Low Cost, High Throughput Hot Plate Track System Used in 150mm GaAs Ohmic Metal Alloying

Moreen Minkoff, Fabian Radulescu, Brad Avrit and Dong Nguyen*

TriQuint Semiconductor,
2300 N.E. Brookwood Parkway, Hillsboro, OR 97124
phone: 503-615-9425, e-mail:
mminkoff@tqs.com

C&D Semiconductor Services, Inc.
775 Montague Expressway, Milpitas, CA 95035

Abstract:

Metal ohmic alloying is unique to the compound semiconductor industry and is therefore often ignored by major equipment manufacturers. The process is carried out on platforms that were not originally designed for alloying. There are two equipment choices for metal alloying; a relatively expensive RTA or a modified photo coat track. This paper discusses a custom modified multiple hotplate coat track system that meets the specific needs of metal ohmic alloying. The advantages of this alloy track are: simplicity, high throughput, no wafer backside contact with the hotplate, low contamination levels, controlled inert (or forming) gas atmosphere, uniform heating of the hotplate and wafer, low warpage and high reliability. It has been found that thermal warpage for the 100-mm wafers is minimal, but this could be a potential problem for the 150-mm size. However, the track's built-in features, such as adjustable temperature ramping and gas cooling, provide good controls to tackle this problem and have proven successful. Methods for minimizing this negative effect will be discussed, along with example process results.

Introduction:

Obtaining a thermally stable ohmic contact with low contact resistance is critical for device function. While the RTA effectively produces ohmic contacts, it is expensive and time intensive. A simplified substitute developed by TriQuint Semiconductor and C&D Semiconductor Services, the alloy track offers a solution that is cost effective and reduces process time. This straightforward approach to ohmic alloying still monitors critical process parameters, including temperature and gas flow. Ohmic contacts on N+ GaAs are analyzed for within wafer uniformity and prove that the alloy track is adequate for ohmic metal alloying.

Equipment:

Wafers can be processed in an ambient or open-air environment, allowing for a wide range of applications. The system includes a backtrack and front track with two aluminum alloy hotplates on each. The alloy track is capable of processing two wafers at a time. This capability doubles the throuhput of the track. In parallel mode a wafer is placed on both hotplates and processing occurs simultaneously. Additionally, there remains the option to bypass a hotplate and process one wafer at a time. The track has a simple and reliable design that has been used for many years in photolithography applications, which means the track is rarely unavailable for production.

Figure 1: C&D Alloy Track

Standard ohmic alloying processes occur at temperatures in excess of 385C°. Direct wafer to hotplate contact may result in wafer breakage or diffusion of unwanted elements to the front side of the wafer. To prevent the wafer from coming in direct conatact with the hotplates proximity pins have been machined into the hotplate in a triangular arrangement. Backside contamination is also avoided, because the wafer sits on several pins, which reduces contact with the potentially contaminated surface.

RTA's offer a controlled environment through the use of gases and uniform temperature ramping. The alloy track was modified to imitate these desirable features. Lids are lowered over the hotplates during processing to prevent airflow from affecting the alloy process. A choice of gases and two methods of entry into the chamber are available.

Temperature ramping control is achieved by varying the wafer up-down moving speed, which controls the wafer-to-hotplate distance. The wafer is placed on three pins that can be programmed to raise and lower at a specified rate. This system helps reduce wafers from warping. It is extremely difficult to obtain a constant temperature when the wafer is not sitting directly on the hotplate, which does limit some applications.

A critical variable for eliminating wafers from warping is the ability of the track to adequately cool the wafers. A flow of nitrogen is applied to the wafer for a variable amount of time through programming. This step insures that the wafer is sufficiently cool before being transferred to the chill plate. The wafer sits on the water-cooled chill plate for a determined number of seconds before being transferred to the cassette.

Figure 2: Closer view of front track.

Manufacturing Cost of Ownership

The competitive nature of the semiconductor industry demands that when purchasing a new piece of equipment, price is one of the main considerations. The alloy track addresses this issue in two ways; reduced start up and long term maintenance costs. The alloy track costs about a third less than an RTA to purchase. While the reduced start-up cost could be incentive enough to choose an alloy track the minimal maintenance costs further add to its appeal.

RTA's require an extensive amount of maintenance including lamp changes and tube wipes. These procedures require trained personnel to maintain the tool along with the cost of replacement parts.

Conversely, the alloy track is relatively maintenance free. The heaters generally have a one year lifespan and with the correct material, the hotplates can last indefinitely. The alloy track offers redundancy within the tool. If one hotplate fails there are three others to use for production. The RTA has only one chamber and therefore if it fails production has to stop until it is fixed.

Table 1: Relative Costs of Alloy Track and RTA

	Alloy Track	**RTA**
Equipment Costs	1	2-3x
Reoccurring Cost	1	2-3x

Experimental:

Within wafer uniformity was measured by first knowing the uniformity of the metal before alloying. The uniformity was determined by measuring the sheet resistance of silicon wafers with oxide and the ohmic metal stack. Next production wafers were used to measure the contact resistance after the alloy process. Both sets of measurements included five points on the wafer for comparison. The resistance data provided a comparison of the amount of variation originally present in the metal and the amount of variation due to the alloy process.

Experimental Results and Observations:

The negligible temperature gradient across the wafer is due to the uniform heating characteristic of the hotplates. The temperature measurements were taken with a CGS Thermodynamics 5 point thermocouple wafer, which was calibrated with NIST standards at two different temperatures of interest. The center to edge temperature gradient was averaged using a significant number of data points.

Table 2: Center to edge Wafer Temperature Gradient

	C&D Alloy Track (processed in air)	C&D Alloy Track (processed with controlled ambient)
Temperature gradient	3%	1.25%

Five hotplate surface temperature measurements were taken for each trial and resulted in non-uniformity of less than 1%.

Table 3: Hotplate Surface Temperature Non-Uniformity

Trial	Non-Uniformity (%)
1	0.61
2	0.49
3	0.14
4	0.68
5	0.41
6	1.00
7	0.87
8	0.34
Average	0.57

Table 4: Wafer Non-uniformity of ohmic metal

	Non-Uniformity (%)
Before Alloy	5.27
After Alloyed in Controlled Ambient	6.50
After Alloyed in air	6.80

The alloy track is an attractive option, because it offers increased throughput over the RTA. It allows the option for one or two wafers to be processed at a time. A typical RTA has a throughput of 10 wafers/hour, while the Alloy track can process 19wafers/hour in serial mode and 28wafers/hour in parallel mode on one track.

Table 5: Throughput of RTA and Alloy Track in Serial and Parallel Mode.

	RTA System	Alloy Track Serial Mode	Alloy Track Parallel Mode
Throughput (wafers/hr)	8-10	19	28

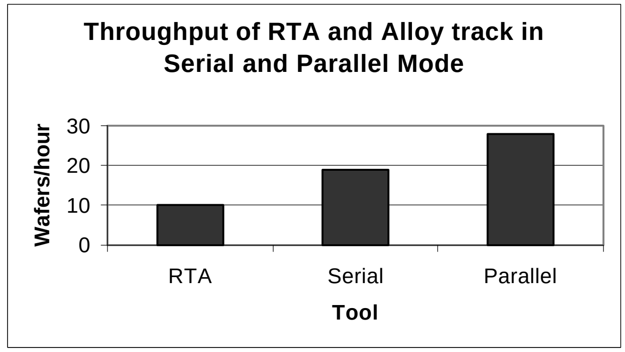

Figure 3: Chart of Throughput

Discussion and Conclusion:

The foundation for good alloy uniformity is dependent upon the hotplate heating characteristics. A center to edge surface temperature gradient of 3% in open air and 1.25% in a controlled ambient environment ensures that the contact resistance is uniform across the wafer after alloying. The within wafer non-uniformity value is confirmed by the sheet resistance variance of 1.4%. This gradient is accounted for by the alloy process and is well within acceptable limits. The alloy track is easy to use and offers a simple means of obtaining high quality ohmic contacts. Furthermore, the improved throughput and lower cost make the alloy track an attractive alternative to the high-end RTA's normally employed for the ohmic alloy process.

Acronyms

RTA; rapid thermal anneal