Elastomers for Control of Wafer Temperature in the <50°C Range During High Dose Ion Implantation

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- 1. Heat transfer in spinning wheel platens
- 2. In-situ sensors
- 3. "Eskimo" Elastomers
- 4. Bipolar gain shifts with implant temperature
- 5. Summary





Heat Transfer in Spinning Wheel Platens

In 1-D*:

 $dQ/dt = \Sigma \{-K^*A^*(\Delta T/\Delta X)\}$

where: dQ/dt = heat flow per unit time.

- $\Sigma{-\kappa^*A^*(\Delta T/\Delta X)}$ = sum through the stack of layers and interfaces from the wafer to the coolant flow region in the wafer mount.
- κ (W/m-K) = heat conductivity of each layer and interface.

A (m^2) = conducting area.

 ΔT (K) = temperature difference across an interface or a layer of thickness ΔX (m).

* Ignoring here:

complex heating cycles for various beam power densities & scan rates, wafer clamping forces, 2D heat transfer uniformity, coolant temperature & flow rate.



The major controllable factors in the heat transfer from the ion beam to the coolant flow are:

(1) the wafer/elastomer contact area

(2) the elastomer heat conductivity.



IR-Temperature Sensors



FLIR sensor image of wafer wheel temperatures, with a chiller flow at 13 C, during early stages of cool down.

Note cooler wafer pad regions along center radial regions with higher heat conductivity over the coolant flow path.



An in-situ IR sensor provides dynamic measures of the wafer/pad temperatures during and directly after high power implants .

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"Eskimo" Elastomers

Optimizing elastomer heat conductivity, while maintaining efficient heat transfer at the wafer/pad interface, results in a >15 C improvement in peak wafer/pad temperature for a 1.2 kW beam.



Long term measurements of maximum wafer/pad temperature show sharp drop for a 1.2 kW beam after installation of an improved elastomer pad, nick-named "Eskimo".

Refresh of a single pad exposed to beam uv for 280 days restores overall low temperature performance.



Measured average wafer/pad temperatures at various beam powers and pad-to-pad uniformity directly after high power implants show improved performance for Eskimo elastomers.

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Bipolar Gain Shifts with Temperature

Bipolar transistor implants with the Eskimo elastomer disk resulted in a 9% gain increase at <30 C.



Bipolar transistor implants:

- Dose: 3e15 to 1.2e16 ions/cm²
- Energy: 60 to 150 keV

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Power: 588 to 1,500 W

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Additional TI data indicates a linear dependence on implant temperature from 30 to 65 C.



Summary

- 1. Bipolar gain performance improves as wafer/pad temperatures during high power implants are kept close to "room temperatures" by use of high heat conductivity elastomer pads.
- Bipolar gain (defect-related carrier lifetime & mobility scattering) variations imply similar implant temperature sensitivities near ≈25 C for CMOS drive currents (and perhaps other properties).
- 3. Improved heat sinking capabilities (elastomers, etc.) are needed for process controls and device performance enhancement.

Range of need for *precision control of wafer temperature* during implants for control of device properties (bipolar gain, CMOS drive current, etc.)



EXAS INSTRUMENTS

6



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Abstract- Wafer/pad temperatures are measured for various elastomer materials for control of wafer temperatures during high-power implantation to less than 40 C. Wafer/pad temperatures during and directly following implant are monitored by in-situ IR sensors and tracked over long operational cycles. Beneficial effects of wafer temperature control is noted for gain characteristics of modern IC devices.

Keywords—elastomers, heat transfer, high power implantation, IR wafer temperature sensing.

The major controllable factors in the heat transfer from the ion beam to the coolant flow are (1) the wafer/elastomer contact and (2) the elastomer heat conductivity.



An in-situ IR sensor provides dynamic measures of the wafer/pad temperatures during and directly after high power implants .



Long term measurements of maximum wafer/pad temperature show sharp drop for a 1.2 kW beam after installation of an improved elastomer pad, nick-named "Eskimo". Refresh of pad exposed to beam uv restores low temperature performance.



Measured average wafer/pad temperatures at various beam powers and pad-to-pad uniformity directly after high power implants show improved performance for Eskimo elastomers.



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Bipolar gain performance improves as wafer/pad temperatures during high power implants are kept close to "room temperatures" by use of high heat conductivity elastomer pads.



