MBE growth of GeSiSn/Si MQW for optoelectronics

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Interest in GeSiSn materials is associated with the ability to create direct bandgap semiconductor, as a double compound GeSn, and the ternary compound GeSiSn. These compounds can be grown directly on a silicon wafer, providing the ability to create silicon photonic and optoelectronic devices, operating in the IR spectrum. Recent years a lot of articles about creation of emitting devices and photodetectors, based on GeSiSn materials, have been published [1, 2]. The structures, which were obtained in these studies, were grown on a silicon wafer using Ge buffer layer 1 µm thick.
In the present work, we suggest to use pseudomorphic elastic-strained GeSiSn films grown directly on Si rather than relaxed layers. The principal advantage of pseudomorphic films against thick relaxed layers is that they are free of dislocations and coherent to the substrate. GeSiSn films are more thermostable than GeSn, their lattice constant and bandgap can be individually controlled as dependent on the composition.
In this work GeSiSn multi-quantum wells (MQW) structures were grown directly on Si(100) substrates by molecular-beam epitaxy (MBE). Data about the initial growth stages of ternary compounds Ge-Si-Sn on Si(100) have been early obtained [3]. Using reflection high-energy electron diffraction (RHEED) method kinetic diagrams of growth of $Ge_{1-x-y}Si_xSn_y$ on Si(100) in wide temperature range (150–500°C) and at different lattice mismatch (1–5%) between GeSiSn film and Si substrate were determined. Based on temperature dependencies of 2D-3D transition the growth temperature and thickness of GeSiSn layers were chosen to achieve a pseudomorphic growth. The GeSiSn layer thickness was 2–3 nm and the growth temperature of GeSiSn layers was 100–200°C. GeSiSn layers act as quantum well which are covered by a Si layer at higher growth temperature (400–500°C) for smoothing the surface and also to create a potential barrier.
The optical properties of multilayer structures were studied using photoluminescence (PL). The PL signal was excited by Nd:YAG laser (532 nm). PL is observed in the range of 0.6 eV to 0.85 eV. With increasing the Sn concentration in the composition of ternary compound GeSiSn, the maximum of PL intensity decreases from 0.77 eV to 0.65 eV. With decreasing growth temperature, and by increasing the thickness of GeSiSn layer PL signal reduces, which may be caused by an increase in point defects in the crystal structure. Progress to longer wavelengths greater than 2 µm requires an increase in the content of Sn in GeSiSn layers more than 10%.

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[3] Tuktamyshev A.R. et al. *Semiconductors*, **49**, 1582 (2015)