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Short communication

New wet etching solution molar ratio for processing T2SLs InAs/GaSb nBn MWIR infrared detectors grown on GaSb substrates

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ABSTRACT

Mid-wave infrared (MWIR) technology is dominated by HgCdTe. However, in terms of performance, InAs/GaSb type-II superlattice (T2SL) has shown the theoretical potential to compete with HgCdTe. T2SLs InAs/GaSb technology is under development, where proper detector's architecture formation must be considered as one of the most important steps of the fabrication process. The paper presents experimental results related to chemical etching of the T2SLs InAs/GaSb with bulk AlGaSb barriers, mesa type nBn MWIR detectors. Although, we attempted to transfer HgCdTe etching solutions: $Br_2+C_2H_6O_2$ into T2SLs InAs/GaSb technology, $H_3PO_4+C_2H_8O_7+H_2O_2+H_2O$ (molar ratio: 1:1:4:16) at temperature ~21 °C was estimated to have optimal parameters in terms of the mesa profile and current–voltage characteristics. Repeatability of the mesa profiles and surface uniformity was reached. Overetching close to the mesa sidewalls was not observed.

1. Introduction

$A^{III}B^{V}$ T2SLs InAs/GaSb material is considered to be the most promising system for the fabrication of the high performance IR detectors suitable for MWIR range. The technology of mesa delineation, is one of the first processing steps which affects the performance of the of the IR detectors, regardless of the architecture. For a lot of sophisticated structures etch-stop layers are needed. High quality structures with sharp mesa sidewalls and less oxidation of the material can be obtained by dry chemical etching. On the other hand, when thin layers have to be removed without crystallographic damage on the surface, the wet chemical etching is preferable to ensure the appropriate parameters of the mesa structures, such as: the homogeneity of the etching rate, high quality surface morphology, and the repeatability of the etching process. The choice of the appropriate wet chemical solution is essential to etch the T2SLs InAs/GaSb where two binary compounds present dissimilar physical and chemistry properties. The kinetic of a given etchant is very sensitive to the amount of each element present in the solution and to the experimental conditions. It must be stressed that the proper etching solution for T2SLs InAs/GaSb is still under development.

In this paper, we report results of T2SLs InAs/GaSb mesa nBn detectors processing with a new molar ratio wet chemical etchant solution. The chemical solution is based on $H_3PO_4+C_2H_8O_7+H_2O_2+H_2O$ (molar ratio: 1:1:4:16) at temperature ~21 °C. The nBn detector performances are evaluated by current–voltage measurements and mesa sidewalls by optical microscopy.

2. Sample structure

The wafers presented in this work were grown by solid-source molecular beam epitaxy (MBE) system in Center for High Technology Materials (CHTM), University of New Mexico (UNM), while device fabrication process was performed at Military University of Technology (MUT). All etching experiments were carried out on the nBn T2SLs InAs/GaSb structure with $Al_{0.2}GaSb$ barrier grown on the GaSb:Te n-type doped (001) substrate. The analyzed MWIR T2SLs InAs/GaSb nBn detector is shown in Fig. 1. The detector structure consists of two 10 monolayer (ML) InAs/10 ML GaSb:Te n-type doped contact layers. Between contact layers, the non-intentionally doped absorber (2.13 μm) and p-type barrier $Al_{0.2}GaSb$ (100 nm) were grown. The total device thickness was estimated 2.96 μm.

One of the most common techniques for obtaining such mesa structure is an etching of an appropriate depth to expose the contact layer. According to Fig. 1, the optimum etching depth, allowing for obtaining the mesa structure should be in the range of 2.55–2.75 μm to reach the appropriate electrical contacts. The main problem during detector processing is the inhomogeneity of the etch rate across the entire surface of the sample and, in particular, around the sidewalls of the "mesa". This inhomogeneity may cause a local overetching to contact layer next to the mesa

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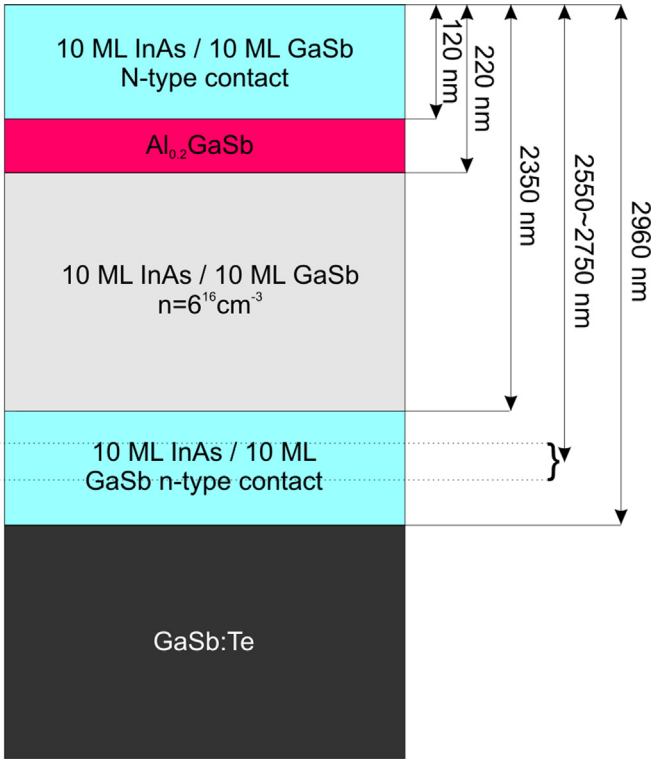

Fig. 1. MWIR T2SLs nBn detector structure.

sidewalls resulting in lack of direct electrical connection between top and bottom contact (see Fig. 1).

3. Experimental results

The analyzed samples were prepared by photolithography process and divided into individual pixels. Each of the individual samples before photoresist deposition were degreased in acetone and dried with N_2. Afterwards, the samples were immersed in a freshly made etching solution for a time within 1 min. The sample during etching was placed horizontally with photoresist facing the top of the solution. After completion of etching, the samples were washed in a strong stream of deionized water to remove the dilution of the etching solution from the surface. The next step was the removal of the photoresist layer using acetone, and re-washing in a stream of deionized water and the drying of the sample.

Numerous wet chemical etchants available mainly for GaSb-based materials were preliminary tested on T2SLs InAs/GaSb. We also tested $Br_2+C_2H_6O_2$ etchant solution used in HgCdTe processing. Etching was performed by several solutions based on (H_3PO_4), hydrogen peroxide (H_2O_2) and purified water (H_2O) with either extra citric acid ($C_2H_8O_7$) or tartaic acid ($C_4H_6O_6$), with chosen chemical molar compositions [1,2].

The initial experiment was a comparison of the profiles obtained from the mesa by an optical profilometer. The surface morphology and roughness were assessed indicating that $H_3PO_4+C_2H_8O_7+H_2O_2+H_2O$ gives the sharpest mesa sidewalls. In addition Fig. 2(a) shows that appropriate selection of etching solution has a significant impact on the final "mesa" shape. The main difference is due to the method of removing the etching reaction products from the mesa surface. The surface reaction products mix with the etching solution, and thus locally affect its molar ratios. The photoresist previously applied to layer do not affect the molar ratios of the etching solution, thus with its edge we can find a solution without reaction products. This effect is clearly visible for the solution of $Br_2+C_2H_6O_2$ in comparison to the solutions having the compositions $H_3PO_4+C_2H_8O_7+H_2O_2+H_2O$ and $H_3PO_4+C_4H_6O_6+H_2O_2+H_2O$ [1].

All above etching processes were performed within the time of 1 min at room temperature. The solutions' molar compositions were experimentally chosen in order to obtain a similar etching rate of ~0.7 μm/min. The next step was to optimize the performance of etching for the different molar compositions of a solution containing: $H_3PO_4+C_2H_8O_7+H_2O_2+H_2O$. Fig. 2(b) shows that the main parameter responsible for molecules removing of the sample material is of phosphoric acid molar ratio in comparison to the rest ingredients (red curve – 0:1:4:16) [3]. In order to improve the smoothness of the sample it is necessary to have a ingredient having the polishing capability [4]. Aqueous citric acid was used in our experiment. This acid causes a slowing in the rate of etching and reduces the surface roughness. Fig. 3((a)–(d)) shows surface topography for the $H_3PO_4+C_2H_8O_7+H_2O_2+H_2O$ selected molar ratios at room temperature. The optimized etching solution was found: 1:1:4:16 [see Fig. 3(d)]. The 16:1:38:150 molar ratio was found to be suitable for the structures with thick contact layer ~10 μm in comparison to the absorber thickness in the range of ~3 μm.

In addition to these parameters, the temperature of the etching solution is also important [5]. The temperature increase causes evolution of reaction products in the form of gas bubbles on the surface during the etching process. This effect significantly affects the dynamics of the chemical etching reaction in the place of the gas bubbles [see Fig. 4(a)]. As a result of these processes, the local

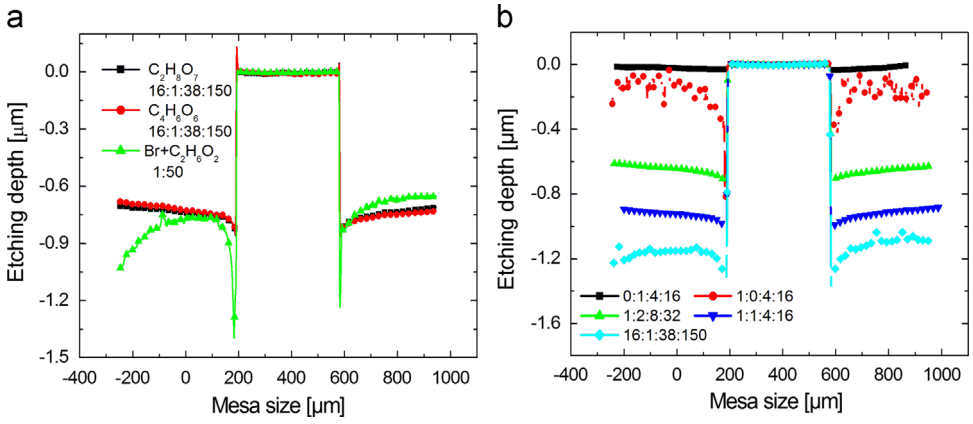

Fig. 2. Mesa profiles obtained for the solutions of compositions $H_3PO_4+C_2H_8O_7+H_2O_2+H_2O$; $H_3PO_4+C_4H_6O_6+H_2O_2+H_2O$; $Br_2+C_2H_6O_2$ (a). Mesa profiles obtained for different molar compositions of etching solutions (b). (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)