Introduction. Over last few decades one of the most important tasks in optoelectronics is to merge Si-based microelectronics with A3B5 components serving as light emitters and/or detectors. Different approaches were examined so far, however with a limited success. In the case of direct growth of A3B5 on silicon several physical reasons (lattice mismatch, thermal expansion difference, phase-anti-phase boundary issues, different crystal structure etc.) are the key factors introducing structural defects at the A3B5 material/Si substrate interface. The way to decrease the sizes of A3B5 structures is now seen as one of the most promising to overcome the intrinsic problem. The object studied in this work is the A3B5 semiconductor NWs grown by MBE directly on Si substrates. It has been recently theoretically shown [1] that NWs can be grown on lattice mismatched surfaces without the formation of the structural defects (e.g., dislocations) due to the ability to accumulate for strain in two dimensions. We will also show that, together with commonly used external Au-catalyzed NWs formation, a self-catalyst Ga-terminated growth method can also be applied to A3B5 NWs fabrication directly on Si.

Experimental. Growth experiments are carried out using EP1203 and Riber 32P setups equipped with effusion Au cell to get Au-metal droplets at the high vacuum conditions. During the growth we have used Si(100) and Si(111). After the desorption of an oxide layer in the growth chamber we did not grow the buffer layer but, according to in situ reflection high energy electron diffraction (RHEED) patterns, the surface was atomically-smooth. After that, the deposition of Au or Ga layer (0.1 – 1 nm) was applied. In the case of nitrogen-content NWs, AlN nanoscale islands were deposited on Si(111) substrate prior to the NW growth. The substrate was then set above the eutectic melting point of a corresponding alloy with Au in order to form seed drops. After this stage the grown of NW with desirable chemical composition was initiated. The growth temperature of NWs, V/III flux ratio and growth rate were varied during our experiments depending on the material. Formation of cubic, polytype or wurzite crystal phases at different stages was clearly observed from RHEED patterns. After the growth, the samples were characterized by scanning electron microscopy (SEM) and photoluminescence (PL) methods.

Results and discussion. The temperature ranges for the growth of A3B5/Si NWs are found to be quite different for the different material systems. The broadest temperature range (380°C – 540°C) corresponds to the cases of GaAs/Si(111) and AlGaAs/Si(111). In opposite, InAs and InP NWs can be growth within a very narrow temperature windows, (370°C – 380°C) and (390°C – 410°C), respectively.
An interesting phenomenon has been detected from the dynamic monitoring of the RHEED patterns. At the beginning of growth, the NWs (independently on the material deposited) have a pure cubic phase, however, it has been rather quickly converted to the wurzite or polytype lattice. As the NWs growth continued, the RHEED pattern (at least, partially) has been transformed back to the cubic phase. This is in opposite to the case A3B5 NWs growth on the own substrates, e.g., GaAs/GaAs(111)B, where the wurzite phase does not change in time after the first transformation from cubic to wurzite (except for the very top of the NW) [2]. According to our preliminary PL measurements of GaAs/Si(111) and InAs/Si(111) NWs [3], the dominant PL peak can be attributed to the cubic phase. This is also confirmed by the transmission electron microscopy studies.

In addition, we have studied the possibility of NW formation using the self-catalized method, where one of the element of the NW (e.g., Ga) is used as a growth catalyst. The use of Ga instead of Au allows one to avoid an unintentional Au doping during the growth. It is well established that Au incorporates during the growth of Si NWs, for A3B5 materials this is still not obvious. In the case of GaAs/Si(111), we use Si substrate covered with a thin (~20 nm) oxide layer. The shape of these NWs is also different from those obtained on the GaAs(111)B surface. In particular, a negative tapering towards the NW foot is clearly seen in Fig.2. The density and diameter of NWs are determined by the density of the openings in SiO layer and can be controlled by the thickness of the latter as well as by the duration of deoxidation process.

Finally, we grow GaN NWs on Si(111) substrates with pre-deposited AlN nanoscale islands. These islands serve as the nucleation sites for the subsequent NWs growth. These NWs exhibit pure wurzite phase with a very low concentration of structural defects. GaN NWs has a strong PL up to the room temperature in spectral range of 3.4 – 3.6 eV.

In conclusion, we have demonstrated the possibility to grow epitaxial, dislocation-free A3B5 NWs on different Si substrates. All of them exhibit a bright light emission thus opening a new way for monolithic integration of A3B5 components on silicon substrates.

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References