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Thesis abstract

This work encompasses the development of new techniques for the fabrication of nanomaterials from the $A^{15}B^{16}C^{17}$ chalcohalides group, the investigation of their properties with regard to photodetection applications, the verification of the potential for modifying their properties at the synthesis stage, as well as measurements of photodetector devices based on $A^{15}B^{16}C^{17}$ chalcohalide compounds and their heterostructures. The scope of the research covered four materials: SbSI, BiSI, SbSeI, and BiSeI. The work began with the modification of the sonochemical synthesis method for $A^{15}B^{16}C^{17}$ chalcohalides, extending it to enable the fabrication of bismuth chalcohalides through the use of appropriate precursors. In parallel, a method was developed for producing $A^{15}B^{16}C^{17}$ chalcohalide layers directly on a selected substrate, based on solution-processing techniques. Scanning electron microscopy (SEM) with energy-dispersive X-ray spectroscopy (EDS), as well as X-ray diffraction (XRD), were used for the microstructural and phase characterization of the obtained materials. The investigations demonstrated the effectiveness of the developed methods, with the results confirming the high purity of the obtained $A^{15}B^{16}C^{17}$ chalcohalide phases. A statistical analysis was performed, which made it possible to determine the average dimensions of the nanowires obtained for each of the investigated materials, as well as the statistical distribution of their dimensions. In the next step, diffuse reflectance spectroscopy (DRS) measurements were carried out on the chalcohalide nanowire samples produced by sonochemical synthesis and on the chalcohalide layer samples produced by solution processing. This made it possible to determine the energy band gaps of the obtained materials. Subsequently, the sonochemical syntheses of $A^{15}B^{16}C^{17}$ chalcohalide nanowires were repeated with modified molar ratios of their precursors. All four investigated materials were synthesized at four different precursor molar ratios, namely 1:1:1, 1.5:1:1, 1:1:1.5, and 1:0.5:1.5, relative to the standard stoichiometry of $A^{15}B^{16}C^{17}$ compounds. This part of the work was aimed at verifying the influence of the precursor molar ratios on the extent of structural defects in $A^{15}B^{16}C^{17}$ chalcohalides, which translates into their properties such as the conductivity type and the charge carrier concentration. This hypothesis was subsequently verified on the basis of a combination of impedance spectroscopy, electrochemical impedance spectroscopy, and Raman spectroscopy measurements. The results obtained proved that both the charge carrier concentration and the conductivity type of $A^{15}B^{16}C^{17}$ chalcohalides can be modified at the synthesis stage by adjusting the precursor molar ratios. In the final part of the work, photodetectors were fabricated using the previously obtained materials, both the chalcohalide nanowires obtained by sonochemical synthesis and the layers produced by solution processing. Devices based on individual chalcohalides and on their heterostructures were investigated under illumination with light of various wavelengths. The photocurrent response results and the determined responsivity of the detectors utilizing $A^{15}B^{16}C^{17}$ chalcohalides demonstrated the application potential of these materials and their heterostructures, with bismuth chalcohalides standing out in particular.