3-3 Heterostructure $CdS_{1-x}Se_x$ Surface Lasers

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1. Introduction CdS, CdSe and mixed crystals of them are efficient materials for visible semiconductor lasers. In the case of the mixed crystals the laser wavelength can be controlled from 490-690 nm by changing the mole fraction of Se in the mixed crystals. These mixed crystals which have been used for laser experiments have been grown by the melt grown or sublimation method. The solid state diffusion is also convenient method to produce the mixed crystals[1),2)]. By using this method a mixed crystal layer can be constructed on the surface of the substrate. Taylor et al. have fabricated the optical waveguides on CdS substrates by this method[3)]. Another method to get a mixed crystal surface layer is the vapor phase epitaxy.

In this paper new-type thin layer semiconductor lasers fabricated by two different methods, solid state diffusion of Se into CdS substrate and epitaxial growth of $CdS_{1-x}Se_x$ on CdS single crystals are reported. Since the refractive index of the mixed crystal is larger than that of CdS, the light is expected to be confined in the surface thin layer similarly to the heterojunction diode lasers. In the field of integrated optics, semiconductors, especially single crystals are promissing materials because they lase by them selves and show efficient electo-optic and acoust-optic effects. Therefore, they have probability of monolithic devices using the established IC technology. In the case of the semiconductor surface lasers where the light is confined in the surface thin region, the thickness of which is the order of wavelength, they have additional merits as elements of integrated optics devices, such as, easier coupling with external waveguides than in the case of diode lasers and efficient interaction with surface acoustic waves because the thickness of the laser region is similar to the wavelength of the acoustic waves.

2. Experimental In the case of the sample by solid state diffusion, the mixed crystal layers were fabricated by the method similar to Taylor et al..[3)] A vapor grown platelets of CdS was sealed in a quarts tube with appropriate amount of sulfur, selenium and CdS powder at a pressure of 3×10^{-6} Torr and fired at 500°C for several hours. In the case of the epitaxial growth, $CdS_{1-x}Se_x$ layer was grown by succesive sublimation of the mixture of CdS and CdSe powder after the growth of CdS platelets. The value of x and the thickness of the layer depends on the time of the second sublimation step and the distance from the source. Since the growth rate perpendicular to the flat surface is very small, it took about ten minutes to get several micron thickness. Figure 1 shows a profile of the Se mole fraction in the thin layer fabricated by the second method. This result was obtained by observing the wavelength of the luminescence of the surface etched step by step. Platelets were cleaved to form Fabry-Perot cavities, the length of which were about 100μm - 200μm. The cleaved samples were attached to a cold finger of a

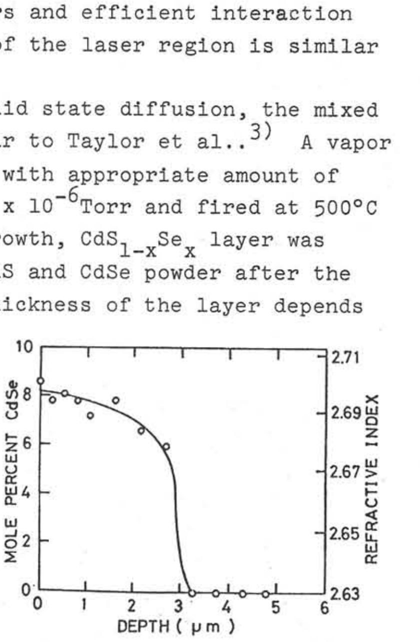

Fig.1 Distribution of CdSe in the mixed crystal layer

liquid nitrogen cryostat and excited by a nitrogen gas laser, the maximum power of which is about 80 kW.

3. Results and Discussion Laser emission was observed from two kinds of samples prepared by the two different methods. However, the samples fabricated by the epitaxial method have lower threshold than those by diffusion. Figure 2 is an example of spectral change with pump power. The laser wavelength at high excitation density shifts toward short wavelength. This is because there is a gradual distribution of CdSe and the minimum threshold which depends on the CdSe quantity and lattice defects is different at different depth. It is clear from the accumulated results of CdS and CdSe that these emission are due to exciton process, however sharp exciton lines were not observed at low pump power as well as the results of mixed crystals prepared by vapor-growth.[4)] Figure 3 is a microphotometer trace of a near field pattern of the laser. Angular distribution of the laser light in the plane perpendicular to the surface layer also indicates that the light is diffracted at the end of the cavity of 2.5μm width. From these results and Fig.1, it is clear that the light is confined in the surface layer. The width of the laser region differs from sample to sample according to the thickness of the layer. However, the depth of the excited region depends on the penetration depth of the pump light and the ambipolar diffusion of carriers. The penetration depth of the exciting light is below 0.1μm and the diffusion length during about 10 nsec which is the pulse width of the laser emission, is estimated to be about 0.3μm using the hole and electron mobility at 100 K.[5)] Therefore, the surface layer of a few micron consists of a gain region and loss region. To minimize the threshold, the thickness of the surface layer should be submicron when excited by the nitrogen gas laser.

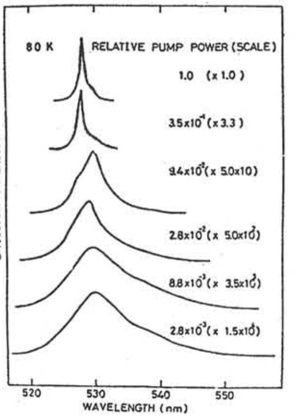

Fig.2 Spectral change with pump power

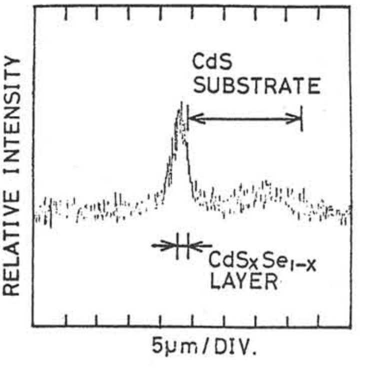

Fig.3 Microphotometer trace of the near field pattern

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