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ELECTRONIC PROPERTIES OF NANOSCALE STRUCTURES FORMED ON THE GAAS SURFACE BY IMPLANTATION OF LOW-ENERGY IONS

Annotation: This article fully reveals the physical essence of devices based on the structures of electronic properties of nano-sized structures formed on the surface of the film by the implantation of heterostructures and a low-energy ion, compares and analyzes the properties of devices based on heterostructures and nano-sized structures.

Keywords: GaAs heterostructure, nanofilm, nanoelectronic, GaAlAs, DBE, optoelectronic , MLE, A3B5, IVE, monocrystalline, singularities.

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ЭЛЕКТРОННЫЕ СВОЙСТВА НАНОМАСШТАБНЫХ СТРУКТУР, СФОРМИРОВАННЫХ НА ПОВЕРХНОСТИ ГААС ПУТЕМ ИМПЛАНТАЦИИ НИЗКОЭНЕРГИЧНЫХ ИОНОВ

Аннотация: В данной статье полностью раскрыта физическая сущность устройств на основе гетероструктур и электронных свойств наноразмерных структур, образующихся на поверхности пленки в результате имплантации низкоэнергетических ионов, сравниваются и анализируются свойства устройств на основе гетероструктур и наноразмерных структур.

Ключевые слова: Гетероструктура GaAs, нанопленка, наноэлектроника, GaAlAs, DBE, оптоэлектроника, MLE, A3B5, IVE, монокристалл.

Three-component heteroepitaxial layers of types created on the basis of A2B5 semiconductors, in particular GaAs, have been comprehensively studied in recent years, due to their wide application in various micro- and optoelectronics devices.Multilayer structures of the GaAlAs type, which are cured on the GaAs surface, are of the most practical interest, since their crystal structures and lattice parameters coincide well with each other [1,2]. Calculations have shown that the compound Al_x Ga_{1-x} As is straight-band at x less than 0.4 non-straight-band and at x greater than 0.45. It follows from this that the optical, electrical and other properties of epitaxial structures depend on X. It is known that with perfect growth MLE, continuous layers are formed at d ≥ 10-15 nm. However, for the creation of a new generation of optoelectronic and nanoelectronic devices, A3B5 layers with a d ≤ 10 nm are of particular interest [3,4].

Thus, the composition, atomic and electronic structure, as well as the physico-chemical properties of multicomponent and multilayer systems based on GaAs are well studied. In recent years, the method of implantation of low-energy ions has been widely used to obtain quantum-dimensional structures on GaAs surface layers. The physical properties of Ga_{1-x} Al_xAs nanostructures in the near-surface region of GaAs were obtained and studied by implantation of Al+ ions followed by annealing (laser + temperature) [5,6].

The SEM image and the DBEO pattern (insert) of the GaAs and GaAlAs surfaces are shown in Figure 1.1. It can be seen that the substrate has a smooth microrelief, and the GaAlAs surface consists of separate single-crystal nanoblocks with dimensions d = 10-20 nm. Apparently, the crystallographic orientations of individual monocrystalline blocks at the boundaries differ from each other; therefore, reflections typical of textured films appear in the DBE picture [7,8].

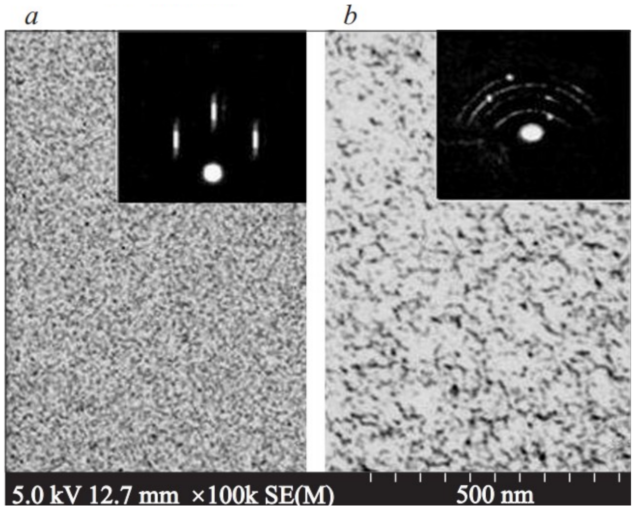
Table 3.1 shows the values of thermal and photoelectronic output operation (eφ and eΦ), the maximum value of δm and the corresponding Epm, as well as the value of the coefficient n measured at an energy of 800 eV, as well as the quantum yield of photoelectrons ν, for a pure GaAs single crystal and GaAlAs/GaAs film with d ~ 50 A. The main emission characteristics of GaAs (p-type) and GaAlAs films [9,10].

It can be seen that the presence of a GaAlAs film leads to a noticeable increase in δm and K, and eφ increase insignificantly. The authors argue that the growth of δm and K is associated with a noticeable increase in Ed and λ IVE. Figure 1.2 shows the angular dependences σ taken at an energy of 800 eV of GaAlAs films created by ion implantation methods with a combination of annealing and MPE

Table 1. Main emission characteristics of GaAs (p-type) and GaAlAs films

The object under study	e_φ, эВ	e_Φ, эВ	E_g, эВ	E_{pm}, эВ	δ_m	H	*K*, (hν = 10,8 эВ)
GaAs	5	5,1	1,4	500	1,1	0,26	$3\cdot10^{-3}$
$Ga_{0,5}Al_{0,5}As$	5,1	5,3	2,1	550	1,4	0,25	$6\cdot10^{-3}$

It can be seen that all the curves σ(φ) have a non-monotonic character.The positions of the maxima and minima correspond to certain crystallographic directions [11]. The positions of the singularities on the curve σ(φ) of the GaAlAs film obtained by ion implantation coincide well with the positions of the singularity of pure GaAs, i.e. epitaxial growth is observed.The study of the dependencies σ(φ) showed that the value of λ at an energy of 200 eV is ~ 50 Å..



1.1. SEM and DBE patterns of GaAs (a) and GaAlAs (b). A three-component film was obtained by implantation of Al+ with an energy of 1 keV at D = 4 - 1020 m-2. With subsequent heating at T = 800 K [12].

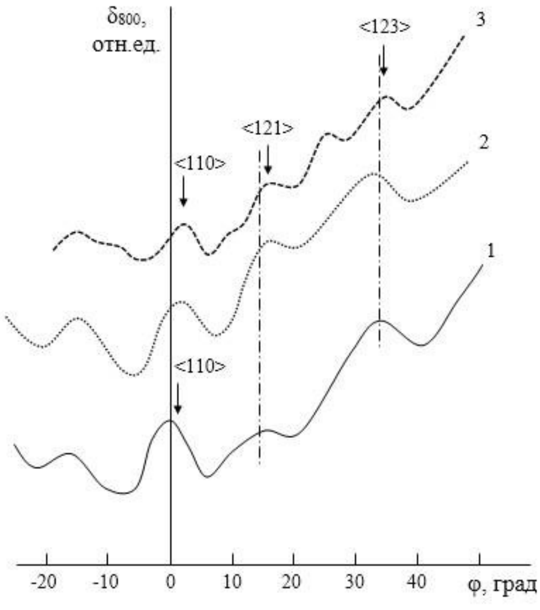


Fig. 1.2. Dependences δ 800 (φ) for: 1) pure GaAs; 2) GaAlAs/GaAs films with d 50 Å obtained by ion implantation; 3) obtained MPEs.The angle φ was determined relative to the normal of the sample.

At the same time, GaAs maxima and minima disappear, and the intensity of GaAlAs maxima and minima increases significantly. Apparently, in the case of the growth of MBE, the three-component compound GaAlAs film and GaAs substrate have a high monocrystalline with practically the same lattice constants, however, their crystal orientations at the boundary do not completely coincide [13]. Note that in the ion implantation process, the thickness of the disordered substrate layers reaches 350-500 Å, i.e. 3-5 times greater than the thickness of ion-doped layers. When heated, the amorphous GaAs layers crystallize simultaneously, and the ion-implanted GaAs layers crystallize and simultaneously the ion-implanted layer forms $Ga_{0,5}$ $Al_{0,5}$ As compounds. This contributes to the formation of an epitaxial $Ge_{0.5}$ $Al_{0.5}$ As film, the crystal orientation of which coincides with the orientation of the substrate [14].

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