Contactless n-type doping measurement of single GaAs nanowire by cathodoluminescence

Hung-Ling Chen[1], Andrea Scaccabarozzi[1,2], Chalermchai Himwas[1,3], Andrea Cattoni[1], Pierre Rale[1], Fabrice Oehler[1], Aristide Lemaître[1], Laurent Lombez[4], Jean-François Guillemoles[4], Maria Tchernycheva[3], Jean-Christophe Harmand[1], Stéphane Collin[1,2]

[1]*Centre de Nanosciences et de Nanotechnologies (C2N), site de Marcoussis, CNRS, 91460 Marcoussis*

[2]*Institut Photovoltaïque d'Ile-de-France (IPVF), 8 rue de la Renaissance, 92160 Antony*

[3]*Centre de Nanosciences et de Nanotechnologies (C2N), site d'Orsay, CNRS, Université Paris-Sud, 91405 Orsay*

[4]*Institut de Recherche et Développement sur l'Energie Photovoltaïque (IRDEP) EDF/CNRS/Chimie Paris Tech, 78400 Chatou*

E-mail : hung-ling.chen@lpn.cnrs.fr

Nanowire arrays are promising architecture to realize efficient opto-electronic device. In photovoltaic application, they present natural light-trapping properties. Small lateral dimension makes it possible to integrate III-V nanowires on silicon cells, or to fabricate flexible devices. However, controlling and measuring the nanowire doping is one of the most challenging issues.

We investigate the carrier concentration from room-temperature cathodoluminescence measurement of silicon doped GaAs samples. Figure 1 shows normalized luminescence of un-doped reference, MBE grown GaAs:Si nanowire, and three planar reference samples with electron density determined by Hall measurements, ranging from 5×10^{17} to 6×10^{18} cm^{-3}. The spectra present only a single peak across the bandgap of GaAs (1.424eV at room temperature), indicating dominant band-to-band transition. We observe a blueshift of the peak energy with increasing electron density (Burstein-Moss shift), confirming n-type silicon dopant since conduction band has much smaller effective density of states than valence band. At lower energy side, luminescence tails are developed with increased carrier concentration as a result of increased potential fluctuation from ionized donor. The doping of GaAs:Si nanowires is estimated to $3\text{-}5\times10^{18}$ cm^{-3}.

Luminescence lineshapes are further analyzed with the generalized Planck's law to retrieve physical parameters such as electron Fermi energy and the band tail broadening parameter. Both of them can be related to the electron concentration. Cathodoluminescence gives an alternative way to probe carrier concentration for nanoscale materials, and is able to detect spatial inhomogeneity of dopant.

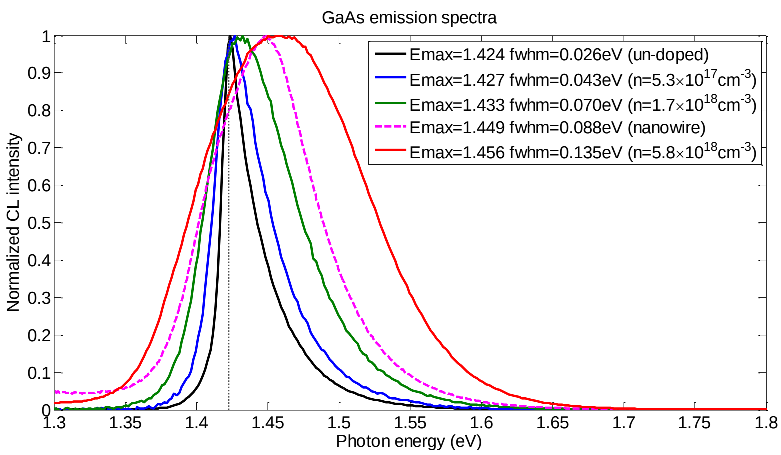

Figure 1: Comparison of GaAs luminescence spectra with different n-type doping concentration.