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Strained GeSiSn Nanoscale Materials Grown by MBE on Si(100)

ALEXANDR NIKIFOROV[1,2], VYACHESLAV TIMOFEEV[1], ARTUR TUKTAMYSHEV[1], ANDREW YAKIMOV[1,2], VLADIMIR MASHANOV[1], ANTON GUTAKOVSKII[1], OLEG PCHELYAKOV[1,2], NATALIYA BAIDAKOVA[3]

[1] Rzhanov Institute of Semiconductor Physics,
Siberian Branch of the Russian Academy of Sciences,
Lavrentjeva 13, 630090 Novosibirsk,
RUSSIA.

[2] National Research Tomsk State University,
36, Lenina Avenue, Tomsk, 634050,
RUSSIA.

[3] The Institute for Physics of Microstructures,
Russian Academy of Sciences,
GSP-105, Nizhny Novgorod, 603950
RUSSIA.

nikif@isp.nsc.ru

Abstract: - The dependence of the critical thickness transition of two-dimensional growth regime to three-dimensional of temperature and composition of the GeSiSn film on Si(100) was studied. The formation of multilayer structures with pseudomorphous GeSiSn layers without relaxed buffer layers directly on Si have been investigated. A possibility of synthesizing multilayer structures by molecular beam epitaxy was shown, and the crystal lattice constants using the high-resolution transmission electron microscopy were determined. Based on multilayer GeSiSn/Si structures the p-i-n-diodes, which demonstrated the photoresponse increasing by several orders of magnitude compared to the Sn-free structures at an increase in the Sn content, were created. Nanostructures based on GeSiSn layers have demonstrated the photoluminescence at 0.7–0.85 eV.

Key-Words: - Silicon, Germanium, Tin, MBE, Strained layers, Optical properties.

1 Introduction

Nanostructures are extremely important objects for nano- and optoelectronics. The studies in teh field are mainly focused on modifying the materials to improve their optical and electronic properties in order to provide the efficient light emission or absorption [1, 2, 3].

Molecular beam epitaxy (MBE) multilayer Ge-based heterostructures can comprise various strained pseudomorphous layers with the lattice constants conjugated to the silicon substrate. Different morphological states are characteristic of the layers: These may be atomic-smooth wetting layers and 3D islands of different size – from hut-clusters to quantum stretching threads. The strained state of epitaxial layers is varied by adding various materials, for instance, C or Sn, to change the band structure of the material.

For recent years, Ge-Si-Sn-based materials have become of special focus due to their potential applications in integrated silicon photonics, micro- and nanoelectronics, photovoltaics [4-6]. Addition of Sn to Ge makes it possible to control the lattice constant, energy diagram, charge-carriers mobility, efficient mass and defects. Besides, the minimum of the conductivity band for the L and Γ-valley decreases with an increase in the Sn content, the decrease at the Γ-point becomes faster. As a result, GeSn may behave as a direct band semiconductor at the 10% Sn content in relaxed layers and 6% in the films with stretching deformations [7, 8]. The progress in the field of GeSn, GeSiSn [9-11] layer growth opens the way to modifying the band structure by controlling the voltage and composition. Besides changes in the electron and optical properties, the surface Sn favors the adatom surface diffusion and the appearance of a series of superstructures unobserved in the GeSi [12] system. The main problems in synthesis of epitaxial GeSn and GeSiSn film are the low equilibrium solubility of Sn in Ge and Si (<1%), segregation and precipitation; they are solved using nonequilibrium growth techniques such as MBE, magnetron sputtering, solid phase epitaxy, recrystallization and