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MICRO-PHOTOLUMINESCENCE IN SILICON NANO-WIRES

Abstract. Silicon nano-wires are a new material with a very attractive for many different application optical properties. The main aim of the presented study is to investigate photoluminescence (PL) properties of silicon nanowires in as a function of temperature and excitation power. In this work silicon nano-wires (SiNWs) were prepared by wet chemical metal-assisted method. Monocrystalline silicon plates with p and n-type conductivity served as a substrate. Micro-photoluminescence spectra of obtained SiNWs samples measured by confocal microscopy setup. It is shown that strong PL signal centered at about 700 nm is observed only from SiNWs. Temperature-dependent PL measurements acquired for a range of temperatures 4K - 300K. It was shown that above 40K, PL signal decrease in intensity due to the increasing effect of non-radiative processes taking place causing carrier thermalization. It is also observed pronounced spectral redshift of PL spectra with increasing temperature, which is probably related with thermal de-trapping and possible migration of excitons from trapped states to lower available ones. From analysis of the PL dependence on excitation power we found that above 4 μW of input power, quenching of PL from carrier recombination in the region >750 nm is observed (slope changes from 1.23 to 0.22). The almost linear power dependence of the emission becomes sub-linear above 4 μW which could be an indication of saturation of Si-NC states (inherently low density of states). At the intermediate to high pump power regime, Auger recombination for example is possible in Si-NC structures as the Auger lifetime is shorter than the single exciton radiative lifetime.

Keywords: silicon nanowires, photoluminescence, temperature dependent photoluminescence, optical properties.

Introduction. Silicon nano-wiser with low light reflectance and high light absorbance values attract a huge interest of researchers during last 10 years because of their great application potential for microelectronics, optoelectronics, photonics, photovoltaics, bio- and chemical sensing [1-6]. One of the wide spread ways to form SiNWs that allows to control growth and structure of nanostructures is a metal-assisted chemical etching (MACE) [7-9]. There are many papers devoted to investigations of SiNWs optical properties [10-14] but only a small part reports photoluminescence studies [15-18]. We have therefore investigated temperature dependence of photoluminescence of SINWs. Here we report on our recent results on the characterization of SiNWs micro-photoluminescence spectra.

Experimental. SiNWs samples obtained by MACE, which performed in a few steps. First silicon surfaces dipped into 2% hydrofluoric acid (HF) aqua solution to remove the thin native silicon oxide layer and dried by argon blow, then silicon they were immersed into the first solution (thermostateted by 20°C) containing 5M HF and 0.01 M $AgNO_3$. After a uniform layer of Ag nanoparticles was coated, the wafers were then immersed in the etchant solution composed of HF, H_2O_2, and H_2O (the volume ratios HF/H_2O_2: 1:10) at room temperature in a sealed Teflon vessel. In the last step Si wafers were immersed in a solution of concentrated nitric acid solution in order to remove the excess Ag nanoparticles and rinsed with deionized water, and then dried in vacuum at 60°C. As substrates, we have used heavy doped n-type, monocrystalline silicon plates

Micro-photoluminescence (micro-PL) measurements were conducted using a confocal microscopy setup. The sample mounted on a continuous-flow liquid-helium microscope cryostat, which enabled