TIME RESOLVED STUDY OF NON RADIATIVE RECOMBINATION IN GaAs GaAlAs HETEROSTRUCTURES

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TIME RESOLVED STUDY OF NON RADIATIVE RECOMBINATION IN GaAs GaAlAs HETEROSTRUCTURES

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I. Introduction: The threshold current in double heterostructure lasers is proportional to the recombination probability in the active layer 1/t. In the case of the GaAs-GaAlAs lasers, the recombination probability has two components: the radiative one 1/t_\text{r} and the non radiative one 1/t_\text{nr}.

\[ \frac{1}{t} = \frac{1}{t_\text{r}} + \frac{1}{t_\text{nr}} \] (1)

The laser will be of practical use if t_\text{nr} is large compared to the radiative life time at threshold carrier density (~\SI{4}{\nano\second}). The non radiative recombination probability, 1/t_\text{nr} (called Schokley-Read) is the sum of the bulk and the interface recombination probabilities:

\[ \frac{1}{t_\text{nr}} = \frac{1}{t_\text{nrb}} + \frac{S}{d} \] (2)

where d is the GaAs layer thickness and S = S_1 + S_2 is the sum of the interface recombination velocity at the two interfaces. Eq. 2 is valid when the GaAs layer thickness is small compared to the carrier diffusion length which is the case here.

Quantum well lasers have proved to be interesting devices (1) (smaller threshold current, larger modulation frequency). However, in such small active layer thicknesses (d~\SI{50}{\nano\meter} to \SI{100}{\nano\meter}), interface recombination can be dramatic.

II. Experiment: We have studied four series of samples (3 grown in MBE and 1 in MOCVD). All the structures consisted of a GaAs layer of thickness d included between two Ga_\text{1-x}Al_\text{x}As layers with x about 0.3.

The experimental technique is as follows: we excite each sample with a synchronously pumped CW dye laser at 0.58 \mu m and observe the luminescence decay with a streak camera. The GaAs luminescence is selected with a monochromator and the temporal resolution of the system is about \SI{10}{\pico\second}. Examples of luminescence decay curves obtained with the streak camera at low excitation are given in fig.1.

The carriers lifetime (t) and the luminescence lifetime (t_L) at the end of the excitation pulse are related by:

\[ t = t_L \frac{d\log(I_L(0))}{d\log(n)} = t_L \frac{d\log(I_L(0))}{d\log(P_{\text{exc}})} \] (3)

where I_L(0) is the luminescence intensity at that time.
The radiative lifetime $t_r$ is obtained from:

$$I_L(0) \sim (dn/dt)_{rad} \sim n.1/t_r \sim P_{ex}/t_r$$ (4)

For each sample, we plot the recombination probability $1/t$ and $I_I/P_{ex}$ as a function of $P_{ex}$ as shown in Fig. 2. At low excitation $1/t$ is nearly constant while $1/t_r$ decreases, showing that this constant value is the probability of nonradiative recombination $1/t_{nr}$. Fig. 3 displays the radiative and the total recombination probability for different GaAs thicknesses.

For large GaAs thicknesses ($d > 200\text{Å}$) $1/t_{nr}$ follows eq. 2 as shown in Fig. 4.

For small GaAs thicknesses ($d < 200\text{Å}$), $S$ (given by $S = 1/t_{nr} \times d$) increases as foreseen by Duggan et al. (1) due to the increase of the leaking of the carriers wavefunctions in the GaAlAs confinement layers.
Fig. 5 shows experimental values of $S$ for small values of $d$ as well as two theoretical curves assuming: 1) uniform distribution of nonradiative recombination centers in the GaAlAs barriers; 2) recombining centers concentrated at the interfaces. The curves are calculated for an offset of the conduction band equal to 67% of the band gap.

Fig. 6 shows $S$ measured for a series of polluted samples. A calculation that extends the previously cited models by adding to the recombination at the barriers the contribution of an impurity profile that decays exponentially from the interface towards the GaAs layer is also shown.

The increase of the interface recombination velocity represented in Fig. 5 is important for (Q.W.) lasers. For example, in the case of the second MBE series, the non radiative lifetime for 0.1 μm thick layers is 100 ns which is negligible compared to the radiative lifetime in usual DH lasers which is about 4 ns. However, in the case of a quantum well of 50 Å, the non radiative lifetime is about 2 ps and increases the calculated threshold current from 110 A/cm² in SCH optimised (Q.W.) lasers.

REFERENCES
