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COMPOSITION AND STRUCTURE OF THE INTERFACIAL INTERFACE Si/Al(111) AND Si/Cu(111)

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ABSTRACT

In this paper the results of experimental studies of the regularity of the formation of the interfacial boundary during the deposition of Si and Ge on the surface of single crystals Al(111) and Cu(111) are presented. Optimal modes of sputtering and annealing for obtaining semiconductor-metal systems have been established. The effect of barium ion implantation on the composition, morphology, electronic and crystal structure of the Si(Ge)/Cu(Al) system has been determined. The optimal temperature for the creation of nanoheterostructure has been shown Si-CuSi-Cu. Based on the data of the IPS and CPE, it was established for the first time that during the deposition of Si on the surface of Al and subsequent annealing, a bond between the Si and Al atoms is not formed.

KEYWORDS

Heterostructure, nanofilms, nanophases, single crystal, energy loss by electrons, intensity, plasma oscillations, photoelectrons.

Introduction

The use of nanoscale materials in the creation of various heterostructures for modern electronics devices requires obtaining the most complete information about the concentration of impurity atoms on the surface and their distribution along the depth. Therefore, nanofilms and nanocrystals of metal silicides and other semiconductor compounds obtained by various methods under ultrahigh vacuum conditions on the Si surface, as well as multilayer Si–Me–Si–Me systems, on the basis of which modern micro- and nanoelectronic devices are being developed, are being extensively studied [1-5].

In particular, nanophases and nanolayers of metal silicides and germanides have prospects in the creation of microwave transistors and integrated circuits, and GexSi1−x/Si heterostructures have prospects in the creation of LEDs, photodetectors, laser sources, optical and electronic devices [6–13].

This paper presents the results of experimental studies of the regularities of the formation of the interfacial boundary during the deposition of Si and Ge on the surface of single crystals Al(111) and Cu(111), the establishment of optimal modes of sputtering and annealing for the production of semiconductor-metal systems, the effect of ion implantation and adsorption of barium atoms on the

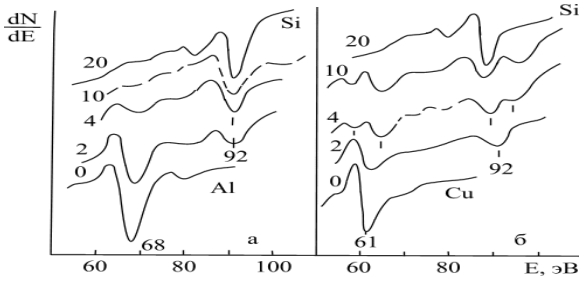
composition, morphology, electronic and crystal structure of the Si(Ge)/Cu(Al) system. Prior to the start of this work, such studies had not been conducted.

Ultra-pure single-crystal samples Al(111) and Cu(111) were chosen as substrates. Before spraying Si, these samples were degassed at T=850 K and 900 K, respectively, at a vacuum of 10-7 Pa for 3-4 hours. Further cleaning was carried out by etching the surface Ar+ with an energy of 1 keV in combination with short-term annealing to 950 (Al) and 1000 K (Cu). At the same time, the surface oxygen concentration was ≥1 at.%, and carbon - 0.5 at.%. Spraying of Si with a thickness of 1 to 20 monolayers was carried out at a vacuum of -10-6 Pa. Changes in the composition and electronic structure of the surface of Al(111) and Cu(111) during the deposition of Si were studied by Auger-electron spectroscopy, spectroscopy of characteristic energy losses by electrons, and ultraviolet photoelectron spectroscopy at a vacuum of 10-7 Pa.

Figure 1 shows the Auger spectra obtained by sputtering Si on the surface of Al(111) (Fig. 1, a) and Cu(111) (1, b). The thickness of the θ films in the monolayers is shown in the curves. It can be seen that in the case of the Si/Al(111) system, the adsorption of Si starting with θSi=2 monolayers is accompanied by the appearance and increase in the intensity of the silicon peak L23VV (E=92 eV) and the weakening of the intensity of the Egger peak L23VV Al (E=68 eV). With the increase in the thickness of the Si film, the position and shape of the Sir peaks Si and Al practically does not change, only their intensities change. Starting from the thickness of θSi = 3-4 of the monolayer, there is a sharp decrease in the intensity of the Al peak, which is explained by the formation of a continuous film of Si. Complete disappearance of the Auger peak Al is observed at θSi ≥ 10 monolayers. The Si concentration in this film is ~35-40 at.%. Analysis of the ECO results shows that up to θSi = 8-10 monolayers there is an intensive interdiffusion of Si atoms into Al and Al into Si. At the same time, a chemical bond between the atoms of Al and Si is not formed, but a mechanical mixture of the [Al+Si] type with a thickness of 14-16 monolayers (35-40 Å) is formed. At θ ≥ 12-15 monolayers, the intensity of the SiL23VV peak practically does not change.

A different picture was observed in the Auger spectra of the Si/Cu(111) system (1, b). At θSi = 2 monolayers, the peak L23VV Si appears in the Auger spectrum, the intensity of the peak Cu MVV (E=61 eV) decreases and its width increases slightly. Starting from θ≈3-4 monolayers, the peak Si with E=92 eV splits into two peaks: 90 and 94 eV [14], and instead of the peak Cu with E=61 eV, peaks with energies of 59 and 63 eV appear. the results show that in this case the chemical compound Cu+Si is formed [15]. Analysis of changes in the intensities of high-energy peaks Cu (ELMM=922 eV) and Si (ELMM=1620 eV) and calculations carried out using the formula Cx=αCstable showed that at θ≈12 monolayers, an amorphous film (Fig. 1.b) of copper silicide is formed with a thickness of θ≈24-26 monolayers (60-65 Å) with an approximate composition of CuSi. At a thickness of θSi ≥ 12-15 monolayers, a film of "pure" silicon is formed. Heating of the Si/Cu(111) system with θSi ≈ 12 monolayers at T= 810 K for 30-40 minutes led to formation of a polycrystalline film (Fig. 1.b) CuSi with a good stoichiometric composition, and at T ≈ 900 K, an insular single-crystal film was formed. In the case of θSi ≥ 15-20 monolayers, heating at T-750 K leads to an increase in the thickness of the CuSi film by 2-3 monolayers, and the surface Si film had a structure close to monocrystalline. At an increase in temperature to 900 K, the morphology of the surface of the Si film changes, due to the formation of islands in the CuSi film. Thus, the optimal temperature for creating a Si-CuSi-Cu nanoheterostructure is 750-800 K. In the case of Si films with θSi ≥ 25-30 monolayers at a temperature

of 900 K, a single-crystal film Si(111) was formed, the composition, structure and properties of which do not differ for massive films (Fig. 1.b). The spectra of CPEE Al and Cu with a Si film with a thickness of θSi ≈8 and θSi ≈20 monolayers are shown in Figs. 1a and 1b, respectively.



Rice. 1. Auger spectra Si sprayed on the surface Al(111) (Fig. 1, a) and Cu(111) (Fig. 1, b). Figures for the thickness curves of Si films in monolayers.

Similar patterns were observed when sputtering Ge on the surface of Al(111) and Cu(111). Therefore, the results of the study for Ge films are not given. It should be noted that at θ ≥20-25 monolayers, heating at a temperature of 950 K leads to the formation of a film of Si(111) and Ge(111) with a good stoichiometric composition.

References

1. Landry O., Bougerol C., Renevier H., Daudin B. // Nanotechnology. – 2009. – T. 20. – №. 41. – C. 415602.
2. Wang D., Zou Z. Q. Formation of manganese silicide nanowires on Si (111) surfaces by the reactive epitaxy method //Nanotechnology. – 2009. – T. 20. – №. 27. – C. 275607
3. Domashevskaya E.P., Terekhov V.A., Turishchev S.Yu., Koyuda D.A., Rumyantseva N.A., Pershin Yu.P., Kodratenko V.V., Appathurai N. // FTT. – 2013. T. 55. - No. 3. - P. 577 – 584.
4. Alekseev A.A., Olyanich D.A., Utas T.V., Kotlyar V.G., Zotov A.V., Saranin A.A. // ZHTF. - 2015. - T.85. - No.10. - P.94-100.
5. B.M. Ротштейн, P.X. Ашуров, T.K. Турдалиев, И.Х. Ашуров // Uzbek Journal of Physics. – 2017. - №4. - C.12.
6. Bolkhovityanov Y. B., Deryabin A. S., Gutakovskii A. K., Sokolov L. V. Unzipping and movement of Lomer-type edge dislocations in Ge/GeSi/Si (0 0 1) heterostructures //Journal of Crystal Growth. – 2018. – T. 483. – C. 265-268.
7. Saito S., Al-Attili A. Z., Oda K., Ishikawa Y. Towards monolithic integration of germanium light sources on silicon chips //Semiconductor Science and Technology. – 2016. – T. 31. – №. 4. – C. 043002.
8. Liu J., Kimerling L. C., Michel J. Monolithic Ge-on-Si lasers for large-scale electronic–photonic integration //Semiconductor Science and Technology. – 2012. – T. 27. – №. 9. – C. 094006.
9. Umirzakov B.E. Dissertation on the Academic Step. Doctor of Physical and Mathematical Sciences Electron Spectroscopic Studies and Analysis of the State of the Surface of Multicomponent Systems Created by Ion Implantation. - 1993. - P. 293.
10. Isakhanov Z.A., Yorkulov R.M., Tulyaganova Sh.A. Study of the Properties of Nanoscale Structures Created on the Surface of the Free Si/Cu Film System // Laser, Plasma Research and Technologies-LAPLAZ-2020. – 2020. – P. 204-205.