WAFE PROCESSING IN RTX™ RTP CHAMBER WITH DEVICE SIDE EMISSIVITY MEASUREMENT AND TEMPERATURE CONTROL

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Increasing demand for RTP applications requires strict controls of the processing metric: Temperature measurement, gas flow dynamics, and the chemistry. A fundamental engineering science approach to RTP chamber design is essential in addressing process thermal budget, within wafer uniformity, repeatability between wafers and widely dispersed tools. There are numerous existing and rapidly emerging RTP processes with widely varying processing conditions and commercial requirements. The RTX™ RTP tool was developed with these scientific, technical and economic objectives. Transient and steady state coupled radiation, convection and conduction heat transfer equations guided the tool's heater and controls system design. Since all processing is conducted at the device side of the wafer, the equations dictate that to measure this surface temperature its emissivity must first be measured. Accordingly, the RTX™ chamber is designed with the wafer in a horizontal device side up orientation. A new emissivity instrument was developed based on Planck and Kirchhoff's laws and integrated into the chamber above the wafer. The average emissivity is measured as the device patterns are averaged by wafer rotation. Heat distribution within the wafer is also enhanced by rotation. The emissivity is measured first upon the onset of the process. This capability leads to very robust wafer-to-wafer process repeatability as the As annealing RTA marathon test shows below.

In the RTX™ tool the wafer is heated from its backside. The heater consists of a multi-zoned tungsten halogen linear lamps matrix. Black Body calibrated sapphire fiber optic probes are located above the wafer enabling a multi-zone wafer surface temperature measurement and control to a precision of +/- 1 °C between 350-to-1200 °C. This temperature range can be changed to 150-to-850 °C by selecting an alternate photo multiplier electronics option. Velocity and pressure profiles were obtained from numerical solutions to the Navier-Stokes gas dynamics equations. Such profiles guided the RTX™ chamber design and its novel multiple options for gas injection and exhaust. These options are key to configuring the chamber for the wide process applications. Furthermore, the solutions showed how the velocity boundary layer thickness varies over the wafer for various gas injection geometries. The boundary layer profiles affects both mass and heat transfer to and from the wafer surface. Knowledge of these profiles significantly assisted in the rapid optimization of a wide range of processes.

The following is a brief summary of some process development results using the RTX™ RTP tool:

RTA: For standard RTA processes the chamber was configured with a center gas injection and side exhaust. The multi-zone temperature controller was optimized for the fastest ramp without any temperature overshoot. When a 200 mm P-type wafer, implanted with 1E16 As at 25KeV is annealed for 10seconds at 1030 °C and 10 Torr pressure, a mean sheet resistance of 111.9 Ohms/square with 0.41% one sigma standard deviation was achieved. Similar results are routinely achieved for 300 mm wafer diameters. Wafer-to-wafer mean sheet resistance repeatability was measured at 0.48 Ohms/square for a marathon of 5000 continuously processed wafers. Furthermore, steady state heat transfer analysis indicates that a temperature difference of about 7 °C can exist between the top and backside of the wafer. Short RTA process times, where steady state is not achieved, would make this difference much greater. Experimental results revealed that this difference might be up to 19 °C when two identically implanted As wafers were processed in reverse orientation to each other. This validates the wafer backside heating and device-side temperature measuring method employed in the RTX™ tool. It also points to the continuous need for temperature offset calibration for tools that employ a reverse temperature measurement scheme.

Four As implanted wafers each with different pattern densities were prepared. These wafers were annealed at 900 °C for 10 seconds in nitrogen. Using the process temperature sensitivity, the effect of the pattern density on actual temperature was evaluated for three types of RTP systems. A temperature deviation of 0-to-1.2 °C was measured for the 0-to-25% pattern density range when the RTX™ tool was used. RTP tool with topside heating yielded a temperature deviation of 0-to-5.2 °C. When a tool with top and bottom heating was used, this temperature deviation was measured at 0-to-4.1 °C. The RTX™ tool demonstrated excellent pattern independency RTA performance.

Cobalt Silicide: It was found that the emissivity of a thin film of Co-on-Si suddenly changed from 0.350 at room temperature to 0.570 at 540 °C. Whereas the emissivity of Co-on-SiO2 remained unchanged at about 0.440. By using the wafer emissivity instrument, the RTX™ tool enabled a quick and accurate determination of the optimal processing temperature region for this phase transformation reaction process.

Wet RTO: While the RTX™ tool offers state of the art dry RTO process results, a wet-hydrogen-rich and wet-oxygen-rich oxidation processes were developed. A Fujikin corporation water vapor generator was integrated into the RTX™ chamber with an off center hydrogen and water vapor injection chamber configuration. The oxide growth for the wet-hydrogen-rich process at 700Torr is as follows:

T (°C)	H2O (%)	Mean(A°)	Range (A°)
950	16.7	15.09	0.78
1000	16.7	18.52	0.90

RPN: A 13.56 MHz novel remote plasma chamber was developed and integrated into the RTX™ chamber top. This enabled nitridation of gate oxide with various nitrogen concentrations. Tests were performed using wafers with 14 A° gate oxide grown by a separate RTO process. The RPN process was run at 50 mTorr pressure and room temperature. Added ellipsometric optical thickness was used as a qualitative indication of the incorporated nitrogen. Results showed that these wafers gained 5.86A° and 8.2A° in optical thickness when subjected to a nitrogen plasma at 200 Watts and 500 Watts respectively. Within wafer post RPN total range was measured at 0.51A°. SIMS analysis indicated that up to 9 atomic % nitrogen was added within the first 1-3A of the SiO2 top surface. It was demonstrated that the nitrogen profile within the gate oxide might be tailored by post RPN high temperature annealing or sequencing of short time RPN and RPO processes.