

## [ME05] Wet etching of GgAs for lateral PIN photodiode

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### Introduction

Photodiode play important roles in optical communication systems nowadays. In this field, fiber optic cable is used as an information signal transmission medium between the light sources, sensors and photodiode. Many materials can provided to make the photodiode substrate in order to produce the detector to be used in application that require higher bandwidth and long distance transmission. Therefore, the optical receiver for long-distance telecommunication has primarily been implemented in III-V materials like GaAs or InGaAs in order to achieve the highest possible performance.

InGaAs/InP PIN photodiodes are highly promising devices for usage in high-speed photodetector system in optical communications because of their excellent frequency and low-noise performance. This high performance is due to the high mobility, high saturation velocity and high sheet-carrier density of the InGaAs/InP system. The fabrication of InGaAs/InP photodiode necessitates pattern transfer techniques with a high degree of precision and a variable anisotropy [1].

Since the recess formation for the Schottky gate is the most critical procedure in the fabrication of photodiode, the selective etching of InGaAs on InP is a useful technique for obtaining high uniformity. Wet chemical etching is a simple technique that offers high selectivity and prevents deep damage to Quantum Well (QW) layers when compared with dry etching techniques [2].

Selective wet etching has three main advantages over dry etching like it causes no damage, it is less costly and it is more reproducible. Besides that, three main purposes are to form pattern to polish and to enable visualization of defects or damages [3]. Wet chemical etching has been the technique most widely employed in device fabrication. Wet chemical process include pattern formation, polishing and detect or damaging visualization [4]. Selective wet etching using a

solution of phosphoric acid and hydrogen peroxide is widely used for gate-recess and mesa-sidewall etching due to its relatively high selectivity.

Most etchants for III-IV compound materials such as InGaAs and GaAs contain an oxidizing agent, a complexing agent and a dilutant such as water. The oxidizers usually are Br<sub>2</sub> [5], H<sub>2</sub>O [6, 7, 8], AgNO<sub>3</sub>/CrO<sub>3</sub> [9], HNO<sub>3</sub> [10] and NaOCl [11]. The oxidized layer is usually insoluble in water. It is made soluble by complex agent such as NH<sub>4</sub>OH [12, 13, 14], NaOH [15], H<sub>2</sub>SO<sub>4</sub> [16, 17, 8, 15], HCl [8], HF [9, 18], H<sub>3</sub>PO<sub>4</sub> [19] and citric acid [6].

This paper described how permanent alignment marks for the GaAs Lateral PIN photodiode are created using GaAs wet chemical etching technique. The substrate-to-photomask alignment is vital in the fabrication of the GaAs Lateral PIN photodiode as several processes required that the dielectric layer to be removed. The removal of this dielectric layer prevents any alignment to be made between the present and subsequent layer, as any marks created on this layer will be completely eliminated.

### Experimental

#### (a) Etchant preparation

A suitable etchant for etching GaAs is the combination of phosphoric acid (H<sub>3</sub>PO<sub>4</sub>), hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) and deionised water (D. I. water) in a ratio of 3-1-25.

#### (b) Etching of GaAs

The sample used is a p-type GaAs with 100 orientation. The samples are cut into 1 inch x 1 inch square samples. The whole process of creating the substrate marker can be described by the following flow chart as below.

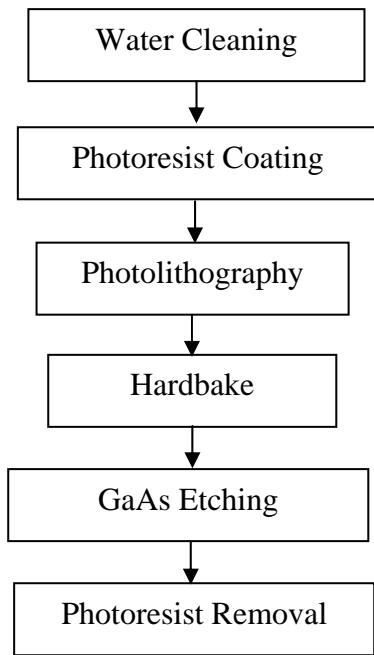


FIGURE 1 Flow chart of the InGaAs etching process

Before the samples are spin coated with photoresist, the samples must go through a complete cleaning process. Contamination on the substrates can seriously affect the adhesion of the photoresist layer. A typical cleaning process includes ultrasonic agitation in chemical solutions such as methanol and acetone. After ultrasonic, the samples are rinsed using D.I water. After cleaning, the samples are blown dry with nitrogen and are prepared for the photolithography process.

After the samples are coated with the photoresist, they are then baked at 120<sup>0</sup>C for 30 minutes. The samples are then etched using the GaAs etchant by immersing them into the mixtures. Subsequently, the samples are rinsed with methanol for photoresist removal and then with D.I.water before blown using nitrogen air.

**Results**

The etched surface of the GaAs samples are illustrated by the photos taken by a CCD camera as shown in Fig 2.

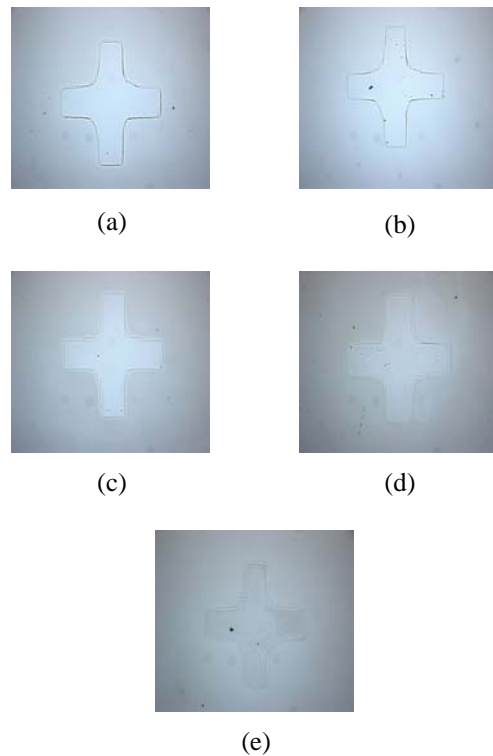


FIGURE 2 The GaAs samples etched for (a) 1 minutes (b) 2 minutes (c) 4 minutes (d) 7 minutes and (e) 10 minutes

The test pattern used is a cross-shaped pattern which is used as the alignment mark in the photodiode fabrication process. Several etch times are selected which ranges from 1, 2, 4, 7 and 10 minutes. The depth of the etched area are measured using surface profiler and hence the etching rate can be determined.

The results of etch-depth thickness for etching time of 1, 2, 4, 7 an 10 minutes are shown in Table 1 as below, These data are measured using surface profiler.

TABLE 1 The etch-depth profile of the GaAs samples

Etching time (minutes)	Etched depth (Armstrong)
1	3684.6
2	8114.2
4	15777.3
7	22960.0
10	35653.7

From the data output of surface profiler programme, the graph of the thickness versus

the etching time for 5 samples can be estimated as shown in Fig 3 below.

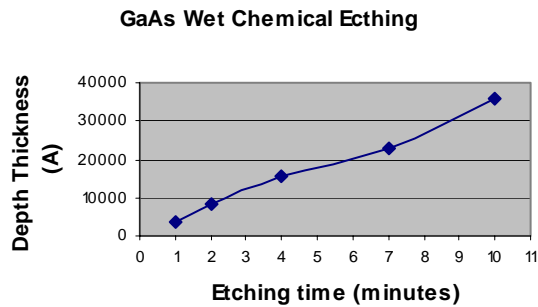


FIGURE 3 Etched depths (Armstrong) versus the etching time (minutes)

### Conclusion

Alignment marks created permanently on the GaAs substrate provide excellent way to align the substrate with any intermediate dielectric layers. Wet chemical etchant with the mixture of Phosphoric Acid ( $H_3PO_4$ ), Hydrogen Peroxide ( $H_2O_2$ ) and deionized water ( $H_2O$ ), can be used to make etch the GaAs surface. The results show that etch-depth of GaAs surface,  $d$  increases with the etching time,  $t$ .

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