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Peculiarities of Ga_2Te_3 thermal oxidation

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Abstract

The processes of Ga_2Te_3 were studied using X-ray photoelectron spectroscopy, X-ray diffraction and cathodoluminescence methods. It was found, that Ga_2Te_3 oxidised stepwise with amorphous gallium oxide and tellurium dioxide formed at the beginning followed by crystallisation of Ga_2O_3 and tellurium trioxide volatility losses. The temperature intervals of intermediate phases existence in own oxide film were established. The similarity in oxidation mechanisms in bulk and on the surface is discussed.

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Keywords: Ga_2Te_3; Own oxide; Thermal oxidation

1. Introduction

Gallium sesquichalcogenides ($Ga_2Te_3, Ga_2Se_3, Ga_2S_3$) belong to the large class of materials with cubic sphalerite low temperature α-modification. Among the other III–VI compounds Ga_2Te_3 seemed to be the less studied. Few works are devoted to the electric and ferroelectric properties of Ga_2Te_3 [1,2]. Meanwhile Ga_2Te_3 attracts the attention of the researcher due to its formation on the interface boundaries of epitaxial ZnTe/GaSb structures [3–5]. Contrary to the GaAs–ZnSe interfaces where appearance of Ga_2Se_3 positively affects the properties of the structure due to zinc selenide structure perfecting, Ga_2Te_3 drastically decreases the quality and electrical properties of corresponding structures. The own oxide formation of gallium sesquitelluride could, in one hand, be used as a method of heterostructures fabrication, as it was done for the other III–VI compounds [6]. On the other hand, the surface properties of Ga_2Te_3 are key factors controlling the properties of the structures containing this compound. So the aim of this work is the development of gallium sesquitelluride own oxide composition and establishing intermediate phases sequence, formed during oxidation.

2. Experimental

For the investigation we used Ga_2Te_3 samples, obtained from the initial elements with purity not less than 99.999%. By X-ray diffraction (XRD) it was proved that samples were crystallized in a low temperature cubic α-modification with lattice parameter $a = 0.5898$ nm being in good agreement with individual crystallographic data [7]. The oxidation

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was conducted in 400−900 °C temperature interval in the air.

For the phases detection in own oxide film X-ray photoelectron spectroscopy (XPS) of core levels, XRD and cathodoluminescent (CL) properties were examined. XPS patterns were recorded using a PHI 5700 MultiTechnique spectrometer with monochromatic Al Kα irradiation ($h\nu = 1486.6\,\text{eV}$) as an excitation source. The spectrometer was calibrated with respect to the binding energy of the 4f level of gold ($E_b(\text{Au}4f_{7/2}) = 84.00\,\text{eV}$) and the scan step was 0.05 eV. The oxidation was observed by measuring the binding energies of gallium, oxygen and tellurium core levels. CL was excited at liquid nitrogen temperature (77 K) by electron pulses with the frequency and duration of 20 Hz and 3 μs, respectively. The electron beam was characterised by the density of current of $100\,\text{mA/cm}^2$ and 9 keV electron energies. Luminescence spectra in the range of 1.2–4.2 eV were recorded using a photomultiplier through a monochromator. The XRD spectra of the samples were recorded using Cu-Kα X-ray source on DRON-4 spectrometer in the range of $10^\circ < 2\Theta < 90^\circ$ with a scan step of 0.05°.

3. Results and discussion

XPS patterns of initial and thermally oxidized during 5 min at 650 °C Ga_2Te_3 are presented in Fig. 1. The spectral position of Ga 3d level practically is not affected by the oxidation. The appearance of high energy shoulder at 23.6 eV (Fig. 1b) is a result of oxygen 2s emission. The same situation was observed both for core 2p and Auger LMM levels of gallium (not shown). This is caused by the coincident of the chemical shifts of gallium levels for the sesquitelluride and oxide [8,9]. The intensity of Ga 3d emission also was not instantly changed, which points out the redistribution of gallium between reactant and oxidation products. Much more informative are oxygen and tellurium core levels. Due to adsorption, the oxygen was detected in the freshly air-cleaved sample (Fig. 1a). The intensities of O 1s emission, corresponding to gallium oxide (at 530.95 eV) and tellurium oxide (at 531.75 eV) practically coincide with the Ga_2Te_3 stoichometry, which proves the equal quantity of chemisorbed oxygen on the surface both by gallium and tellurium. The oxidation increases the intensity of O 1s emission with simultaneous redistribution of Te–O bonds (Fig. 1b). The band, attributed to Ga–O bonds is much more intense than the one corresponding to tellurium oxide. The band at 533.75 eV can be connected with hydroxide groups [7], adsorbed from ambient. The most sensitive to chemical bonds switching seemed to be a doublet of Te 3d. Evolution of chemical shifts of $\text{Te}3d_{5/2}$ line correlates well with shifts of oxygen 1s. The spectrum of initial sample consists of components characteristic for tellurium (IV) oxide (at 576.55 eV)

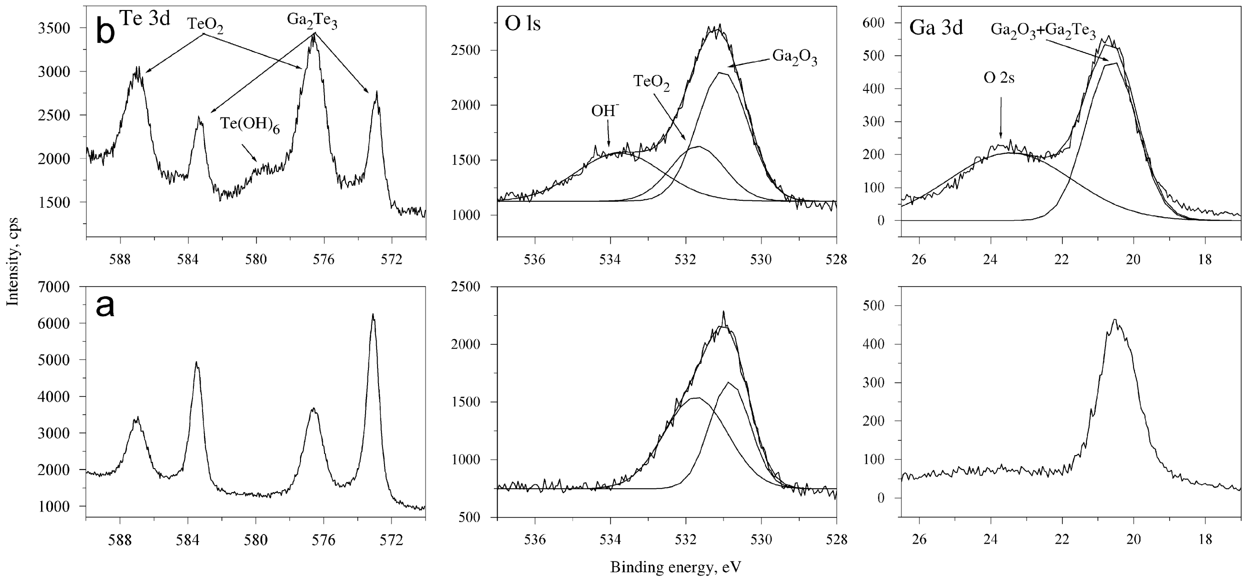

Fig. 1. Detailed XPS scans of initial Ga_2Te_3 (a) and thermally oxidized during 5 min at 650 °C (b).