ESRF	**Experiment title:** **Strain engineering studies of individual GaAs/AlGaAs nanowires**	**Experiment number**: MA-2784
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Report:

The aim of this experiment was to study the X-ray excited optical luminescence (XEOL) of single GaAs nanowires as a function of an applied mechanical strain. For this purpose, GaAs/AlGaAs/GaAs core-shell nanowires with a diameter of 200 nm were fabricated by molecular beam epitaxy where the AlGaAs and GaAs layers serve as passivation and protection layer of the GaAs core, respectively (Fig. 1(a)). For the X-ray excited optical luminescence and X-ray fluorescence measurements, the wires were transferred from their growth substrate onto a 10 µm kapton foil or a Si wafer. The wires were then located by optical microscopy and more precisely by X-ray fluorescence mapping (see Fig. 1(b)) employing a 17.5 keV pink X-ray beam which was focused down to 70 x 70 nm^2 using KB mirrors.

Due to the fact that the XEOL intensity emitted by a single GaAs nanowire at ambient temperature was below the detection limit (also tested with a 2D single crystal epi-ready wafer), the new cryostat of the beamline was installed allowing for cooling down the sample to 8 K increasing the emission yield by several orders of magnitude. XEOL spectra for GaAs nanowires taken at 8, 40, and 80 K are presented in Fig. 1(c) showing the emission line at around 830 nm (1.49 eV) shifting to lower wavelength with increasing *T*.

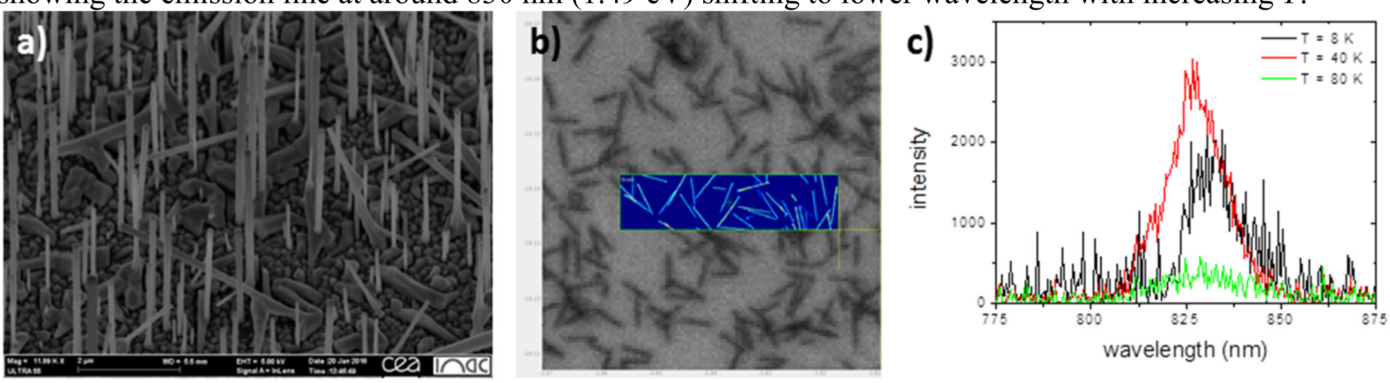

Fig. 1: a) Scanning electron micrograph of free-standing GaAs nanowires. b) Optical microscopy image overlaid with Ga-Kα fluorescence of GaAs nanowires deposited on a kapton foil. c) XEOL intensity collected at 8, 40, and 80 K.

Due to the space constraints in the cryostat and the fact that the luminescence of GaAs nanowires was too low to be measured at ambient temperatures, we performed strain engineering studies on GaN nanowires instead, which exhibit strong luminescence at 300 K for the near-band edge emission (the emission of InGaN/GaN multiple quantum wells is almost one order of magnitude higher). Silicon-doped gallium nitride nanowires with a diameter of 600 nm were grown on a sapphire substrate by MOCVD and were deposited subsequently on a kapton foil with a thickness of 125 µm. For strain engineering studies the wires were first measured on a plane membrane. Then, the membrane was mounted around a cylinder with a radius of 4 mm resulting in a strain of 1.5 % assuming that the wires are completely attached to the substrate. XEOL spectra of a pristine nanowire and the same nanowire under strain are presented in Fig. 2(b) showing a redshift of the luminescence of about 5 nm (corresponding to ~ 45 meV). Besides the effect of strain, a distribution of the wavelength of the emitted XEOL was found along nanowires which may be caused by the existence of domains of different polarity within the wires (domains with inversion of c-polar axis). This variation in the emitted XEOL wavelength (having the same order of magnitude than what is presented in Fig. 2) underlines the necessity to study a single wire that have a single polarity at different strain states in order to conclude on the impact of the mechanical strain on the electronic band structure.

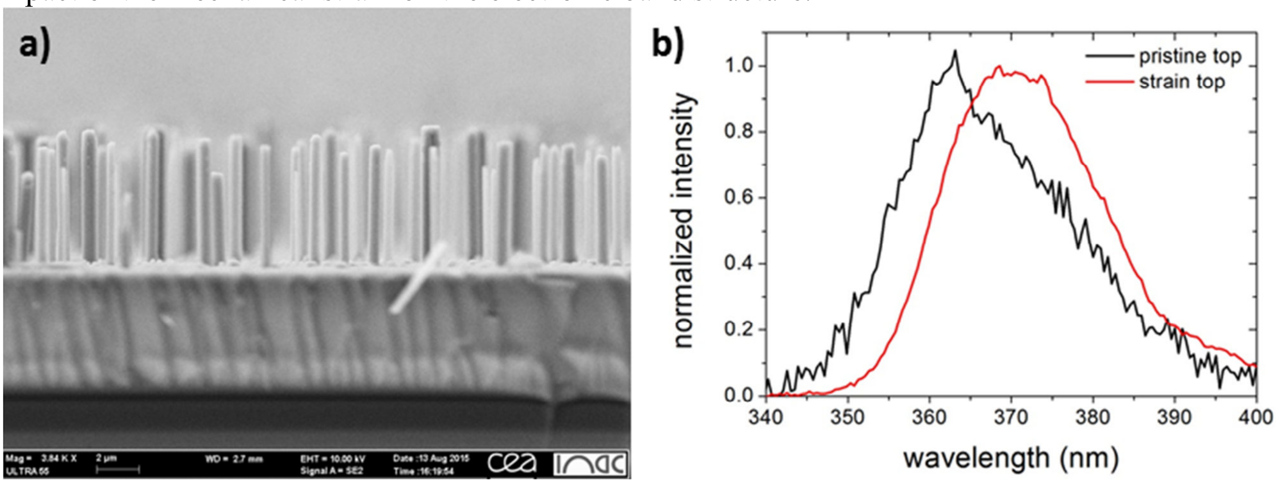

Fig. 2: a) Scanning electron microscopy image of free-standing GaN nanowires grown on a sapphire substrate. b) XEOL spectra for a pristine and strained GaN nanowire.

To understand this effect in more detail is interesting by itself. Therefore, we studied the homogeneity of long GaN wires with a length of 300 µm and a diameter of 2 µm. We selected homogeneous and defective zones to quantify this effect that may be attributed to a variation in silicon incorporation, built-in polarization and trapped states. The mappings shown in Fig. 3 evidence such fluctuations in the emission and confirm previous measurements performed from the top of the wires.

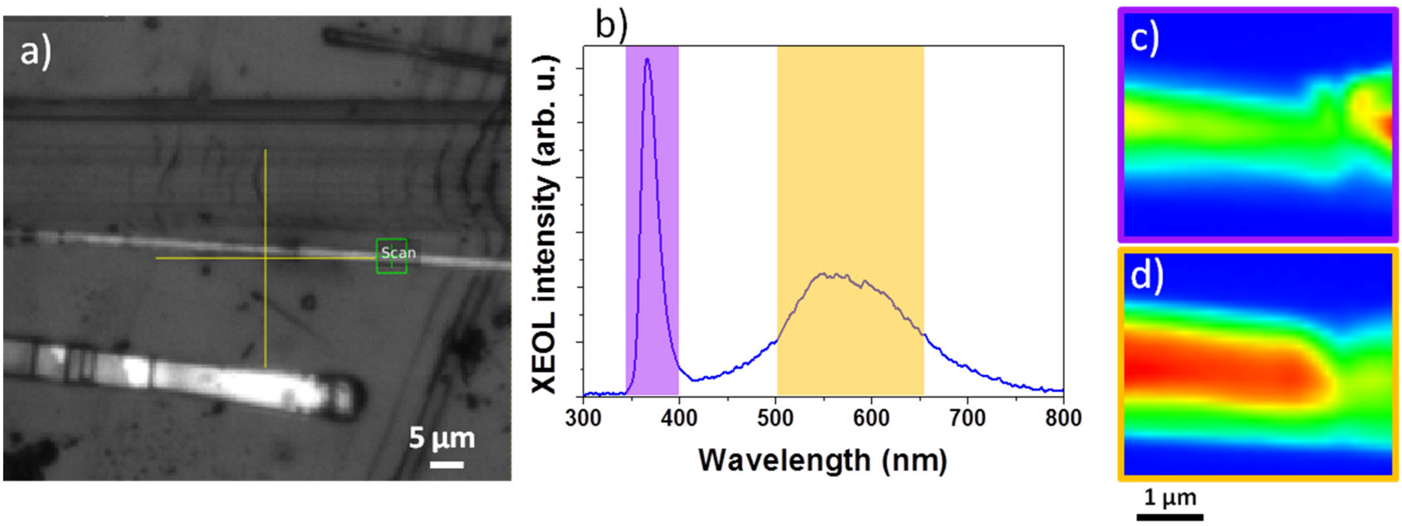

Fig. 3: a) Optical microscopy image of long GaN wires. b) Integrated XEOL spectrum in the scanned region. XEOL mappings of c) the GaN near band edge and d) the yellow band emissions.

The experiments demonstrate the feasibility of studying the band structure of single GaAs/AlGaAs/GaAs and GaN semiconducting nanowires at low as well as at ambient temperatures by spatially resolved X-ray excited optical luminescence. Moreover, this experimental approach gives access to investigate the influence of mechanical strain on the electronic band structure.