Structural and optical properties of GaSe/GaAs(001) layers grown by molecular beam epitaxy

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The development of epitaxial growth techniques of layered materials is of great importance due to a large number of their potential applications. This paper reports on molecular beam epitaxy (MBE) growth of GaSe layers on GaAs (001) substrates as well as studies of their structural and optical properties. A standard Ga cell and a Se valve cracking cell with the cracking zone temperature T_{Se}(cr)=500°C were used as molecular beam sources. The growth temperature (T_S) was varied within 400−540°C range. The samples were studied by using transmission electron microscopy (TEM), X-ray diffraction (XRD), scanning electron microscopy (SEM), and Raman spectroscopy techniques.

Bulk GaSe crystals consist of vertically ordered ~0.8 nm-thick layers which are bonded together by weak van der Waals forces. Different stacking sequences of the layers form different polytypes (β, ε, γ, and δ). Using both transmission electron diffraction and Raman spectroscopy techniques it has been found that the GaSe layers grown on GaAs (001) substrates at T_S=400°C are of γ-polytype. In this case, the GaSe ***c*** axis is normal to the growth surface (see fig. 1). These findings agree well with previous reports [1,2]. At higher T_S>500°C the GaSe ***c*** axis is inclined to the substrate surface due to chemical bonding between the substrate and GaSe. However, no growth is observed at T_S>530°C even at high Ga flux in contrast to ref. [1]. The effect of MBE growth parameters (Se/Ga flux ratio and T_S) on the surface morphology of GaSe layers have been studied using SEM. Only GaSe layers grown at low T_S=400°C and Se/Ga flux ratio close to stoichiometric one (Se/Ga ~ 12÷14 at growth conditions used [3]) demonstrate the nearly planar surface morphology. With increasing the Se/Ga flux ratio, a number of so-called “nanoplatelets” appear on the growth surface. In addition, GaSe layers grown under the strong Se-rich conditions demonstrate an existence of α-Ga_2Se_3 phase inclusions. With raising T_S up to 500°C, the surface morphology becomes rougher, and the nanoplatelet surface density increases significantly.

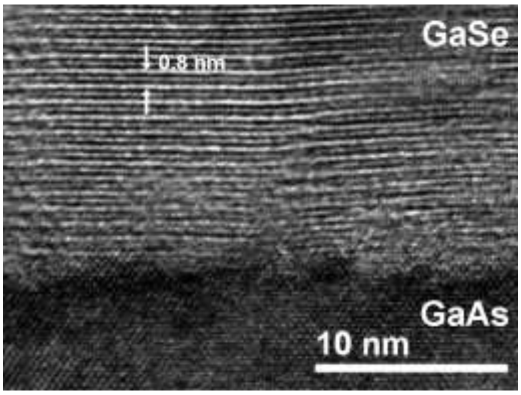

Figure 1. Cross-section TEM image of the GaSe layer grown at T_S=400°C

The Raman spectroscopy data indicate that the dominant polytype in GaSe layers grown at T_S=500°C is of ε-type. Moreover, the GaSe layers grown in a two-step regime (with the initial nucleation layer grown at T_S=400°C and the top layer grown at T_S=500°C) have been also identified, using both Raman spectroscopy and electron diffraction technique, to be predominantly of ε-polytype. The GaSe layers grown at high temperatures demonstrate near band-edge photoluminescence at room temperature. The work was supported by the Government of the Russian Federation (contract #14.W03.31.0011 at the Ioffe Institute).

[1] N. Kojima et al., *Jpn. J. Appl. Phys.* **33**, L1482 (1994).
[2] Z.R. Dai et al., *J. Appl. Phys.* **85**, 2603 (1999).
[3] S.V. Sorokin et al., *to be published in Semiconductors* (2019)