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CdZnSe-ZnSe Multilayers by MOVPE Using Dimethylselenide

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The growth of CdZnSe-ZnSe multilayers using $(CH_3)_2Se$ at 475°C is reported. Despite the occurrence of thermally induced diffusion, observed by SIMS, quantum wells of the desired alloy composition can still be grown if the well width is greater than about 10 nm. The uniform layers allow stimulated emission to be obtained at 77 K from a multi-quantum well sample under nitrogen laser excitation.

1. INTRODUCTION

The growth of CdZnSe-ZnSSe multilayer structures has recently led to the production of the first blue/ green laser diodes by molecular beam epitaxy (MBE)[1]. However comparatively few studies have been made using metal-organic vapour phase epitaxy (MOVPE). This may be due to a number of factors: the absence, at present, of high quality p-type MOVPE grown ZnSe; the problem of poor surface morphologies - leading to wavy interfaces using hydride based MOVPE[2], and the potential problem of inter-layer diffusion for structures grown with $(CH_3)_2Se$ due to the higher growth temperature that is required[3,4].

Photopumped lasing has been observed in MOVPE grown ZnSe-CdSe superlattices using H_2Se as the group VI source[5]. However, the maximum temperature that lasing can be observed at is very low, around 40 K, due to the layer fluctuations that are observed in such structures, for example by TEM[2].

In this paper we examine the possibility of growing CdZnSe-ZnSe multilayer structures using $(CH_3)_2Se$ as the group VI source. The growth of CdZnSe has been reported previously[4]. In this study the stability of the resulting structures against interface diffusion in particular is examined.

2. EXPERIMENTAL

The epitaxial structures were grown on (100) GaAs substrates prepared in the usual manner[4] in a vertical transport MOVPE reactor. Dimethylzinc, dimethylcadmium and dimethylselenide were used as the reactants. Growth was carried out under the conditions listed in Table 1.

Table 1: MOVPE Growth Conditions

Substrate	(100) GaAs
Growth Temperature	475°C
Growth Pressure	780 Torr
Total H_2 Flow	2 $l min^{-1}$
Flow $(CH_3)_2Zn+(CH_3)_2Cd$	18 $\mu molmin^{-1}$
Flow $(CH_3)_2Se$	38 $\mu molmin^{-1}$
VI/II Ratio	2.1

The resulting layers were examined by secondary ion mass spectrometry (SIMS), transmission electron microscopy (TEM) and photoluminescence (PL).

SIMS was performed using Cs^+ ion ablation. TEM samples were prepared for examination in (110) projection by thinning using Ar radical milling. A He-Cd laser was used to excite the samples, which were cooled in a variable flow He cryostat.

3. RESULTS AND DISCUSSION

In order to assess the interface stability of CdZnSe-ZnSe superlattices two structures, 'A' and 'B' were grown, each consisting of two CdZnSe quantum wells of the same thickness sandwiched between ZnSe layers. The total thickness of the structures were kept below the critical thickness of the layer as a whole in order to prevent misfit dislocations, which may affect the diffusion properties of the layers, from forming. The CdZnSe well widths in the two samples were 5 nm in structure A and 20 nm in structure B respectively and the nominal Cd compositions, x, were 0.3 (A) and 0.05 (B). In both cases the structures were analyzed by SIMS and TEM.

Figure 1 shows the SIMS profiles for the layers described above. In both cases the deeper well is less well defined than the shallower one, and the interfaces become progressively poorer as one goes deeper into the layer. Furthermore in structure A (Figure 1a) the maximum composition of the two wells is different. (The maximum well depth even of the shallower layers is also much less than was expected - but the effect is too large to be due to diffusion alone suggesting that other factors may be at work.) These results are as one would expect if interdiffusion during growth is a problem.

TEM of the two structures showed that the layers were sub-critical thickness, with no misfit dislocations being observed at the substrate-epilayer interface. However the low Cd composition of the wells made them difficult to see. Furthermore orienting the sample onto a projection more sensitive to compositional variations was impossible. In structure B the shallower well only could be clearly discerned, while the contrast was not sufficient to observe the lower well - confirming the presence of interdiffusion during growth.

These results confirm that it is essentially impossible to grow atomically abrupt CdZnSe based common-anion multilayers using $(CH_3)_2Se$ as the group VI source. However wider wells, greater than about 10 nm may be grown if some diffusion is acceptable and the growth time after the start of the multiple layer growth is not excessive.

Based on these results a sample consisting of 3, 30 nm $Cd_{0.05}Zn_{0.95}Se$ quantum wells separated by 30 nm ZnSe barriers and surrounded by a thick 2 μm buffer and 1 μm cap was grown (Structure C).

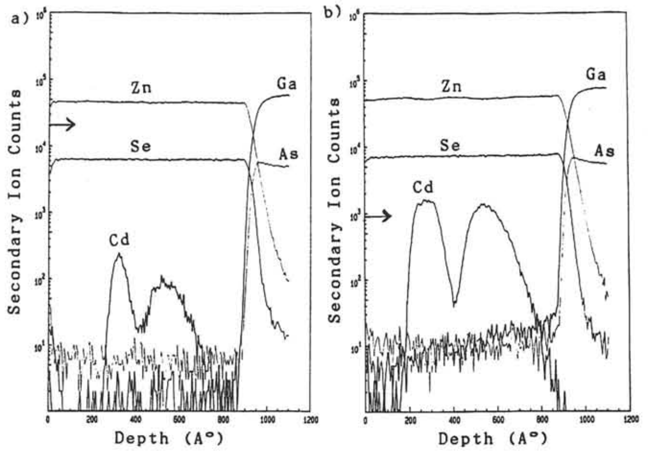

Fig.1 SIMS profiles for a) structure A and b) structure B. Arrows mark expected Cd level.

Figure 2 shows the SIMS profile through this sample. Three wells of the expected alloy composition are found. Unfortunately the resolution of the SIMS is not sufficient to determine the amount of interdiffusion that has occurred in this case. Three wells are also observed by TEM.

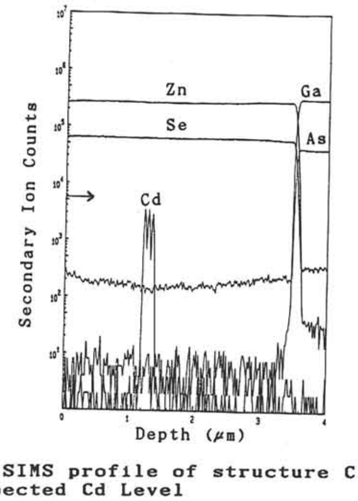

Fig.2 SIMS profile of structure C. Arrow marks expected Cd Level

The very low Cd concentration in the wells of structure A made the photoluminescence difficult to interpret. A relatively weak peak around 445 nm was observed at 77 K. In contrast, structure B showed much stronger emission, with a main peak around 465 nm, suggestive of quantum well luminescence. Two other peaks, visible as shoulders on either side of the main peak were also found. The emission was quite broad, with a full width half maximum (FWHM) of 4.5 nm suggesting that some inhomogeneity was present in the wells, either in alloy composition or in well width.

Structure C exhibited strong photoluminescence around 460 nm when excited at 77K. Furthermore the main peak was considerably narrower than for structure B, with a FWHM of less than 1.5 nm, this value decreased further to around 1 nm at liquid Helium temperatures. A second higher energy peak was also found.

For both samples which exhibited bright luminescence (structures B and C) strong emission could be observed up to over 100 K. As the temperature was raised the intensity ratio of the various near-bandedge peaks varied - in a different manner in each of the two cases - suggesting that the multiple peaks come from different sources in structure B and C.

4. PHOTOPUMPED LASING

Laser cavities were prepared from structures B and C by thinning the substrate, followed by cleaving strips varying from .25 to 2 mm in length. When excited by 600 ps N_2 laser pulses at 77 K bright polarized edge emission (Figure 3), indicative of lasing, is observed at a wavelength of 465 nm from structure C. However from structure B no such luminescence could be observed.

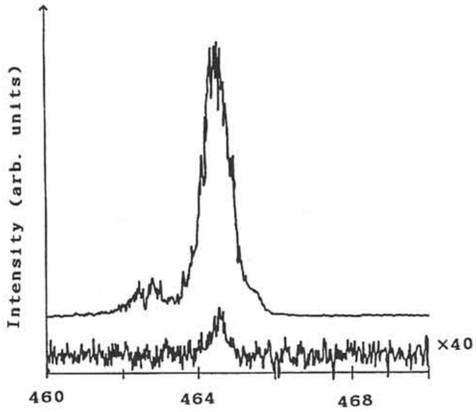

Fig.3 Polarization of the edge emission of a cavity cleaved from structure C. T=77K, $I=10I_{th}$.

For a 250 μm cavity of structure C a threshold of around 100 $kWcm^{-2}$ was estimated (Figure 4). The relatively high value for the threshold intensity may be due to the extremely short pulse length of the N laser leading to a relatively inefficient pump. Further experiments using a longer pulse length laser are in progress.

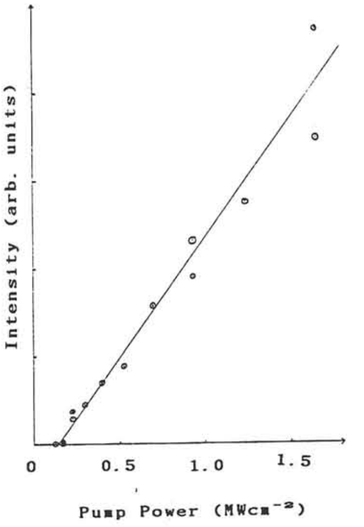

Fig.4 Sample intensity vs. N laser pump power for a 250μm cavity of structure C.

5. CONCLUSIONS

It has been shown that multiple layer structures of CdZnSe-ZnSe can be grown using dimethylselenide, despite the higher growth temperatures that are required. However, atomically abrupt interfaces are not achievable and a minimum thickness limit of about 10nm must observed. If these conditions are followed highly planar wells, from which lasing can be observed under optical pumping, are achievable.

6. REFERENCES

1) M. A. Haase, J. Qui, J.M. DePuydt and H. Cheng, Appl. Phys. Lett. 59(1991) 1272.
2) P.J. Parbrook, P.J. Wright, B. Cockayne, A.G. Cullis, B. Henderson and K.P. O'Donnell, J. Crystal Growth 106(1990) 503
3) P.J. Parbrook, B. Henderson, K.P. O'Donnell, P.J. Wright and B. Cockayne, Semicond. Sci. Technol. 6(1991) 818.
4) P.J. Parbrook, A. Kamata and T. Uemoto, J. Crystal Growth (submitted).
5) K.P. O'Donnell, Y. Fujii, P.J. Parbrook and I. Suemune, J. Crystal Growth 117(1992)1077.