Contactless cathodoluminescence method for GaAs doping measurement at the nanoscale

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Nanotechnology is widely used in all domains of photovoltaics to understand material properties and improve the conversion efficiency. In particularly, III-V nanowire arrays are promising novel structures to explore new concepts and integrate III-V on Si without threading dislocations. To ensure the optimal performance of the device, the control and characterization of doping at the nanoscale are essential and require a technological effort.

We demonstrate the use of cathodoluminescence (CL) mapping as a way to probe the doping level in a single GaAs nanowire (NW). A series of planar GaAs samples are used to establish a distinct luminescence signature as a function of both n-type and p-type doping levels. GaAs NWs are grown by Molecular Beam Epitaxy (MBE) with Si as n-type dopant and Be as p-type dopant. NWs are dispersed on a Si substrate and individually measured by CL at temperatures ranging from 20 to 300 K.

For degenerate n-type GaAs (n>5×10^{17} cm^{-3}), we observe a blueshift of the CL emission (Burstein-Moss shift), and the generalized Planck's law is used to fit the whole spectra and to extract precisely the electron concentration [1]. We demonstrate electron concentrations of n=10^{18} cm^{-3} [1]. For moderately p-doped GaAs (p<7×10^{17} cm^{-3}), we observe luminescence from a separated acceptor band above the valence band edge at 20 K. At higher doping level, the acceptor band merges with the valence band and results in a single wide CL peak (Fig. 1(b)). The CL spectra continuously redshift with increasing p-doping level, corresponding to the bandgap narrowing effect. A careful spectral analysis is conducted to correlate the optical bandgap with the doping level, and we achieve p>10^{19} cm^{-3}. This study demonstrates the possibility of mapping free carrier concentrations at the nanoscale by a contactless optical method for both n- and p-type semiconductors.

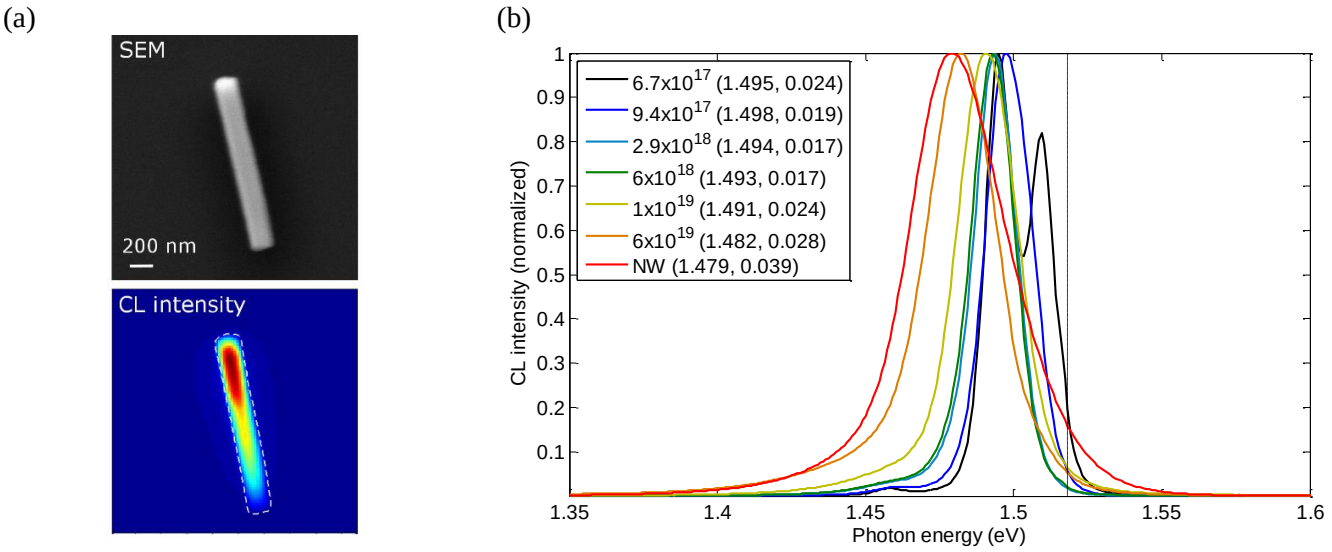

Figure 1: (a) SEM image and CL intensity map of a single Be-doped GaAs NW. (b) 20K CL spectra of GaAs films (p-doping levels are shown in cm^{-3}) and of NW. (Peak energy, FWHM) of each spectrum are noted in eV. The vertical line indicates the GaAs bandgap.

[1] "*Determination of n-type doping level in single GaAs nanowires by cathodoluminescence*", H.-L. Chen et al., submitted (2017).