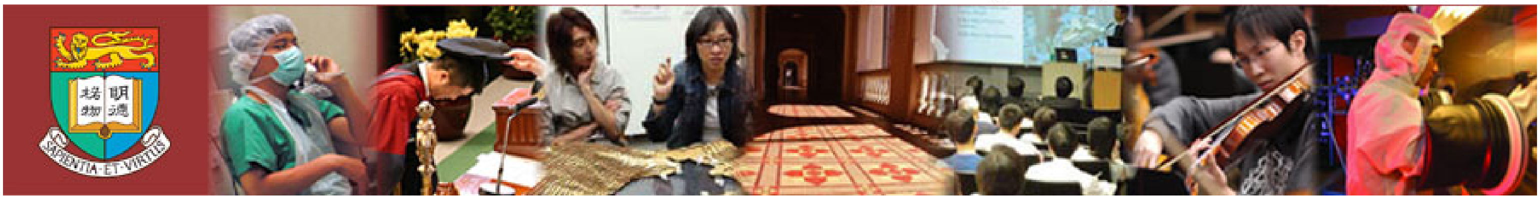

Single versus double ion implantation defined AlGaAs/GaAs Quantum Well Waveguide

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Over the past years, the effect of impurity induced disordering (IID) on Multi-Quantum Wells (MQW) waveguides with particular emphasis on the interdiffusion of AlGaAs/GaAs QW materials has been extensively studied [1]. This technique of IID, which provides an efficient way to realise waveguide structures for optoelectronic integrated circuits, offers a planar technology capable of altering the band gap [2] and optical properties [3] of the material. Although there has been a lot of efforts spent in studying the electronic and optical properties of IID modified AlGaAs/GaAs MQW structures, limited work has been reported so far about the improvement of the waveguiding properties of this type of device. The purpose of this work, therefore, is to investigate into this aspect by considering the effect of member of ion implantations on a two-dimensional IID waveguide structure.

The waveguide structure, to be analyzed here consists of AlGaAs/GaAs MQWs on a thick $Al_{0.3}Ga_{0.7}As$ buffer layer, and is shown in Fig. 1. The mask width is varied from $0.5\mu m$ to $3\mu m$ and the MQW layers are composed of 20 to 50 periods of 100Å GaAs QWs and 100Å $Al_{0.3}Ga_{0.7}As$ barriers ($0.4\mu m$ to $1\mu m$ thick). A $3\mu m$ thick $Al_{0.3}Ga_{0.7}As$ buffer layer is introduced to avoid the diffusion of impurities from the substrate layer. In the single implantation, the implant energy of 1MeV, which projected range falls near the middle of a $1\mu m$ thick waveguide, is chosen as a constant in order to have a wider range of investigation. In order to maintain a constant and an even distribution of implanted impurities, different combinations of the implant energy and dose of the double implantation are carefully chosen for each sample, and are listed in Table 1. The cross section views of the double implantation of these combinations are shown in Fig. 2. This implantation is assumed to be carried out at room temperature and the waveguiding characteristics are studied at 0.85μm to 1.55μm operating wavelengths. The effect of the number of QWs (or the depth of the structure) and the width of the mask on ion implantations are evaluated by studying the full width half maximum, F_x, of the near-field intensity pattern of the fundamental lateral mode [4].

The best lateral confinement is obtained by double implantation set C. It is shown in Fig. 3 that the double implantation can offer an improvement from an effectiveness of 1% to more than 12% as compared with the 1MeV single implantation. With a shorter operating wavelength, and hence a larger refractive index difference, Δn_r, the lateral confinement is already quite strong. Therefore, in this case, double implantation seems not necessary. Likewise, when the interdiffusion time is increased, the lateral confinement becomes strong and so the enhancement of the double implantation becomes ineffectual. Under the same conditions as in Fig. 3, for 1.55μm operation, the effect of the mask width on F_x is shown in Fig. 4 for different implant energies. The lateral confinements of all the double implantations are stronger than that of the single implantation, where set C is the best. This improvement is larger with a smaller the mask width. On the other hand, lateral confinement can also be affected by the thickness of the waveguide (periods of QWs). Single implantation is best if the periods of QWs are larger than 35 while double implantation is preferred if the periods of QWs is smaller than 35 (see Fig.5). It may be due to the fact that the single implant energy is fixed as a constant 1MeV.

The modal properties of MQW waveguides fabricated using the ion-implantation IID technique have been investigated. Optical confinement properties are examined by studying on F_x as functions of annealing time. After reviewing all the results, it is found that double implantation is not as useful as expected for all situations. It is effective only when the refractive index difference is small, $\Delta n_r < 0.03$, the mask width of the waveguide is narrow, less than 0.9μm, and the core thickness of the waveguide is thin, less than 0.7μm.

Table 1. The combinations of different implant doses and energies used as samples

Combinations	1^{st} Energy	1^{st} dose	2^{nd} Energy	2^{nd} dose
Single implantation, I_s	1 MeV	1×10^{13}	0	0
Double implantation A, I_A	1 MeV	7.86×10^{12}	200 keV	2.14×10^{12}
Double implantation B, I_B	1 MeV	6.73×10^{12}	400 keV	3.27×10^{12}
Double implantation C, I_C	1 MeV	5.97×10^{12}	600 keV	4.03×10^{12}
Double implantation D, I_D	1 MeV	5.41×10^{12}	800 keV	4.59×10^{12}

Fig. 1 The schematic of the structure.

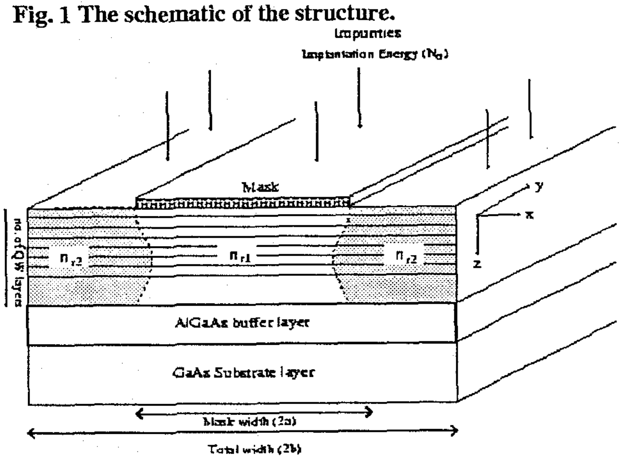
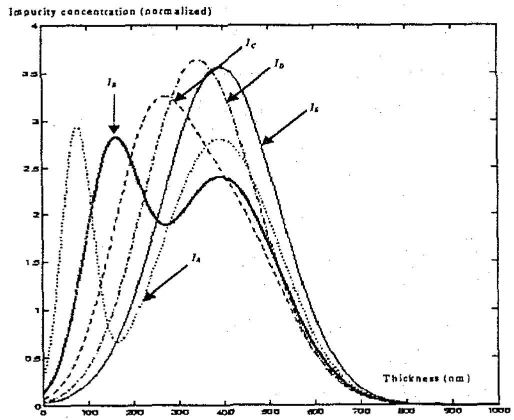


Fig.2 The cross section views of the implantation combinations.



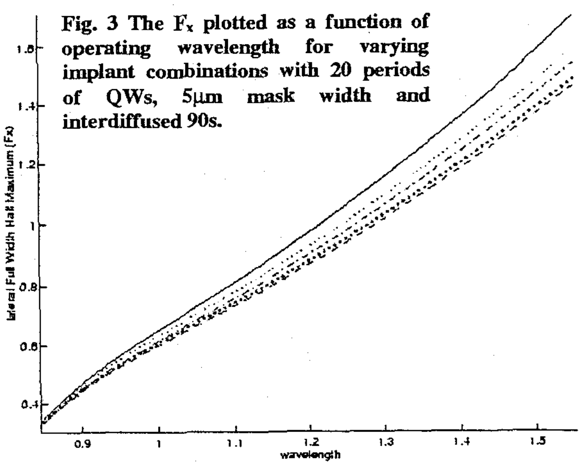


Fig. 3 The F_x plotted as a function of operating wavelength for varying implant combinations with 20 periods of QWs, 5μm mask width and interdiffused 90s.

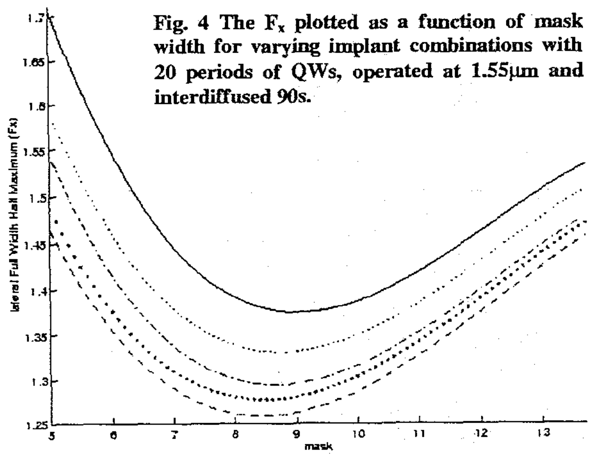


Fig. 4 The F_x plotted as a function of mask width for varying implant combinations with 20 periods of QWs, operated at 1.55μm and interdiffused 90s.

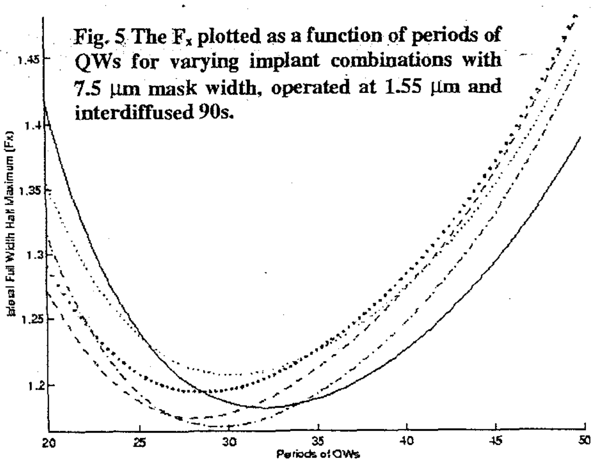


Fig. 5 The F_x plotted as a function of periods of QWs for varying implant combinations with 7.5 μm mask width, operated at 1.55 μm and interdiffused 90s.

References:

[1] K. P. Homewood and D. J. Dunstan, "Optical characterization of thermal mixing in quantum wells and heterostructures using a Green's function model", *J. Appl. Phys.*, Vol. 69, pp. 7581-7584,1991.

[2] E. H. Li, B. L. Weiss, and K. S. Chan, "Effect of interdiffusion on the subbands in an $Al_xGa_{1-x}As/GaAs$ single quantum-well structure", *Phys. Rev. B.*, vol.46, pp. 15180-15191, 1992

[3] I. Harrison, "Impurity-induced disordering in III-V multi-quantum well and superlattices," *J. Mat. Sci.: Mat. in Electron.*, vol. 4, pp. 1-28, 1993.

[4] E. Kapon, N. G. Stoffel, E. A. Dobisz, and R. Bhat, "Birefringent channel waveguides defined by impurity-induced superlattice disordering", *Appl. Phys. Lett.*, vol. 52 (5), pp. 351-353, 1988.