Advanced Thin Film Processing for MMIC Manufacture

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Introduction

The widespread acceptance of wireless communication devices in recent years has led to a boom for manufacturers of III-V Monolithic Microwave Integrated Circuits (MMICs). As a result, these device fabricators have needed to adopt a significant amount of technology from leading silicon device makers in order to provide timely responses to the large demand for their products. This paper will review some of the advances available today for deposition and etch solutions.

Hardware Platforms

The most significant change observed at device manufacturers is the routine implementation of cluster tool platforms and automated batch systems for high volume manufacture. These architectures are significant upgrades from the manually loaded systems often employed in the past and are needed for a variety of reasons.

Cluster Tools:

- *Flexibility*: Systems can be configured with either redundant modules to provide high throughput or integrated process steps. Although limited at this time, process integration requirements are expected to increase as device requirements become more stringent. One area where this synergy is apparent is at the end of the wafer fabrication process, where GaAs vias need to be integrated with advanced metallization processes in order to provide high device reliability from the high aspect ratio features.
- *Small Cleanroom Footprint*: By sharing a common handling system, multi-chamber cluster tools are often seen to have small footprints as compared to the same number of stand alone systems.

Automated Batch Tools:

- For sputtered front- and backside contacts, as well as resistors, automated batch systems can provide lower cost per wafer with the same performance and reliability at a lower tool complexity.

- For liftoff metallization, such as Ti, Pt, and Au metals, evaporation technology is still the best performing and lowest cost method. The latest breakthrough in automated wafer loading to spherical domes will make evaporation also a viable technology for the future.

Leading GaAs equipment makers have proven the performance of cluster tools as well as automated batch tools to provide exceptional reliability in GaAs production operation. Typical operating specifications include MTBFp >300

hours, MTTR <4 hours, and >90% uptime. A leading cluster tool platform for GaAs manufacturing is shown in Figure 1.

Hardware Subsystems

Integrated into the cluster tool platforms, a number of significant subsystems are required to provide true production level device processing.

High density plasmas, such as Inductively Coupled Plasma (ICP), have been shown as production worthy solutions for a number of etch processes. GaAs Vias, Frontside Transistor Etches, and InP films are typically etched with these techniques. Reasons for this include high etch rates, exceptional selectivities to both masks and substrates, low device bias', and tight profile control.

Electrostatic chucks are needed in high volume etch processes for a number of reasons. This method of clamping eliminates frontside wafer contact, thereby reducing wafer breakage. Additionally, improved wafer cooling is typically observed when compared to mechanical methods. Lastly, process edge exclusions are minimized with this clamping technique, allowing for high device yields.

Process Solutions

The result of the above are a number of exceptional processes available today.

GaAs Via Etching is performed at high etch rates and exceptional selectivities. Processes have been proven to scale easily to 150mm at a number of production facilities. Figure 2 shows a typical via etch result.

Frontside Etching has found to be critical in both PHEMT and HBT process flows, where it is needed to replace wet chemistries. Improved profile control and reduced defects are major reasons driving this change. Processes for AlGaAs/GaAs/InGaP systems are available for both selective and non selective etching, as shown in Figure 3.

Silicon Nitride Deposition has also been proven in high volume production of GaAs devices. High quality films are deposited at high throughput and low temperature (<300^{o}C) using batch techniques. A picture of this reactor is shown in Figure 4.

Sputtered contacts, resistors and dielectrics deposited on patterned wafers demand very low process temperatures as well as soft etching techniques to avoid any damage to the photoresist. This is all proven in high volume production with automated batch sputtering tools.

Liftoff processing by evaporation has gained a lot of attention for frontside contact metallization in the HBT manufacturing process due to its intrinsic profile control and the elimination of wet etching processes.

Summary

Through the implementation of cluster tools and automation in general, GaAs production manufacturers have been able to implement state of the art processes in their fabs to meet their aggressive manufacturing demands. This trend is expected to continue as other processes, such as PVD, will need to be integrated with today's leading plasma etch and deposition processes.

Figure 1: A Leading GaAs Manufacturing Cluster Tool

Figure 2-Typical GaAs Via Etch Result

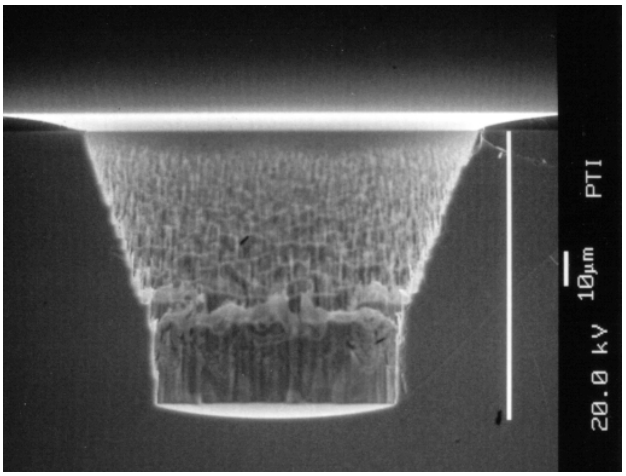

Figure 3-Selective GaAs/AlGaAs Etch Result

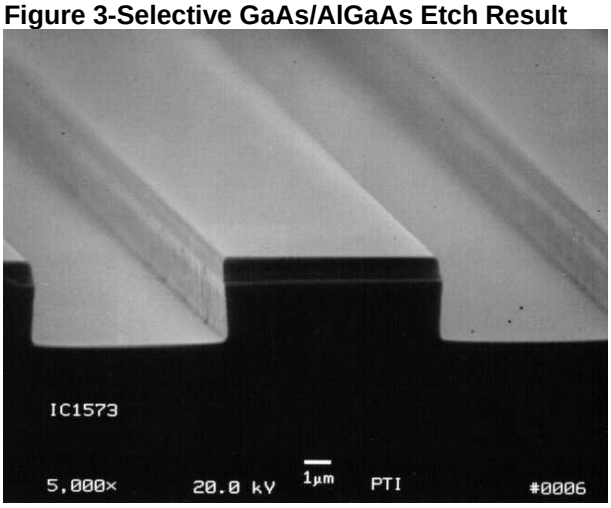

Figure 4-Batch PECVD Reactor Showing Five 150mm Substrates