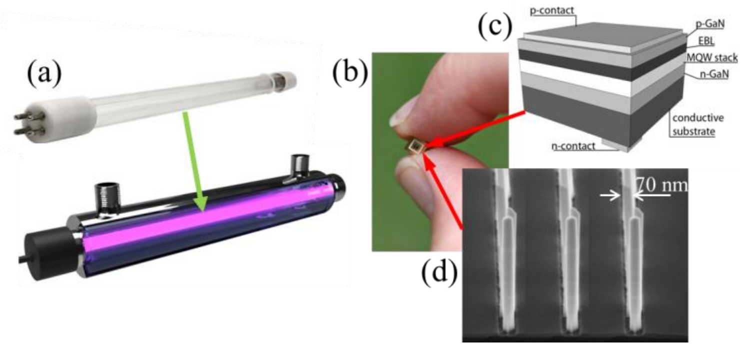
The commercial success of solid state lighting systems containing nitride light emitting diodes, supported by intensive research on the physical and chemical properties of group III nitrides and creative technical solutions, has not ended the search for an energy- and economically efficient light sources. There are still limits of the efficiency of converting electricity into visible light, associated with specific the physical phenomena or technological problems. An important limitation is the lack of cheap substrates for the growth of gallium nitride (GaN). GaN and SiC-6H substrates available on the market are very expensive while cheap ones like Si and sapphire have large lattice and thermal expansion coefficient mismatches relative to GaN. Therefore, to obtain acceptable defect density in the active area of the device, growth of thick and complicated sandwich of layers is required in planar structures on sapphire or Si substrates. One of the intensively studied approaches in light emitters, photodetectors and sensors is to replace a stack of planar layers by “a brush” of one-dimensional crystalline elements named nanowires (NWs). Due to a small diameter and a small contact area with the substrate, the stresses formed at the nanowire/substrate interface are efficiently relaxed on the side walls of nanowires. Therefore, such form offers material of very high crystalline quality even on substrates with a completely different crystal structure, also on amorphous substrates. In addition, the ratio of the surface to bulk volume in nanowires is very large, which predisposes them to applications in light emitters, sensors and photodetectors. The project is focused on fabrication and testing of efficient blue and UV light emitters and photodetectors based on nanowires of nitride semiconductors. Now this is one of the mostly studied group of materials for micro- and optoelectronics, which is due to their unique electronic and optical properties as well as high chemical resistance.



The role of blue and UV light is significant. The blue LED allowed the construction of a semiconductor white light source. Its discovery contributed to the development of blue lasers that are widely used in today's world. Additionally, UV radiation is used for sterilization of medical equipment, medical diagnostics and water purification. As example, Fig. (a) shows a simple system for water disinfection in which UV light is used to inactivate microorganisms by destroying their DNA in water flowing through the UV transparent tube. Efficiency of the process is high for light wavelengths between ~200 nm and ~300 nm (the so called UV-C band). Mercury-vapor lamps have been used as the light sources. However, recent developments in LED technology have led to compact UV-C LEDs (Fig. (b)) which allow for point-of-use applications and offer longer lifetime and lower power consumption. Moreover, LED sources do not contain mercury, so they are environment-friendly. Up to now commercially available LEDs contain a stack of layers of semiconductors (Fig. (c)) designed to tune the wavelength emission and electrical parameters of the device. However, the performance of planar AlGaN based UV devices has been severely limited by the inefficient strain-induced polarization fields and prohibitively large defect densities. Therefore, in the project we plan to use nanowires, as shown in Fig. (d), instead of planar design since they offer lower density of defects and thus much better operational parameters of LEDs.

As for the semiconductor to choose, wide band-gap AlGaN is very promising for the next generation of efficient UV light sources. Therefore, the main goal of the project is to design, fabricate and test novel GaN/AlGaN nanowire arrays for photonic UV devices using ZrN nucleation layer as conductive bottom electrode to the NWs and as a back reflector for photon recycling. This will require studies of the mechanisms active during plasma-assisted MBE growth of GaN/AlGaN NWs as well as of the physical phenomena which limit the efficiency of electric energy conversion to UV light in such NW heterostructures. The research plan takes into account all steps starting from MBE growth of NW structures through their post growth characterization and processing till the final electrical and optical tests of the pilot device structures. Various MBE growth recipes, AlGaN/GaN NW diode designs, processing steps will be compared using parameters of the final UV devices as the main criterion and allowing determination of the structure-to property relation.

Results of our studies will allow to optimize parameters of efficient blue and UV light emitters and photodetectors based on AlGaN/GaN nanowires on metallic substrates. This will help to improve considerably properties of such devices, including their power, efficiency and extension of the spectral range. Moreover, the research proposed will contribute to our understanding of crystal growth processes, physics of semiconductor photonic devices and general knowledge on physics and technology of group III-nitride semiconductors.