INFICON

TECHNICAL NOTE

The Practical Use of Residual Gas Analysis in a Semiconductor Thermal Processing Module

INFICON Residual Gas Analyzers (RGA) are used to characterize and troubleshoot diffusion furnaces and rapid thermal anneal (RTA) reactors in a thermal processing module. They can reduce the number of test wafers/runs since, each adjustment does not require another test wafer and effects on gas chemistry can be seen immediately. Tools that have been characterized are Tokyo Electron Ltd. (TEL) vertical atmospheric furnaces, TEL vertical LPCVD furnaces, and Applied Materials (AMAT) Rapid Thermal Anneal Systems.

Thermal processes are dependent upon three key parameters: temperature, gas flow/gas chemistry, and the pressure within the reactor. Temperature and pressure control are realized through external closed loop methods. However, the only control afforded for the monitoring and control of the reactor chemistry is MFC setpoint. This is inadequate since reactor chemistry is affected by external leaks in the gas lines or reactor seals, outgassing from components, backstreaming from the exhaust, chemical reactions not taking place in the ratios expected producing unknown byproducts, unoptimized recipes, etc.

THE BENEFITS OF AN RGA FOR GATHERING GAS CHEMISTRY BASELINE DATA

Without the RGA, many of the tool setups and tool chemistry matching must be done using the tedious process of test wafer runs to gather data. In addition, troubleshooting these reactors can be difficult. The reactors are generally contamination-free and the tolerance to contamination exceedingly low. The RGA allows the engineer to peer within the reactor and measure the chemistry in real time with sensitivity of better than 1 part per million.

SUCCESSFUL TROUBLESHOOTING USING AN RGA WITH A RAPID THERMAL ANNEAL SYSTEM

An example of setting up a Rapid Thermal Anneal cluster tool is shown in figure 1. The RGA was used to complement an ongoing troubleshooting effort; RTA tools were qualified using 2 qualification tests: annealing a known doped wafer followed by measurement of the sheet resistance and growing an oxide on a bare Si wafer and measuring the thickness and thickness uniformity. The primary symptom was that this reactor (A) did not match either reactor (B) that was mounted on the same system or the two reactors from another similar tool. Specifically, if temperature adjustments were made to the tool to tune in the sheet resistance, the oxide thickness would not match; if the oxide thickness was adjusted, the sheet resistance would not match.

The oxide growth qualification process uses 100% O_2 for the actual SiO_2 growth followed by a purge with 100% N_2. Using an RGA, it was found that once the oxide deposition process began , the purge Nitrogen was not completely replaced by

RGAs SHOULD BE USED FOR:

- improving new and existing tool setups and processes;
- qualifying or improving tool facilities;
- ensuring like tools are well matched in terms of how process chemistry affects performance;
- gathering historical performance of the reactors for use in comparison when difficult process problems or process drifts arise;
- ensuring that repaired reactors can be set back to previous known conditions.

the oxygen resulting in a thinner oxide than expected for the corresponding temperature, as illustrated in the figure 1.

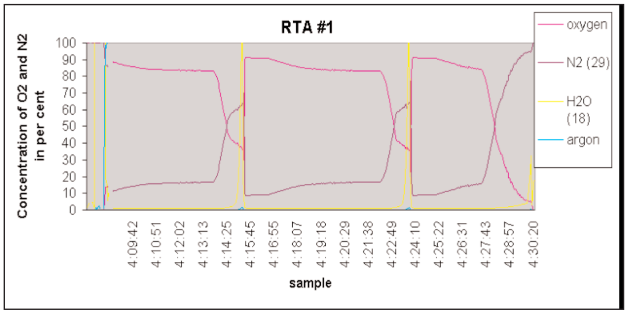

Figure 1: RGA of an RTA chamber

With this information, the tool equipment engineers discovered that the pneumatic valves responsible for shutting down the flow of nitrogen were not receiving the command to close; hence, only the mass flow controller at zero setpoint was restricting the flow. This was found to be true on all four reactors. However, the mass flow controller on Reactor A seemed to be less successful at limiting the flow (MFCs are not designed to be positive shutoff devices). Tool equipment engineers then solved the problem by making changes to the system configuration which caused the isolation pneumatic valves to shut while the oxidation process was running.

SUCCESSFUL TROUBLESHOOTING USING AN RGA WITH AN ATMOSPHERIC OXIDATION FURNACE

An example of troubleshooting an atmospheric oxidation furnace is shown in figure 2. The tool, when compared to similar tools, was exhibiting non-uniform thickness across the batch, especially at the bottom part of the tube. Using RGA data, it was determined that process nitrogen from the quartz N_2 purge was leaking into the bottom zone of the furnace, diluting the amount of O_2 reactant in that zone, which resulted in poor thickness uniformity in wafers in that region. Figure 2 shows the amount of N_2 in the top and bottom zones of the furnace, with the bottom zone having the largest concentration of N_2 (about 3x times). Given this finding, the tool quartz was audited and a better sealing part installed. In addition, changes to the quartz N_2 purge flows resulted in improvements in the thickness uniformity zone to zone, as well as across the whole load.

The RGA was a significant asset for the diffusion module in this fab. The system was used to troubleshoot machine and process problems, to characterize the reactors, and to enhance process development.

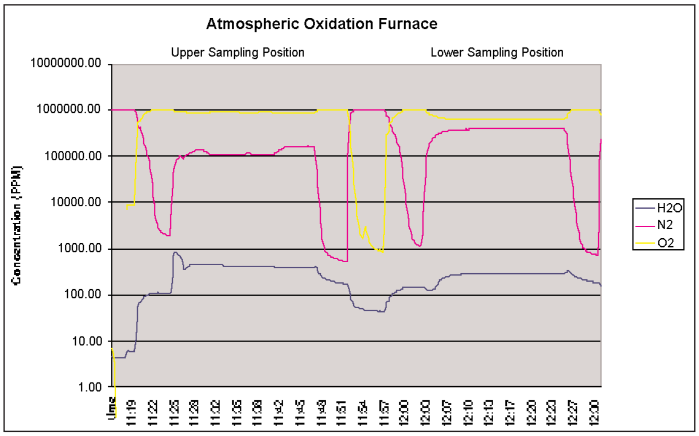

Figure 2: RGA of an Atmospheric Oxidation Furnace

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