Hybrid photovoltaic detectors based on the van der Waals/(Al)GaN junction

Photovoltaic detectors are used to measure the intensity of light and their principle of operation is based on the absorption of radiation that generates carriers in the area of the *p-i-n* junction. The generated carriers are spatially separated by the built-in electric field and lead to the flow of current. In many applications spectral selectivity of the detectors is required. A good example of this are UV radiation detectors, which could count radiation doses in three spectral ranges, i.e., UVA, UVB and UVC. In this case, the natural semiconductor system for the production of such detectors is the third group of nitrides (III-N), which are characterized by a wide band gap and therefore, by appropriately selecting the composition of the AlGaN absorber, they can absorb light in the UV range up to a specific wavelength. Within this material group, it is also possible to produce detectors covering the visible range and the near infrared range by alloying GaN with InN. But so far, the technology of detectors based on III-N materials is not sufficiently developed despite the fact that the technology of III-N materials is already a mature technology (the market for lighting and high power transistors is based on this technology).

One of the reasons for the lack of UV-selective III-N detectors is material limitations, which are related to the lack of AlGaN layers with good conductivity. Another problem is the lack of appropriate technology of electrical contact for this type of layer. In the case of detectors for the visible and near infrared range, there has been no motivation to develop the technology of III-N detectors so far because there are very good detectors for this spectral range made on the basis of other group III-V semiconductors. However, switching to III-N materials makes it possible to integrate entire optical systems (light source, waveguide, transducer, detector) on one semiconductor platform, which in this case would be the gallium nitride platform. Therefore, both UV detectors and visible and near infrared detectors are still important and still a challenge for III-N technology.

In this project, we want to develop the technology of III-N detectors by integrating III-N structures with van der Waals (vdW) crystals. We mean such crystals as MoS_2, MoO_2, MoO_3, GaS, GaSe, InSe and others, and their structures such as graphene/h-BN, graphene/MoS_2, graphene/MoS_2/h-BN and others. These types of crystals are characterized by strong covalent bonds in one plane and weak van der Waals bonds between these planes. Due to van der Waals bonds, such a crystal can be very easily exfoliated into single layers that are semitransparent to light and that exhibit crystal surface properties other than those observed for covalent crystals, including GaN.

We assume that the selected vdW crystals can be transparent electrodes that will form *p-i-n* junctions with the III-N structures necessary for the separation of carriers and the operation of photovoltaic detectors. Additionally, we assume that vdW crystals will solve the problem with electrical contacts in this type of detectors. In addition, vdW crystal layers can be used as absorbers that extend the spectral range of the response of such detectors. Thus, the subject of research in this project will be hybrid detectors, the essence of which will be the vdW/III-N junction. Therefore, one of the main goals of this project is to understand the physical phenomena occurring at the vdW/III-N junction. We assume that the knowledge of these phenomena will enable us to produce a photovoltaic detector with record sensitivity and a quick response to the selected spectral range in UV.