

The study of influence of the gas flow rate to etched layer thickness, and roughness of the anisotropy field of gallium arsenide is etched in the plasma chemical etching process

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Abstract. In the experiments on the etched surface of gallium arsenide were performed. We studied the effect of BCl_3 gas flow rate on the thickness of the etched layer. GaAs etching rate was: 537,4 nm/min 28,7 nm/min 2,6 nm/min, the values of the flow rate of BCl_3 N_{BCl_3} - 15, 10, 5 cc/min, respectively. The effect of BCl_3 gas flow rate to the mean-square roughness of the etched surface. The influence of the anisotropy of the process on the geometry of the etched area. Revealed that the deflection angle for the samples treated with the working gas flow rate N_{BCl_3} - 15 cc/min in the [110] direction was $\alpha_{[110]} = 65,5^\circ$ in direction [111] was $\alpha_{[111]} = 45,58^\circ$. For samples treated with the working gas flow rate N_{BCl_3} - 10 cc/min in the [110] direction was $\alpha_{[110]} = 20,94^\circ$ in direction [111] was $\alpha_{[111]} = 11,37^\circ$. For samples treated with the working gas flow rate N_{BCl_3} - 5 cc/min in the [110] was $\alpha_{[110]} = 0,32^\circ$ in direction [111] was $\alpha_{[111]} = 0,21^\circ$. The results can be used to produce discrete diodes, heterojunction devices, and others.results.

1. Introduction

The widespread use of plasma chemical etching processes in micro- and nanoelectronics technology represents an important development trend of technology, is the transition from the liquid to the processes of "dry" gas-phase processes [1-6]. For plasma BCl_3 characterized by significantly lower concentrations of chlorine atoms, but is often seen planting solids plasma-chemical reactions on the walls of the reactor and the surface of the treated material, but its benefits are not fully realized due to poor knowledge of the mechanisms of active plasma particles interact with GaAs [7-8]. The lack of information about the types of active particles, interoperable, limiting stage of the process, their kinetic characteristics (probability, rate constants) does not control the result of the processing efficiently, optimize the process mode, as well as to carry out an adequate comparison of the output parameters of the process with a studied system [9- 12].

Atomic force microscopy is one of the most promising methods for studying the surface topography, the past treatment. The big advantage of this method is the possibility of obtaining nanometric resolution without the use of vacuum [13- 17].



The aim of this work was to study by atomic force microscopy etched layer thickness, quality of the etched surface of the structure and anisotropy profile gallium arsenide after plasma chemical etching in combination plasma capacitive and inductive discharge of the mixture at changing the working gas flow [18- 21].

2. Description of the experiment and research methods

In this paper, the method of plasma chemical etching in combination with perchloric capacitive and inductive plasma discharge. This method makes it possible to combine the two modes of plasma chemical etching: reactive ion etching and etching in inductively coupled plasma. Installation STE ICPe68 is used for plasma chemical etching. The diameter of the processed wafers - 150 mm, with the ability to use samples of arbitrary shape, it can be used as a platform for application development and research and for industrial production. The unit is equipped with a reactor gas supply system, to optimize the uniformity of processes and reduce pumping time is also provided for installation in helium cooling for long etching processes [22].

As experimental samples fragments own GaAs wafers were used having a standard liquid surface after polishing. Preparation of gallium arsenide substrate was the fact that the surface of the deposited protective mask pattern plasma resistant photoresist.

Control surfaces after plasma treatment was carried out by means of nano-lab «NTegra» probe using a "semi-contact" mode. For samples treated with plasma AFM images were obtained which was built profillogramma on which determines the depth of etched layer and the etching angle. So with the help of a specialized package «Image Analysis» estimated etched surface roughness. Prior to the measurements on the microscope photoresist mask is removed.

In this paper, experimental studies were conducted to identify the etching rate, the roughness of the etched area and the process of the anisotropy of BCl_3 working gas flow rate in the combined plasma. Samples were processed at a pressure of 2 Pa, a capacitive plasma source power W_{RIE} - 35 W, bias voltage $U_{\text{bias}} = 102$ V, the power source is inductively coupled plasma W_{ICP} - 300 W, the buffer gas flow rate was N_{Ar} - 100 cc/min speed working gas flow changed N_{BCl_3} - 5, 10, 15 cc/min, the etching time at all stages was $t = 1,2,3$ minutes.

3. Results and discussion

Experimental samples obtained during the first phase, were investigated by atomic force microscopy. Figure 1 shows the SEM image obtained by scanning and profillogramma samples after the plasma etching process gas flow rate was N_{BCl_3} - 15 cc/min.

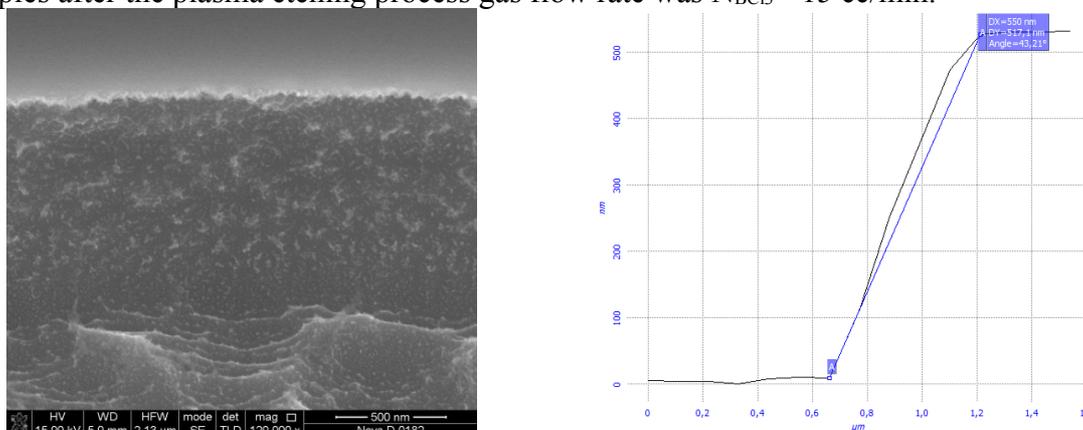


Figure 1. SEM of etched layer and profillogramma GaAs at BCl_3 - 15 cc/min, the etching time of 1 minute.

According to the results of this stage of experimental studies have been constructed according to the thickness of the layer etched by the etching time for various values of working gas flow rates shown in Figure 2.

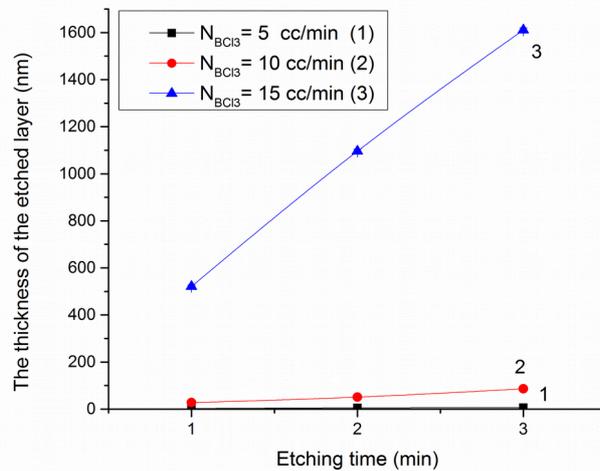


Figure 2. The dependence of the thickness of the etched GaAs times, for different values of the working gas flow rate.

The results of the research of the dependencies, presented in Figure 3, we can estimate the rate of etching. GaAs etching rate was: 537,4 nm/min; 28,7 nm/min; 2.6 nm/min, the values N_{BCl_3} working gas flow rate - 15, 10, 5 cc/min, respectively.

As was the dependence of the mean square roughness of the etched area of the etching time for various values of the flow rate of the working gas, which is shown in Figure 3.

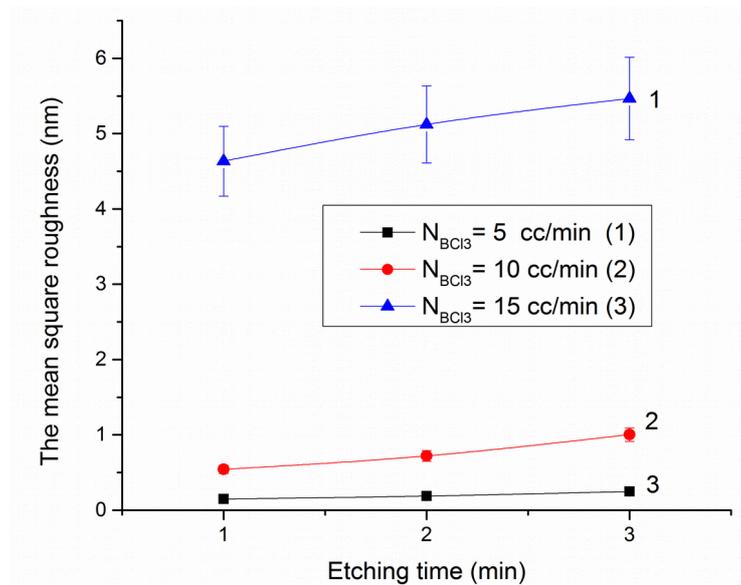


Figure 3. The dependence of the mean square roughness of the etched GaAs layer from time to time, for various values of the working gas flow rate.

Because of dependencies that at least the values of the working gas flow rate are reduced etch rate and, accordingly, the root mean square roughness of the etched surface. As it is known, in plasma-chemical etching of the etched area has a trapezoidal shape and anisotropy etched surface can be estimated by the vertical wall angle different directions. Figure 4 shows two lateral profilogrammy etched surfaces.

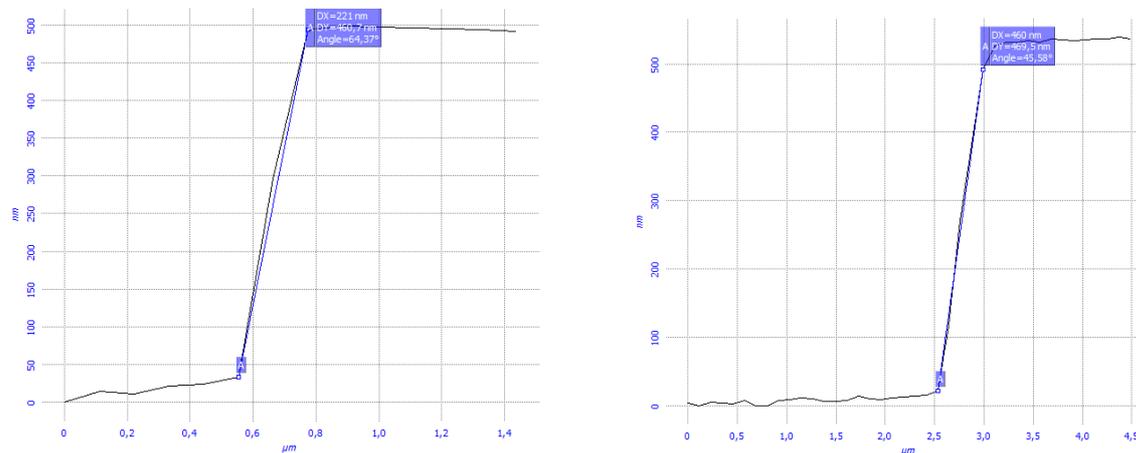


Figure 4. Profilogram etched sides along different crystallographic directions:

a) crystallographic direction [110];

b) crystallographic direction [111].

Revealed that the deflection angle for the samples treated with the working gas flow rate N_{BCl_3} - 15 cc/min in the [110] direction was $\alpha_{[110]} = 65,5^\circ$ in direction [111] was $\alpha_{[111]} = 45,58^\circ$. For samples treated with the working gas flow rate N_{BCl_3} - 10 cc/min in the [110] direction was $\alpha_{[110]} = 20,94^\circ$ in direction [111] was $\alpha_{[111]} = 11,37^\circ$. For samples treated with the working gas flow rate N_{BCl_3} - 5 cc/min in the [110] was $\alpha_{[110]} = 0,32^\circ$ in direction [111] was $\alpha_{[111]} = 0,21^\circ$.

The results of the experiments were built according to the angle of the anisotropy of the working gas flow rates N_{BCl_3} (Figure 5).

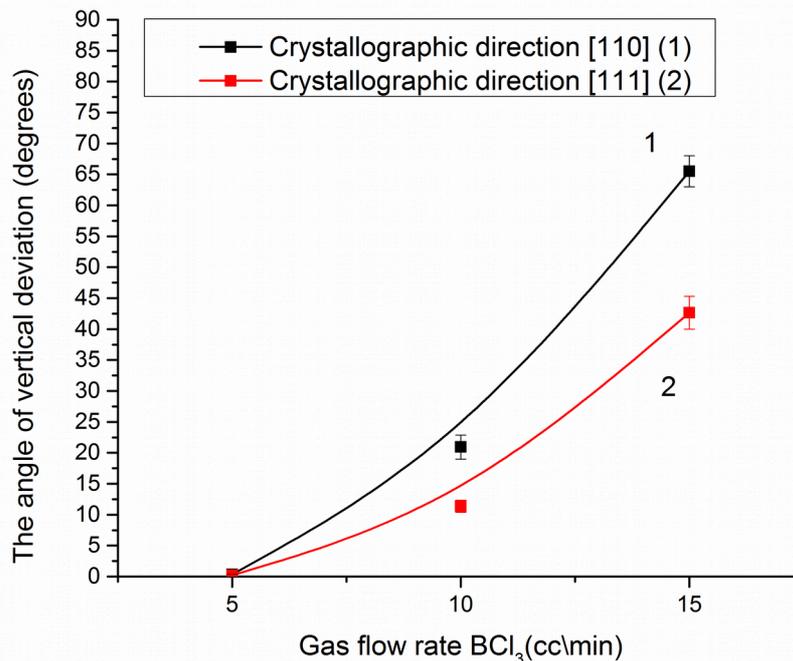


Figure 5. The dependence of the deflection angle from the vertical of the working gas flow rate.

The dependence can be seen that at lower flow of the working gas and, respectively, and the angle of anisotropy etching is reduced at lower speeds, in different crystallographic areas seeking to vertical.

4. Conclusion

In this paper we studied the influence of working gas flow rate of plasma-chemical etching process in a combined plasma etched layer thickness, roughness of the etched surface and the anisotropy of the process in an environment of technological gases BCl₃ and Ar.

The rates of the etching, the value of the mean square roughness and anisotropy angles for modes shown in the work. It was also found that when the power source is inductively coupled plasma burr remains relatively constant, while reducing capacitive plasma source power and bias voltage decreases accordingly decreases the rms roughness of the etched surface.

Using the experimental results, we can find the optimal etching modes, which allow the most precise control over the thickness of the etched layer is etched surface roughness based on the anisotropy of the process.

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