Molecular beam epitaxial growth and properties of high quality GaN nanowires on multicrystalline solar grade Si wafers

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Fig.1. SEM image of GaN NWs grown on mc-Si substrate.

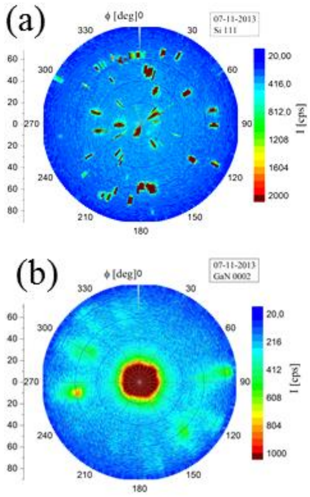

Fig.2. X-ray diffraction 111Si (a) and 0002GaN (b) pole figures of GaN NWs on mc-Si.

It is well established that GaN nanowires (NWs) are promising building blocks for new electronic and optoelectronic devices. Due to easy accommodation of lattice mismatch NWs offer a large degree of freedom in the design of heteroepitaxy of highly lattice mismatched materials. This is why growth and properties of GaN NWs on various substrates attract so much attention and are of both fundamental and technological interest. In this work we report on growth of GaN NWs on multicrystalline Si wafers (mc-Si) cut from directly solidified silicon blocks. The final goal of the project is development of tandem cells by a direct integration of GaN photovoltaic devices with commercially available silicon solar cells.

GaN NWs nucleated spontaneously and were grown catalyst-free by plasma-assisted molecular beam epitaxy at T = 740^{o}C (see [1,2] for details). Mc-Si wafers were cut from directly solidified ingots and used for growth after HF-etch without any other surface preparation steps (e.g. polishing). Fig. 1 shows SEM image of GaN NWs on mc-Si substrate. As seen well developed NWs 50 nm in diameter and 1 μm long, similar to those on monocrystalline Si(111) substrates [1], were obtained. Note that NWs grew along the c-axis being perpendicular to the local segment of the Si surface. This is confirmed by XRD analysis showing that despite a random orientation of Si grains in the substrate (Fig.2a) the NWs are aligned perpendicular to the substrate surface (Fig.2b). The tilt distribution of NWs is quite broad which is due to the roughness of the as-cut substrate surface. Much narrower tilt distribution is obtained on the flat polished substrates. We explain these results in the framework of recent model of nucleation of GaN NWs [3]. Photoluminescence measurements show that the donor bound exciton (DX) and acceptor bound exciton (AX) peaks are at 3.471 eV and 3.466 eV, respectively, i.e. exactly in the same position as in unstrained GaN layers. The AX peak was very narrow; its full width at half maximum was 1.8 meV. The luminescence was very bright and PL intensity from GaN NWs grown on different crystallites was similar; only on grain boundaries was slightly lower. All these findings confirm high quality of NWs obtained and opens the route towards monolithic integration of GaN-based photovoltaic devices with both, hybrid and standard mc-Si solar cells.

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