Si(100) by the Hot Wall Epitaxy (HWE) system. The crystalline structures of single crystal thin films were investigated by double crystal X-ray diffraction (DCRD). Hall effect on this sample was measured by the method of van der Pauw and studied on carrier density and mobility depending on the temperature.

2 EXPERIMENTAL

$ZnGa_2Se_4$ single crystal thin films were deposited on throughly chemical etched Si(100) by using hot wall epitaxy system. During the growth of $ZnGa_2Se_4$, the substrate temperature was maintained at 590℃, and the source temperature was 450℃. The growth rate of the epilayers was about 2㎛/h. The Hall data were measured from van der Pauw method.

3. RESULTS AND DISCUSSION

The electrical transport properties were determined by Hall effect measurement in the van der Pauw geometry. The Hall measurement results show that the carrier density for as-grown $ZnGa_2Se_4$ was 9.36×10^{23} /m^3 and mobility was 2.95×10^{-2} m^2/v.s at the room temperature, as shown Table 1.

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Table 1. Resultant analysis on Hall effect $ZnGa_2Se_4$ single crystal thin films grown by HWE

Temp. (K)	carrier density n (m^{-3})	Hall coefficient R_H (m^3/c)	conductivity σ ($\Omega^{-1}m^{-1}$)	Hall mobility μ (m^2/v-sec)
293	9.36×10^{23}	3.23×10^{-5}	366.14	2.95×10^{-2}
270	6.68×10^{23}	4.25×10^{-5}	402.48	3.72×10^{-2}
250	5.01×10^{23}	4.67×10^{-5}	432.02	4.46×10^{-2}
230	3.64×10^{23}	5.85×10^{-5}	463.99	5.36×10^{-2}
200	3.02×10^{23}	6.73×10^{-5}	513.87	8.04×10^{-2}
180	2.65×10^{23}	8.19×10^{-5}	540.62	9.81×10^{-2}
150	2.27×10^{23}	9.06×10^{-5}	576.80	1.08×10^{-1}
130	1.98×10^{23}	1.07×10^{-5}	586.65	1.09×10^{-1}
100	1.85×10^{23}	1.11×10^{-5}	570.48	1.12×10^{-1}
77	1.79×10^{23}	1.22×10^{-5}	560.23	9.81×10^{-2}
50	1.45×10^{23}	1.39×10^{-5}	522.30	8.28×10^{-2}
30	1.28×10^{23}	1.53×10^{-5}	485.68	7.67×10^{-2}

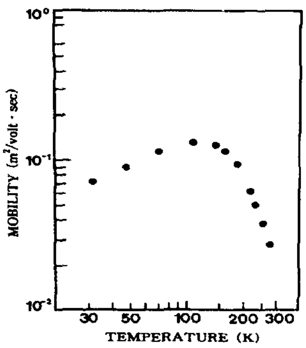

Fig. 1. Temperature dependence of mobility for $ZnGa_2Se_4$ single crystal thin films

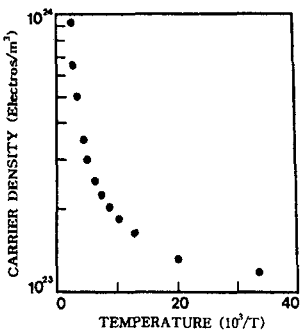

Fig. 2. Temperature dependence of carrier density for $ZnGa_2Se_4$ single crystal thin films

The optical absorption spectrum in the visible region was measured by a UV-VIS-NIR spectrophotometer at room temperature. Fig. 3. show the temperature dependence of the direct band gaps of the $ZnGa_2Se_4$. The temperature dependence of the direct energy gap is well satisfied with the Varshni equation

$$E_g(T) = E_g(0) - \frac{\alpha T^2}{T + \beta} \quad ---(1)$$

where, $E_g(0)$ is the band gap at absolute zero, α and βare constants. We can deduce from Fig. 3 that $E_g(0)$ is 2.38eV for the $ZnGa_2Se_4$. The constants of the Varshni equation are given by α =7.83×10^{-4} eV/K, and β= 195 K, respectively.

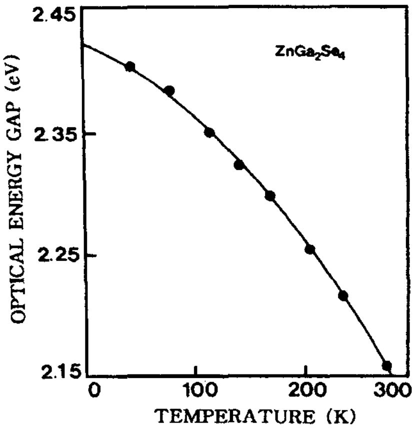

Fig. 3. Temperature dependence of the energy gaps in $ZnGa_2Se_4$ single crystal thin films. The solid line represents the fit to the varshni equation

4. CONCLUSIONS

As result of measuring Hall effect of $ZnGa_2Se_4$ single crystal thin film, we determined it was the p-type semiconductor. Activation energy obtained from ln n of carrier density versus 1/T was 0.45eV. Hall mobility was caused from piezoelectric scattering between 30K and 200K and decreased according to polar optical scattering betweem 200K and 293K. According to characteristic of photoabsorption, energy gap was 2.16eV at room temperature.The constants of the Varshni equation are given by α=7.83×10^{-4} eV/K, and β= 195 K.

REFERENCE

1. Sadao Adachi and Tsunemasa Taguchi, Phys. Rev. B 43, 9569 (1991).
2. M. A. Haase, J. Qiu, J. M. DePuydt and H. Cheng, Appl. Phys. Latt. 59, 1272 (1991).
3. T. Yasuda, I. Mitsuishi and H. Kukimoto, Appl. Phys. Latt. 52, 57 (1988).