Chemical Method for the Gallium Arsenide Rectification Structure Divide into Crystals

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***Abstract* - Thise investigations are referred to power semiconductor devices (PSD) area manufactured by gallium arsenide (GaAs) advanced technology. The work's objective is excluding the break-down effect on the p-n junction surface of high voltage devices, which is advance progressed with diminishing the crystal dimensions in the dividing process of the semiconductor structures.**

We propose the method of the GaAs deep etching by a mixture utilizing concentrated acids as nitric and hydrochloric acids in equal rates. After 30 min of mixing up the solution formation is consorted of the endothermic reaction, bound up by nitrosyl chloride (NOCl) formation, which dissolves the GaAs decomposed product in solution by arsenic oxidation up to As(V), forming ortoarsenic acid and gallium chloride. This method is used for dividing semiconductor structure of GaAs with 0.4-0.6 mm of thickness in small dimensioned crystals. The advantages of this technology are the great speed of GaAs dissolving, low costs of manufacturing and profitableness.

Keywords: gallium arsenide, dissolution, chemical divide of the structure in crystals.

1. INTRODUCTION

In present power semiconductor devices (PSD) manufacturing field is ascended in development [1] because a pronounced worldwide energetic crisis makes appearance.

One of the problems existing at PSD producing by advanced gallium arsenide (GaAs) technology is to excluding the break down effect in high voltage device on p-n junction surface. There are several known methods of reducing the electrical field on one surface [2] in the planar construction of device as:

- Formation of a protection semiconductor circle at the brim of the recovery element with more specific resistance (SR) than SR utilizing one.
- Formation of a contact on p-n junction surface by high dielectric material.
- Formation of an inclined facet on p-n junction surface in massive construction and the conduction of the inclined angle Fig.1 utilized in industry as a method for limiting the junction break-down on the surface.

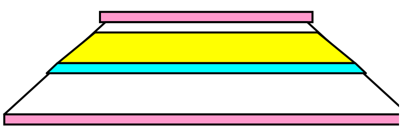


Fig.1 Recovery element with facet on p-n junction side (n_o- base, Mo – molybdenum).

The p-n junction with inverse facet [2] may have maximal break down voltage. But the facet formation needs specialized equipment and a big volume of work which increases the production costs. Mechanical divided of the massive recovery structure in crystals with less 6 mm^2 of size by diamond disc DAR-2 utilized in EM-225 equipment by microelectronic industry costs much more in case of high voltage.

If technological process includes the operation of passivation by chemical method after the operation of the facet formation, it is useful to make the recovery structure dividing by chemical technology too, this way it is advantaged by surface processing quality and is already known in microelectronics. The known methods for chemical dividing of crystals (GaAs) elaborated for different specific goals [3] have a small speed of semiconductor corrosion and the utilized solutions are loosing their dissolving capacity depended upon quantity of dissolved material in solution.

We present below a technological research of deep GaAs corrosion by a mixture of the strong concentrated acids as nitric (HNO_3 , 70%) and hydroxide (HCl, 37%) in equal rates following the objective of chemical dividing in crystals the semiconductor structure with the thick base (up to 100 μ).

2. EXPERIMENTAL METHODS.

2.1. Preparation of dissolving solution.

The solution of corrosion was performed in accordance with the method [4] of dissolving the solid waste process from technological reactor after epitaxial growth of GaAs semiconductor structure in cleaning. The time of solution stabilization is determined by an experimental control (checking) of the thermal effect which accompanies the chemical reaction. A thermostatic volume with constant pressure (about 8 Cm. Wt. Col.) was made for this experiment. The HA tip of thermocouple in glass coat for acids mixture was utilizing. Dynamics temperature during chemical reaction was measuring with micro-voltmeter F30 for three rates of solutions and it is shown in the Fig.2.

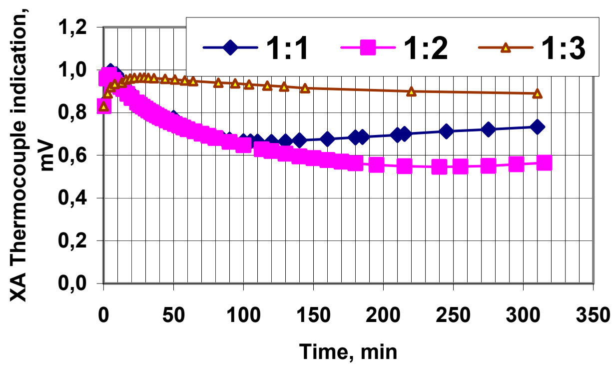
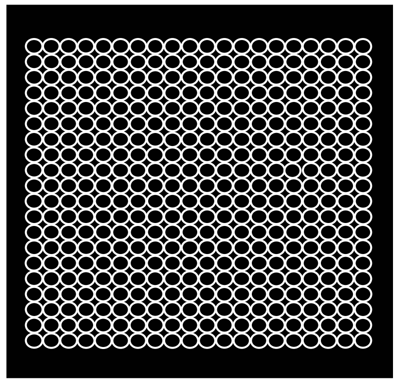


Fig. 2 The temperature dynamics of etching solutions HNO_3: HCl.

As shown in Fig. 2 the beginning of chemical reaction for all solutions is accompanied of the heat emitting, followed by gases elimination, which intensity increase with temperature and concentration of nitric acid. The intensity of eliminated gases achieves maximum value for rates 1 :1 and 1 :2 after 5-10 min. After 30 min the temperature of solution achieves the room temperature values and the eliminating process is finished. The temperature continues to dimish up to 80 of Minuits. There is shown that the chemical reaction in the solution continues it is produced an endothermic effect for a long time which depends on concentration of nitric acid in solution. We consider that this effect is generated on nitrozol chloride formation, which serves in etching solution as dissolvent of GaAs oxidizing products by nitric acid. The optimal concentration of HNO_3 in solution is 25 – 50 %.

2.2 CRYSTALS DIVIDING

The dividing method of crystals includes two technological processes. Preparation process includes the covering of semiconductor structure with photo-sensible coat (AZ4533) resisting at acidic solutions, the photolithography mask design exposure on the photo-sensible coat utilizing EM-576 model of equipment and windows opening by coat etching. The second process is GaAs etching in acid solution. Windows shown in Fig.3 represent some circles with 2 mm of internal diameter and 0.25 mm of thick, through which the semiconductor has a contact with the acidic solution. Etching reaction is produced by sinking the semiconductor structure in acid solution prepared in according with com. 2.1.



Fig, 3 Photolithography mask for 2 mm of diameter.

Semiconductor structures are placed on quartz support, which is permanently moved during reactions. Solution exiting is stabilizing the homogenous etching speed on structure surface.

3. RESULTS AND DISCUSSION

The investigation subject is the guided dissolving process through mask's windows of the GaAs plate with recovery structure about 400 µ of thickness in acidic solution compound from oxidant – nitric acid and dissolvent – nitrosyl chloride (NOCl) in a equal rate. Two effects differ the investigation object. NOCl dissolves the GaAs component by arsenic oxidation up to As (V) Fig.4 forming orthoarsenic acid [5] and gallium chloride. The other effect is a great potential for GaAs oxidation [6] of the nitric acid in HCl mixture. Thus the etching solution can accumulate as ion form up to 160 g/l of GaAs with 2 – 12 [mg/ cm^2 x min] of speed in the static conditions.

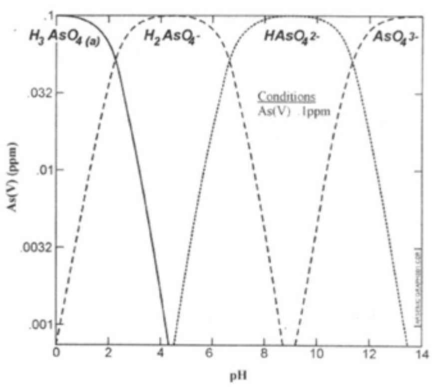


Fig. 4 Concentration – pH Diagram for As (V) [5]

The dissolving speed dynamics of GaAs plate vertically installed in optimal acid solution depending on quantity of the dissolving material is shown in Fig. 5. Quantities of dissolved GaAs in solution are presented by the concentrations of gallium. In solutions with ratio 1:2 and 1:3 contents of HNO_3 the speeds of dissolution achieves values of 4 to 10 [mg/cm^2 * min] and diminishes considerably at the concentrations of 20 g/l.

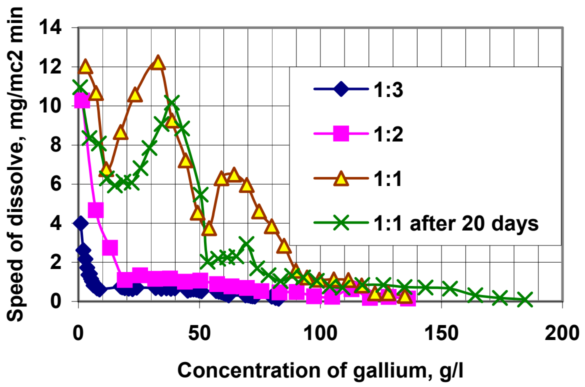


Fig.5. Dissolution of GaAs in solution of HNO_3 : HCl

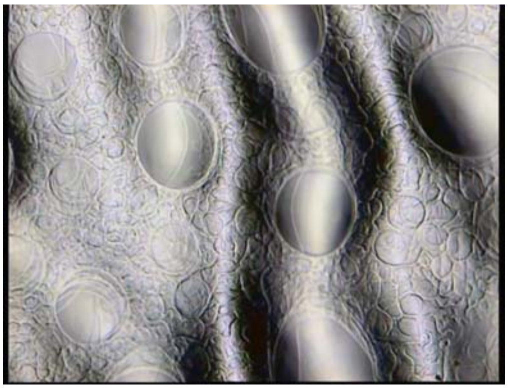


Fig. 6 AFM image of GaAs surface in acidic solution at 7.23 g/l of gallium.

The stated above reaction model of GaAs in acidic solution is kept until 33 -38 g/l of the dissolving value, that shows the AFM image Fig. 6 of the GaAs plate surface after etching. The image was obtained with the assistance of National Center of Materials Study and Testing of the UTM.

3. CONCLUSIONS

The result of reaction between nitric and hydrochloric acids contains nitrosyl chloride, which participates directly in GaAs dissolving process. Although GaAs solubility in this solution reaches 1.94 mol/l the optimal dissolving speed 8-10 [mg/ cm^2 x min] is kept depending on the quantity of GaAs, dissolved in solution with equal rate of oxidant and dissolvent, until 38 g/l.

Elaborated chemical method is destined for technological applications of dividing into crystals the high voltage GaAs semiconductor structure with 0.4 – 0.6 mm of thickness. Advantages of this technology are the high speed of GaAs dissolving, low costs of implementation, reducing of eliminated gases and profitableness.

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