doi:10.1017/S1431927610058162
Microsc. Microanal. 16 (Suppl 2), 2010


# Novel Picosecond Time-Resolved Cathodoluminescence to Probe Exciton Recombination Dynamics in GaN and GaN Based Heterostructures

S. Sonderegger*, P. Corfdir**, L. Balet**, T. Zhu**, A. Dussaigne**, D. Martin**, J. Ristić**, P. Lefebvre***, J.-D. Ganière**, N. Grandjean**, B. Deveaud-Plédran**

*Attolight GmbH, Ch. de la Raye 13, 1024 Ecublens, Switzerland
**Institut de Physique de la Matière Condensée, Ecole Polytechnique Fédérale de Lausanne (EPFL), 1015 Lausanne, Switzerland
***present address : ISOM, Universidad Politécnica de Madrid, Ciudad Universitaria, 28040 Madrid, Spain

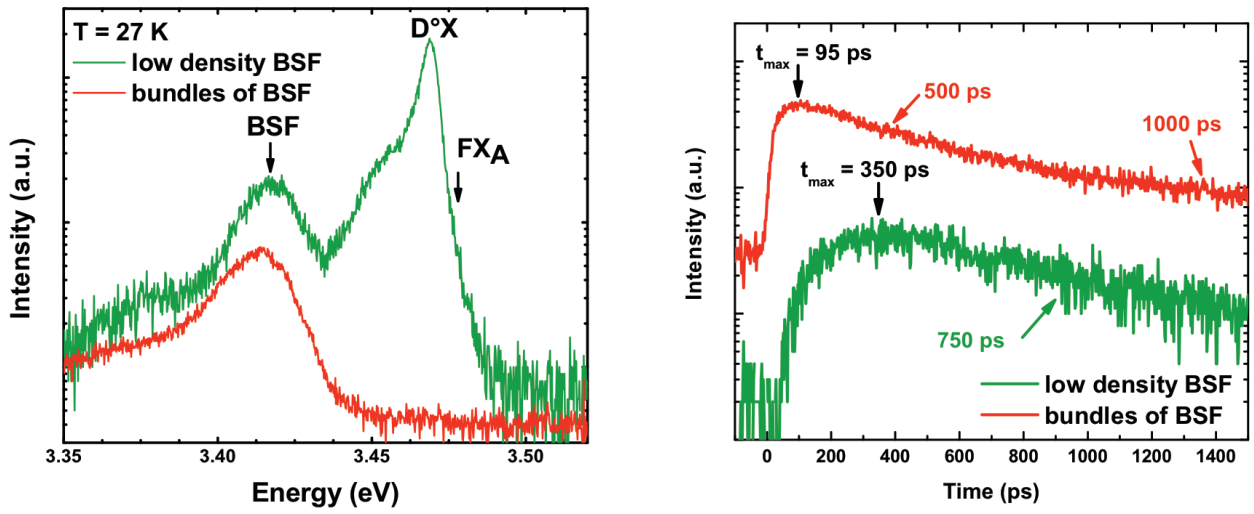
Picosecond and femtosecond spectroscopy allow a detailed study of carrier dynamics in nanosctructured materials [1]. In such experiments, a laser pulse usually excites several nanostructures at once. However, spectroscopic information may also be acquired using pulses from an electron beam in a modern scanning electron microscope (SEM), exploiting a phenomenon called cathodoluminescence (CL). This approach offers several advantages. The multimode imaging capabilities of the SEM enable the correlation of optical properties (via CL) with surface morphology (secondary electron mode) at the nanometer scale [2]. The large energy of the electrons allows to excite wide-bandgap materials. Here, we present results obtained with an original time-resolved cathodoluminescence (TRCL) setup [3]. This setup uses ultrafast UV laser pulses to create short photoelectron pulses. The laser pulses illuminate a metal photocathode from which the electrons are extracted and accelerated inside the electro-optical column of the microscope and focused on the sample surface. The collected CL signal is analyzed in a spectrometer and in an ultrafast camera (STREAK camera) to obtain high time resolution.

We reach combined space and time resolutions of 50 nm resp. 10 ps at an average probe current of 10 pA. Measurements can be carried out at temperatures between 20K and 300K. Here, we present results on InGaN quantum wells (QW) [4] and *a*-plane GaN [5] and will also describe the TRCL setup in detail.

We have first studied metal organics vapour phase epitaxy grown $In_{0.18}Ga_{0.82}N$/GaN quantum wells (QW). We observe a contrast inversion between monochromatic CL maps corresponding to the high energy side (3.13 eV) and the low energy side (3.07 eV) of the QW luminescence peak which can be perfectly correlated with the morphology of the sample surface obtained by atomic force microscopy measurements showing pronounced valleys in the <1-100> directions. When exciting inside such valleys, the time resolved measurements exhibit a pronounced spectral diffusion (~80 meV) towards lower energies. This is an unambiguous indication of carrier diffusion processes from high to low energy regions, evidencing an energy screening of dislocations inside these valleys. This may provide an explanation for the high luminescence efficiency of (In,Ga)N based devices.
The second sample is an epitaxial lateral overgrown (ELO) *a*-plane GaN grown by hydride vapor phase epitaxy on *r*-plane sapphire that has been studied at 27 K. Large densities of basal stacking faults (BSFs) are usually observed in *a*-plane GaN. These extended defects can be seen as a type-II

QWs and give rise to a broad and intense emission at 3.42 eV (50 meV below the emission energy of the D°X of wurtzite GaN [6]).

We evidence that exciton localization and recombination processes are strongly dependent on the local BSF density. In low-BSF-density zones, we show that diffusion of free excitons towards BSFs is donor assisted. On the other hand, zones with BSF bundles are shown to totally inhibit the D°X emission (Fig. 1-a). The change in BSF-bound exciton luminescence decay time is explained through direct relation to the local BSF density (Fig. 1-b).




(a) (b)

Figure 1. Time-integrated CL spectra of *a*-plane ELO GaN (a) and luminescence decays of the BSF emission (b) taken at 27 K when exciting on low-density or on bundles of BSF (respectively green and red spectra and transients).

**References**

[1] Shah, J. Ultrafast Spectroscopy of Semiconductors and Semiconductor Nanostructures Ch. 8 (Springer, Berlin, 1999).
[2] Reimer, L. Scanning Electron Microscopy Ch. 1 (Springer, Berlin, 1998).
[3] M. Merano *et al.*, Nature 438, p479 (2005).
[4] S. Sonderegger *et al.*, Appl. Phys. Lett. **89**, 232109 (2006).
[5] P. Corfdir *et al.*, Appl. Phys. Lett. **94**, 201115 (2009).
[6] P. Corfdir *et al.*, J. Appl. Phys. **105**, 043102 (2009).

https://doi.org/10.1017/S1431927610058162 Published online by Cambridge University Press