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NN PAIR EMISSION IN $GaAs_{0.15}P_{0.85}$:N UNDER HYDROSTATIC PRESSURE*

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The photoluminescence of $GaAs_{0.15}P_{0.85}$:N has been studied at 77K under hydrostatic pressure. The NN_1 emission is clearly observed when P>10kbar. This result indicates that pressure enhances the thermally assisted $N_x \to NN_1$ exciton transfer. The pressure behaviors of N_x and NN_1 levels are analysed.

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In GaP:N, nitrogen atoms could produce a set of sharp bound exciton luminescene lines, attributed to isolated N atoms (A line) or *i*th nearest neighbor pairs of N atoms (NN_i lines)[1]. In $GaAs_{1-x}P_x$:N, due to alloy disorder effect the spectral lines are inhomogeneously broadened[2]. The relationship between the widths of spectral lines and compositions indicates that alloy disorder plays a very important role in $GaAs_{1-x}P_x$:N system. Wolford et al.[3] showed that for $x \leq 0.87$ there were not any observable NN_i lines at low temperature, and the spectra were composed of N_x band and its phonon sidebands. Kash[4] suggested a mechanism for $N_x \to NN_i$ exciton transfer in $GaAs_{1-x}P_x$:N and explained the disappearence of NN_i lines at low temperature. He also suggested that due to the different As-P configurations around nitrogen centers, they could be immonoenergetic, so there exist so called local energy minimum sites (LEMS). Bound excitons will rapidly transfer to these LEMS, which may effectively inhibit the tunneling transfer of $N_x \to NN_i$. However, with increasing temperature, thermal activation processes may be helpful for the $N_x \to NN_i$ exciton transfer. Kash et al.[5] have observed the NN_i lines due to thermally assisted exciton transfer in sample with x=0.96. But for samples with lower x, there are still no observable NN_i lines in normal photoluminescence even increasing the temperature.

This work has investigated the bound exciton luminescence of $GaAs_{1-x}P_x$:N with x=0.85 under hydrostatic pressure, ranging from 0 to 32kbar. The pressure system was a diamond anvil cell submerged in liquid-nitrogen bath. The details of experimental methods and optical set up were described in ref.6. The sample was excited by an Ar-ion laser with

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excitation density about $10^3 W/cm^2$. The detection system was composed of GDM-1000 monochrometer, C31034A PMT, PAR1112 photo counter etc.

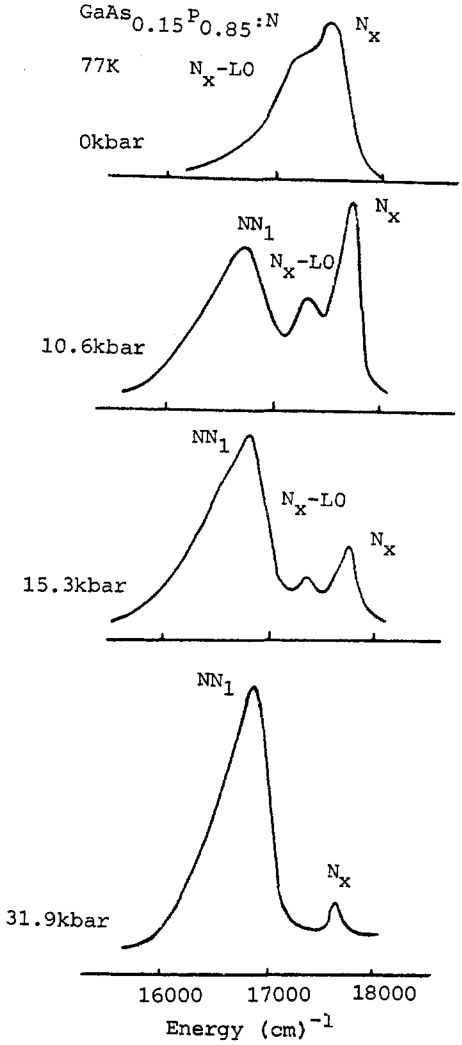

Fig.1 Photoluminescence spectra under different pressure.

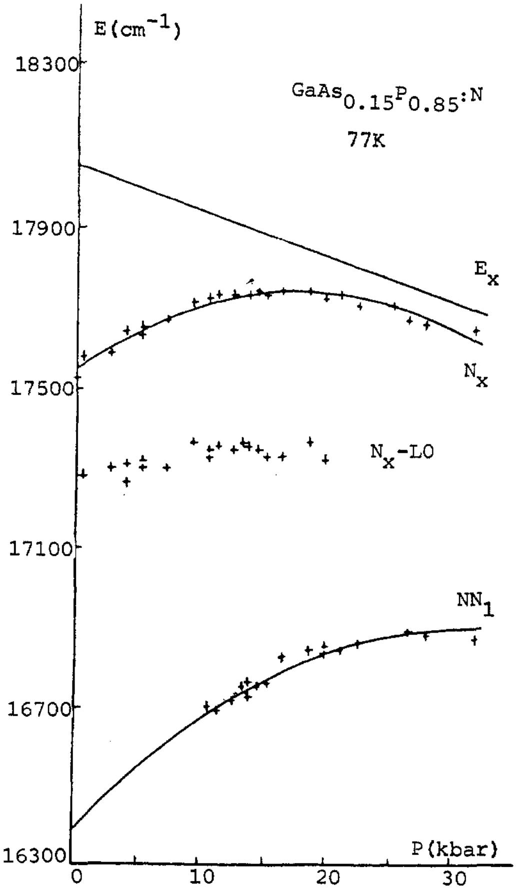

Fig.2 Pressure dependences of the peaks of luminescence lines and band-edge.

Under the hydrostatic pressure, we have clearly observed NN_1 line in such a somewhat low x $GaAs_{1-x}P_x$:N sample. Figure 1 shows the dependence of photoluminescence spectrum on pressure. Under normal pressure, the spectrum only shows N_x band and its phonon sidebands. As excitation density decreases, luminescence at low energy side of N_x band increases relatively to N_x band, which indicates that there might be some contribution from NN_i pairs although the NN_i lines are still unresolvable. When P >10 kbar, a new luminescence peak appears at energy 126meV lower than N_x band. As the pressure increases, the intensity of this peak enhances gradually and finally exceeds N_x band and is dominant in the spectrum. Since its energy position related to N_x band and its dependence on pressure are quite alike to the NN_1 in GaP:N, we consider this new peak as NN_1 pairs. This is similar to the assignment in ref.5, where in a higher composition sample the NN_1 emission line was observed at such a relative energy position by increasing temperature. The asymmetry in its low energy side suggests that NN_1 emission contains some phonon structure. The appearence of NN_1 under pressure indicates that $N_x \to NN_1$ exciton transfer should be enhanced by the applied hydrostatic pressure.

Figure 2 shows the dependences of the peak positions of N_x and NN_1 bands on the pressure. In $GaAs_{1-x}P_x$, the pressure coefficients of the Γ and L valleys are positive, and that of X valley negative[7,8]. For N_x level, as P < 10kbar, the pressure coefficient is 2.22meV/kbar; as P> 10kbar, its pressure behavior shows nonlinearity. After reaching a maximum at about 14kbar the energy of N_x level descends with a negative pressure coefficient, approaching to that of X valley. These phenomena may be explained that pressure makes the deep level shallow and increases the X valley contribution in bound exciton wavefunction. In addition, there is an increasing interaction between free and bound excitons since they get approach at higher pressure. This fact also affects the pressure behavior of N_x level. But the behavior of N_x level is different from that of line A in GaP:N (ref.7). The pressure coefficient of line A was nearly zero, as P > 8kbar, a line was replaced by free exciton line. Meanwhile, N_x band keeps existing up to 32kbar with its binding energy reducing to 9meV from 69meV at normal pressure. It is likely that because of having much larger binding energy and being more localized, N_x level composes of more Γ and L valley contribution in its wavefunction. Thus, its pressure behavior shows more characteristics of Γ and L valleys. Another important result is that the inhomogeneous broadening of spectral lines induced by alloy disorder is weakened under pressure. The width (FWHM) of N_x band reduces from 55meV to 17meV while pressure increases to 32kbar. The cause for this is that pressure makes the wavefunction more localized in k space, or, spatially more extended, so the energy dispersion due to different As-P configurations decreased by averaging in a larger spatial range. In fact, the density of LEMS was decreased by the narrowing of N_x band. For the NN_1 level, as P<20kbar, the dependence of the observed NN_1 band on pressure is nearly linear with pressure coefficient 2.38meV/kbar, which is larger than that of N_x level and also that of NN_1 level in GaP:N (1.43meV/kbar). With further increase of pressure, it becomes nonlinear. The disparity compared to N_x or NN_1 levels in GaP:N should be expected since NN_1 center is more localized in GaAsP alloy, so its pressure behavior possesses much characters of Γ and L valleys.

The pressure which decreases the binding energy of N_X level and weakens its inhomogeneous broadening leads to the enhancement of the thermal activation processes of N_X level, thus, enhancing the $N_X \rightarrow NN_1$ thermally assisted exciton transfer. The transfer may be attributed to two coexisting processes[5]. The first is related to retrapping at NN_1 centers caused by the thermal release of N_X bound excitons to free states (free exciton or free carrier). The decrease in binding energy is a favor to this process. The second is that excitons in lower levels of N_X band is thermally excited to the higher levels than tunnel to NN_1 centers. The narrowing of N_X band is a favor to this process. With the enhancement of $N_X \rightarrow NN_1$ transfer, the intensity of N_X band quenches severely under pressure at least by two orders. In practice, it means that thermal quenching processes are enhanced under pressure.

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