INTERPLAY BETWEEN STRUCTURAL PARAMETERS AND ELECTRO-PHYSICAL CHARACTERISTICS IN HYPERDOPED SILICON: A COMPLEX ANALYSIS

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In recent years, there has been significant research interest in universal technologies that enable the manipulation of solid-state properties for application across various scientific and technological fields [1]. Among these advancements, the laser hyperdoping technique applied to bulk silicon stands out as an exemplary example [2]. Through the implantation of electroactive chemical element atoms at concentrations above the equilibrium solubility limit, intermediate energy bands are generated within the crystalline silicon structure. This unique effect allows for precise control over the band gap of the semiconductor material. Notably, this development presents opportunities for the detection of infrared radiation using silicon-based photodetectors [3].

Recent studies mainly have shown the complex influence of the parameters of the resulting hyperdoped silicon on the final characteristics of the photodetector. These characteristics include sensitivity, quantum efficiency, current-voltage characteristics, among others. Nevertheless, when developing technologically advanced devices, it is imperative to adopt an integrated approach that comprehensively examines diverse characteristics and their interdependencies.

This study examines the impact of laser processing parameters on the deep distribution of impurity atoms in the hyperdoped layer, as well as their influence on the electrical conductivity type and charge carrier concentration. Various characterization techniques, including X-ray photoelectron spectroscopy, terahertz spectroscopy, and Hall measurements, were employed. The findings indicate a correlation between impurity concentration and charge carrier concentration, as evidenced by corresponding responses in THz spectral measurements. The insights obtained from this study have potential implications for further research in laser hyperdoping of silicon and the development of photodetectors using such materials.

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[1] Heck M. J. R. et al. Hybrid silicon photonic integrated circuit technology //IEEE Journal of Selected Topics in Quantum Electronics. – 2012. – Т. 19. – №. 4. – С. 6100117-6100117.

[2] Kovalev M. et al. Au-Hyperdoped Si Nanolayer: Laser Processing Techniques and Corresponding Material Properties //Materials. – 2023. – Т. 16. – №. 12. – С. 4439.

[3] Kudryashov S. et al. CMOS-compatible direct laser writing of sulfur-ultrahyperdoped silicon: Breakthrough pre-requisite for UV-THz optoelectronic nano/microintegration //Optics & Laser Technology. – 2023. – Т. 158. – С. 108873.