Leveraging k-Space Associates’ expertise in integrating critical thin film metrology equipment, the MOS Thermal Scan system utilizes the patented MOS (Multi-beam Optical Sensor) stress measurement technology to provide unparalleled curvature, stress, and bow height resolution and repeatability. The system is configured with a high performance vacuum annealing and process chamber utilizing a patented quartz heater lamp array to maintain wafer temperature uniformity across the entire rated temperature range from room temperature to 1200 Degrees C for non-IR transparent substrates. The high-resolution, sub-micron scanning stage ensures accurate, user programmable scanning on samples as small as 10mm up to 300mm. Measurements can be performed at stabilized temperatures using 2D scans or during thermal cycling processes using rapid data acquisition at a single wafer point to ensure accurate stress information is obtained. Measurements can be made during introduction of process gas or air with two manually controlled gas lines included in the standard product configuration. All process and operation are fully automated with the included software control.
### kSA Measurement Technology

<table>
<thead>
<tr>
<th>Technology Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2D Curvature or Bow Map At Stabilized Temperature</strong></td>
</tr>
<tr>
<td>At a fixed set point temperature, a 2D laser spot array is reflected off the sample surface. Individual laser spot positions are tracked in real-time to within 0.1μm via high resolution CCD. Each laser spot is tracked relative to other spots positions as the local sample shape exhibits concave or convex curvature due to stress. Changes in spot positions are accurately monitored as samples undergo localized compressive or tensile stress.</td>
</tr>
<tr>
<td><strong>2D Stress Map At Stabilized Temperature</strong></td>
</tr>
<tr>
<td>At a fixed set point temperature, localized changes in curvature at any sample position are compared to the pre-process curvature map with substrate and film properties used to provide a quantitative stress map.</td>
</tr>
<tr>
<td><strong>Stress Measurements During Thermal Ramp</strong></td>
</tr>
<tr>
<td>Single point, rapid stress measurements can be made during thermal ramping, up to 30 data points/second.</td>
</tr>
</tbody>
</table>

**STANDARD SYSTEM HARDWARE LAYOUT**

- **Laser Array Optics**
- **CCD Spot Position Detector**
- **Film/substrate**
- **Wafer Holder**
- **Vacuum Heating Chamber**
- **Thermocouple or Optical Temperature Monitoring**
STANDARD HARDWARE

● High Sensitivity 12-bit Detector
   High resolution, high sensitivity, anti-blooming, monochrome CCD detector and power control board.

   Specifications:

   CCD format: 3-phase interline transfer CCD, removable IR cut filter, selectable electronic shutter, AGC (On/Off), Gamma(On/Off), on-chip integration capability
   Well depth: 100,000 e-
   Pixel resolution: 768(H) x 480(V), 11µm x 13µm pixel size
   Sensing area: 2/3” format (8.8mm x 6.6mm)
   Spectral range: 400-1100 nm (w/ IR filter out)
   S/N: 56 dB
   Sensitivity: 400 lux, f4, under 3200K lighting
   Exposure time: Variable from 1/10,000 to 1/30 sec (dip switch selectable)
   Triggering: Selectable field-on-demand triggering for synchronization with substrate rotation
   Output format: RS-170
   Lens mount: C-type
   Power: 12V DC (internal from computer) or external 120/240V 210mA current consumption
   Camera Dimensions: 86mm x 52 mm x 39mm

● Integrated Laser and Optics System
   The MOS Thermal-Scan system utilizes a pair of etalons to generate a 2-D array of parallel laser beams from a single beam laser source. All optics are rigidly mounted to reduce vibrational noise. The laser system is stabilized and temperature controlled to maximize lifetime.

   Diode Laser Module and Custom Optics

   Specifications:

   Fiber coupled, Peltier cooled laser diode package with integrated current controller and temperature controller.

   Laser Wavelength: 660nm nominal (other wavelengths available upon request.)
   Laser Output Power: >20 mW, measured directly at laser output. Note: All high-power beams are confined within the MOS housing even when the cover is removed for alignment. Direct access to the main beam is necessary during alignment. The total output power in the sample compartment is typically less than 50 microwatts.
   Beam Geometry: Circular Gaussian output with integrated long focal length lens cell
   Operation Mode: Constant current output
   Stability: ≤ 0.2%

High Performance Diode Laser Controller

   Linear, low-noise diode laser controller operates in constant current mode with output power stability ≤ 0.2% typical (24 hours). Output power is current limited with slow start circuitry for extended diode laser life. Output power is computer controlled from threshold power to
full rated output. Temperature control is factory set for 13°C and has an absolute stability of <0.2°C.

**Heating Chamber and System Frame**

The vacuum heating chamber is a completely integrated system with water cooled chamber, vacuum compatible sample compartment with sample locating features, 100mm mount with integrated thermocouple. The heating is performed with a high uniformity quartz halogen heater design for maximum temperature uniformity. The system capable of heating non-IR transparent substrates to 1200 °C under vacuum.

**Vacuum Chamber**
- Vacuum heating chamber with water cooling.
- Chamber and power supply mounts in the existing 19-inch k-Space Thermal Scan equipment rack.

**Substrate Heater and Temperature Control** All substrates are free standing (no hold down clips) and held on the sample holder with integrated thermocouple.
- Heater is of quartz halogen array design, with bottom and top heating elements for maximum substrate temperature uniformity.
- Substrate temperature will be controlled via a programmable closed-loop temperature control unit and power supply.
- Temperature uniformity: ± 5 °C across central 80 percent of 100mm sample at 1000 degrees C.
- Maximum heating rate of 200 °C /min.
- Maximum cooling rate of 30 °C /min.
- Temperature stability of +/- 0.1 °C at 600 °C.
- Temperature measurement accuracy is dictated by standard thermocouple accuracy.

**Pumping:**
- Diaphragm backing pump with all related manual isolation, control valves, and pump controllers are fully integrated to achieve 10 mbar base pressure.
- Vacuum gauging includes one gauge with digital readout and process pressure setpoint relay for safety interlock control.
Frame Assembly:

- The chamber will be mounted within a robust steel and aluminum frame enclosure with plexiglass panels. Enclosure doors are interlocked for laser safety.
- A fully integrated electronics rack below the chamber section will house the entire chamber, system electronics, and pump.
- The frame includes leveling pads.

- **Patented, Automated Mirror Tracking with Servo Control**

A dual-axis, servo-controlled, optical flat mirror is used for tracking the reflected laser array as the wafer is scanned. Integrated software routine automatically redirects the 2D laser array onto the detector center as needed with large sample tilt or bow.

- **Linear XY Stage and 5-Phase Stepper Controller and Multi-Sample Holder**

200mm XY scanning stage, driven by 5-phase stepper controller. Resolution better than 5 um, with maximum scan speed of 20mm/sec. Full stage control via kSA MOS Thermal-Scan software. Up to 300mm XY scanning stage available.
**Computer System and Control Boards**

The MOS Thermal-Scan system is supplied with a fully configured rack-mounted computer system, populated with the MOS Thermal-Scan data acquisition and control boards. The current specifications are listed below.

- Windows 7 Professional 64-bit, QuadCore Processor, 4GB DDR3 SDRAM, 500GB (minimum) SATA Hard Disk, 512MB DVI+HDMI Video Card, Gigabit Ethernet, USB2, USB3, DVD +/-RW, 22-inch Flat Panel Monitor, USB keyboard, USB optical mouse

**OPTIONAL HARDWARE**

**Alternate Laser Wavelengths**

To accommodate alternate materials with higher reflectivity values at shorter wavelengths, optional 405nm or 532nm laser and optics are available.

405nm or 532nm Diode Laser Module and Custom Optics

**Specifications:**

- Fiber coupled, Peltier cooled laser diode package with integrated current controller and temperature controller.

  **Laser Wavelength:** 405 or 532nm nominal
  **Laser Output Power:** >25 mW, measured directly at laser output. Note: All high-power beams are confined within the MOS housing even when the cover is removed for alignment. The cover is not interlocked. Direct access to the main beam is necessary during alignment. The total output power in the sample compartment is typically less than 50 microwatts.
  **Beam Geometry:** Circular Gaussian output with integrated long focal length lens cell
  **Operation Mode:** Constant current output
  **Stability:** ≤ 0.2%

**System Platform Options**

<table>
<thead>
<tr>
<th>Up to 100mm Sample Sizes</th>
<th>Up to 300mm Sample Sizes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 500 Degrees C Operation</td>
<td>Up to 1200 Degrees C Operation</td>
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</tbody>
</table>
kSA MOS THERMAL-SCAN SOFTWARE DESCRIPTION

Summary of capabilities:

- Complete data acquisition and analysis control.
- Automatic laser spot detection.
- Automatic laser power control to ensure no saturation of detector as surface reflectivity changes.
- Real-time plotting of curvature, radius of curvature, stress-thickness product, stress, and tilt.
- Data acquisition modes:

  1) **Focus mode:** for facilitating laser alignment and optics focusing by simultaneously monitoring the image and a line profile of the laser spot array.

  2) **Scan Mode:** An arbitrary number of laser spots, user configured, are tracked simultaneously, yielding two-dimensional curvature, radius of curvature, tilt, and stress. Completely programmable scanning over entire range or any sub-range, with programmable step size in both x and y.
1) Standard line profile, statistical analysis, and contour plotting.

2) Full surface and polar plots of curvature, tilt, bow, and stress. Alternatively, simple centroid position and spot separation distance may be plotted.

- User-friendly Windows-standard environment with extensive error checking and file handling. Data storage in ASCII and binary file formats facilitate alternative data analysis by user. Direct printing of images or graphics using currently loaded Windows printer drivers. Cut-and-paste directly to clipboard, or into other applications such as MS Word.

- (30) 2-D curvature/stress measurements per second (maximum rate) when acquiring data at center point of wafer. Slower data rates are fully programmable.

- Thermal scan software to provide fully automated multi-segment ramp/soak recipe control for annealing studies. Curvature and stress can be monitored and plotted as a function of temperature and time. Up to 100 cycles.

- High-quality 2D and 3D graphics for data display. Numerous image and graphics editing capabilities, including false coloring using pre-loaded or user-defined color palettes, and label editing. Transport of graphics directly to Windows clipboard or exported to Windows Metafile or Tiff format.