Characterization of GaAs/GaAlAs MOCVD Superlattice by STM/AFM Technique.

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Introduction.

Compound semiconductor superlattices are considered as structures with high potential for microwave, optoelectronics and very high speed devices application [1]. To control structures parameters and to assess their properties the development of characterization technique, especially express methods, is of great importance.

Auger electron spectroscopy, LEED and SEM techniques are mostly often used to analyze the multilayered compound semiconductor structures [2]. However they are cumbersome and expensive and rather long time is required for the analysis. Besides the resolution necessary for the layers of nanometer thickness cannot be achieved by these methods .

Scanning probe microscopy (SPM) which is near - field imaging and spectroscopy technique such as scanning tunneling microscopy/spectroscopy (STM/STS), atomic force microscopy (AFM) and others provides new possibilities for surface analysis and diagnostics with very high resolution. STM technique for multilayered compound semiconductor structure analysis was used by O.J.Glembocki et al [3] in vacuum and J.A.Dagata et al [4] at an open air. In this paper we report on the complex STM/AFM imaging of GaAs/AlGaAs superlattice at an open air. Comparing the different modes images one may get rid of artifacts and the reliable results may thus be achieved.

Experimental.

We used SPM - P4 device produced by "NT-MDT" (Russia) in our experiments. The device is a combination of STM and AFM. AFM enables elastic force and lateral force surface distribution imaging alongside with surface relief imaging through Van der Waals force.

The samples with GaAs/AlGaAs superlattice structure were obtained using MOCVD process at the EPIQUIP-502RP equipment. The structures was produced under lowered pressure (50 mbar) at 650°C. The peculiarity of the process is that the threemethylaminalan is used as a source of Al. Structure contains 9 alternating GaAs and $Al_xGa_{1-x}As$ p-type layers of equal thickness about 90 nm on n^+-GaAs wafer with AlAs buffer layer. The doping concentration in the layers is more than 10^{18} cm^{-3} and AlAs mole fraction x≈0.6. The AlAs buffer layer thickness is about 200 nm. The above structure parameters were found from Auger spectroscopy, C-V profiling and other measurements [5].

The edge of a spalled sample was analyzed using STM and AFM modes of operation at an open air. For the precise determination of the lattice period the spatial Fourier - transform analysis of the output signal was applied in line with the structure imaging.

Results and discussion.

The STM image of the superlattice is shown at Fig.1. At Fig.2 the AFM image of the superlattice is presented, while Fig.3 shows the elastic force imaging of the same region of the surface. Fig.4 represents the lateral force image. Periodic structure and every individual layer of the superlattice are very well distinguished, all the images being of good contrast. The buffer layer is also very well visualized in AFM images.

Spatial Fourier - transform of the images was used for the determination of superlattice period. Two symmetrical reflexes corresponds to 83 nm one - dimensional lattice period. The value is in a good accordance with that estimated by other methods [5].

The results allow to suggest that STM technique is sensible to different mole fractions x of AlAs in AlGaAs compound while scanning over the surface of a spalled edge at an open air. That may result from the difference in the electron work functions of the materials. The AFM and other near - field force modes of operation register the spatial relief or force relief of the layers interfaces. All the results are in full agreement which allows the reliable identification of the structure.

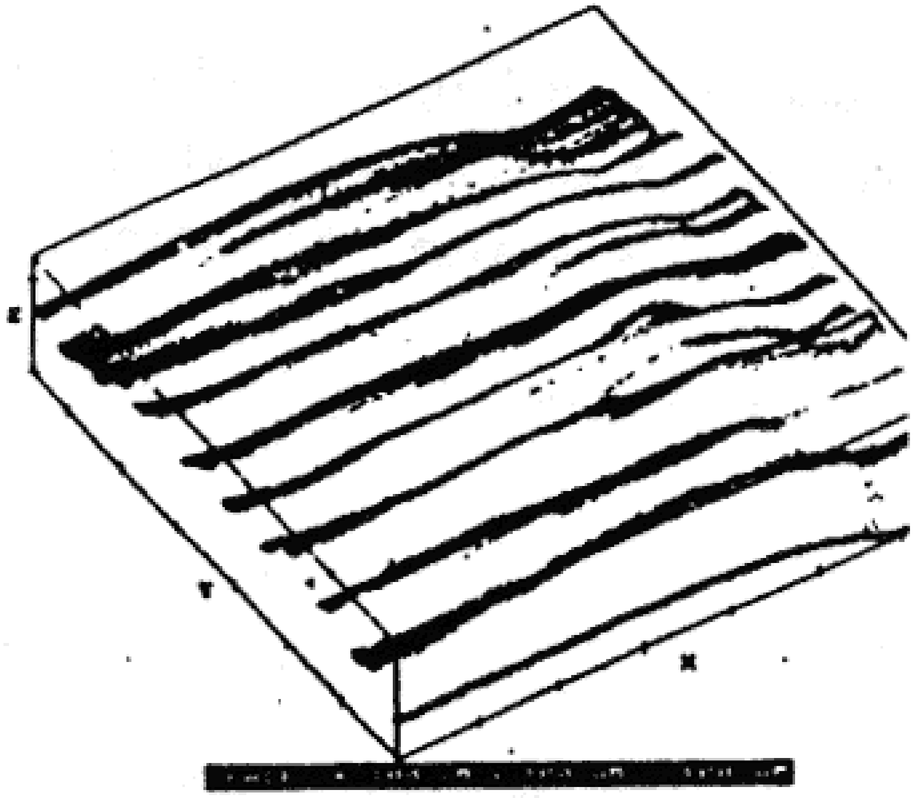

Fig.1. STM image of the superlattice.

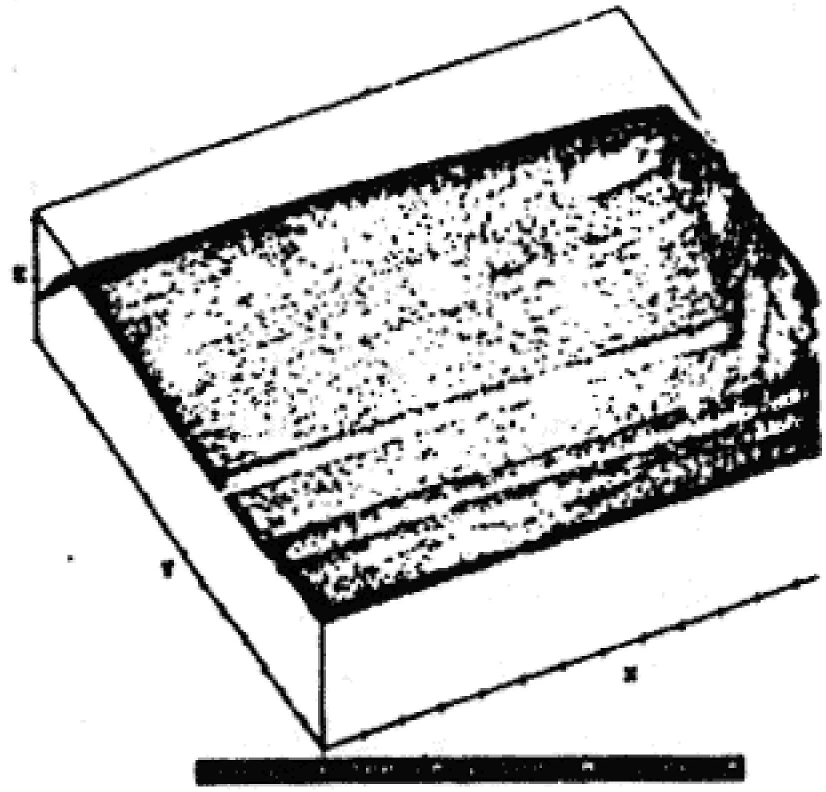

Fig.2. AFM image of the superlattice.

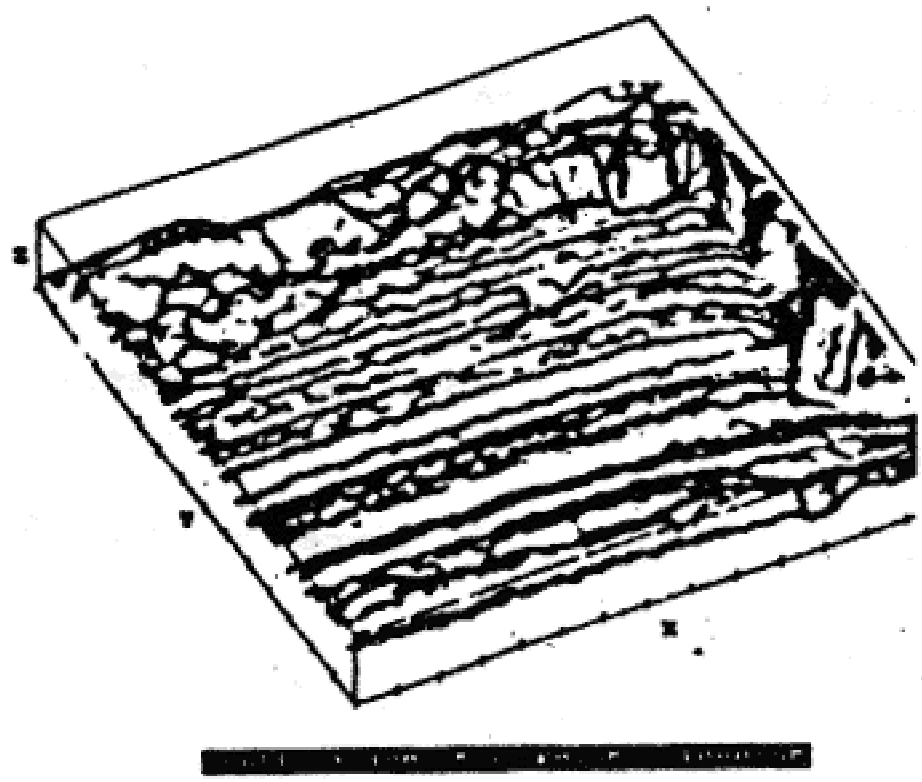

Fig.3. Elastic force relief at the superlattice surface (a.u.).

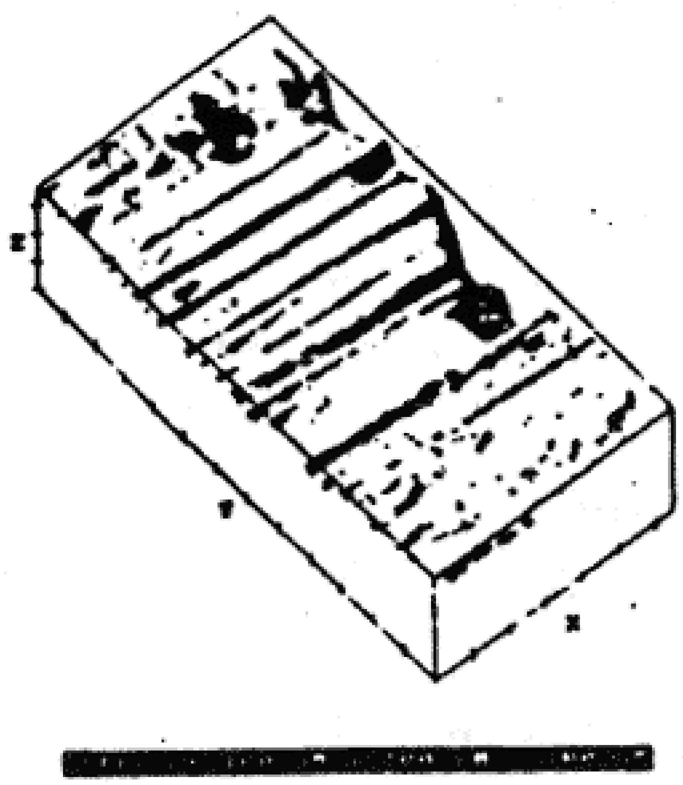

Fig.4. Lateral force relief at the superlattice (a.u.).

There is surely no problem in distinguishing more delicate multilayer structures with periods magnificently less than that studied in this work.

Conclusion.

The STM/AFM technique at an open air proves effective for the analysis of the of GaAs and $Al_xGa_{1-x}As$ multilayer structures with good contrast. The superlattice period may be found with high accuracy using spatial Fourier - transformation of the output signal while scanning over the surface. The advantages of the SPM technique are:

- high resolution combined with the possibility of large scale imaging;
- simplicity and rapidity of the imaging procedure;
- direct space imaging;
- reliability of the results based on different modes of operation.

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