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SYNTHESIS OF EPITAXIAL FILMS BASED ON Ge–Si–Sn MATERIALS WITH Ge/GeSn, Ge/GeSiSn, AND GeSn/GeSiSn HETEROJUNCTIONS

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Results of investigations into the synthesis of heterostructures based on Ge–Si–Sn *materials by the method of low-temperature molecular beam epitaxy are presented. The formation of epitaxial films during structure growth has been controlled by the reflection high-energy electron diffraction method. Films with* Ge/GeSn, Ge/GeSiSn*, and* GeSn/GeSiSn *heterojunctions are grown with Sn content changing from 2 to 10 % at temperatures in the interval 150–350°C. The stressed state, the composition, and the lattice parameter are studied by the x-ray diffraction method using Omega-scan curves and reciprocal space maps. A tensile strain in the Ge film during* $Ge/Ge_{0.9}Sn_{0.1}/Si$ *structure growth has reached 0.86%.*

Keywords: epitaxy, diffraction, heterostructures, thin films, lattice parameter, deformation, Omega-scan curve, reciprocal space map, IR photodetector, CMOS transistor.

INTRODUCTION

At present great attention to the class of Ge–Si–Sn materials is caused by the possibility of their application both in advanced CMOS technologies and in optoelectronics [1–3]. Despite low Sn solubility in Ge (<1%), large discrepancy between the lattice parameters, and instability of diamond-like α-Sn structure, GeSn and GeSiSn single-crystal films have been grown with Sn content up to 20% by the methods of molecular beam epitaxy and chemical vapor deposition [4–6]. The successful synthesis of such compounds becomes possible due to considerable levels of substitution of Ge and Si atoms by Sn atoms under nonequilibrium conditions at temperatures 100–350°C.

It has appeared that incorporation of Sn into the Ge lattice decreases its absorption edge ($\lambda = 1.55$ μm) [7]. Thus, GeSn can be considered as a perspective material for photodetectors and applications in photovoltaics that requires the bandgap smaller than that of Ge (0.8 eV). In addition, the GeSn alloy with Sn content exceeding 10% can become a direct gap semiconductor [8] and is very attractive not only for optoelectronic applications, but also for devices with high electron mobility due to a smaller effective mass in the G valley of the semiconductor. The most significant feature of GeSiSn is the possibility of independent adjustment of the lattice constant and bandgap. For the same lattice constant, the bandgaps can be obtained that differ by more than 0.2 eV even if the concentration of Sn is smaller than 20%. This property can be used for the development of multi-color detectors. In addition, changing the semiconductor composition and keeping the lattice parameter at the constant value like that of Ge with the bandgap close to 1 eV, the GeSiSn films can be used in multicascade solar elements [9].

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