Natural quantum dots formed in GaN nanowire-UV-LED

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Semiconductor nanowires provide a number of possibilities for the design of various sophisticated heterostructures and consequently enable development of advanced electronic and optoelectronic devices. They are both efficient light harvesters and emitters, which makes them suitable building blocks for production of solar cells as well as light emitting diodes (LED) and lasers. It is known that incorporation of quantum wells, which enable carrier confinement, improves the efficiency of light emitting devices.

In this communication we present our research on GaN-nanowire-UV-LED with built-in quantum wells. Our sample is grown by plasma-assisted molecular beam epitaxy (PAMBE) on n-type Si, and consists of two sections. The bottom section are n-type AlGaN nanowires with AlN composition gradient from 0 to 15 %. The sample's top part consists of fully-coalesced p-type $Al_{0.2}Ga_{0.8}N$ nanowires forming a p-n junction. Three GaN quantum wells with width of 3,5 nm separated by 15 % AlGaN barriers are built in the active part of the structure.

The sample was studied using electroluminescence and microphotoluminescence spectroscopy. As expected, electroluminescence measurements showed bright room-temperature emission originating from quantum wells near energy of 3,25 eV. Low-temperature photoluminescence spectra obtained for different excitation power are shown in Fig. 1. They are dominated by emission bands originating from AlGaN barriers with different Al concentrations observed at energies of 3,5 – 3,65 eV, as well as GaN buffer emission clearly observed at 3,47 eV. In the low energy part of the spectrum less intensive emission which could be assigned to GaN/AlGaN QWs is observed. Interestingly enough, a number of sharp lines with halfwidths of about 0,5 meV appear at random energies in the middle part of the spectrum. As shown in Fig. 2, these lines are clearly visible for rather small excitation power and saturate for high power excitation. We propose that these sharp emission lines originate from natural quantum dots formed within our structure. The QWs form disks of 3,5 nm thickness and 50 nm diameter. In such disk, even small potential fluctuation is enough to reduce space available for electrons to quantum dimensions and create a quantum dot. Fluctuations can be due to AlGaN barrier composition, defects or strain caused by overgrowth of $Al_{0.2}Ga_{0.8}N$ layer.

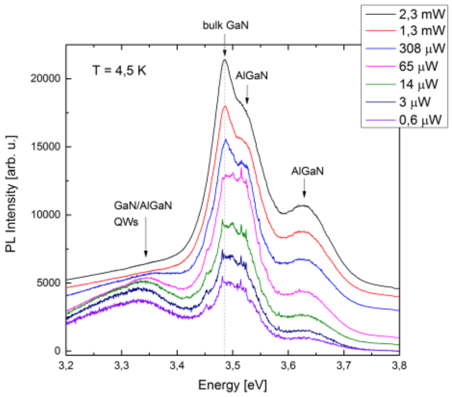

Fig. 1. Photoluminescence spectra obtained for different excitation power.

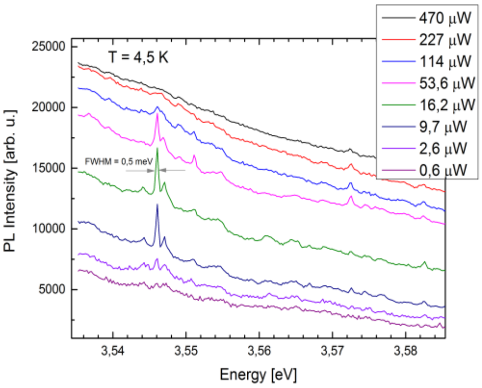

Fig. 2. Photoluminescence spectra with sharp emission lines measured for different excitation power.