

IClaim:

1. A system operable to measure temperatures of and control a multi-zone heating plate in a substrate support assembly used to support a semiconductor substrate in a semiconductor processing apparatus, the heating plate comprising a plurality of planar heater zones, a plurality of diodes, a plurality of power supply lines and a plurality of power return lines, wherein each planar heater zone has at least one heater element, is connected to one of the power supply lines and one of the power return lines, and no two planar heater zones share the same pair of power supply line and power return line, and a diode is serially connected between each planar heater zone and the power supply line connected thereto or between each planar heater zone and the power return line connected thereto such that the diode does not allow electrical current flow in a direction from the power return line through the planar heater zone to the power supply line; the system comprising:
- ~~a current measurement device;~~
- 15 a first switching arrangement configured to connect each of the power return lines selectively to an electrical ground, a voltage supply or ~~an~~ a first electrically isolated terminal, independent of the other power return lines; and
- a second switching arrangement configured to connect each of the power supply lines selectively to the electrical ground, a power supply, ~~the~~ a current measurement device or ~~an~~ a second electrically isolated terminal, independent of the other power supply lines, wherein the current measurement device is connected between the electrical ground and the second switching arrangement; and
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2. ~~The system of Claim 1, further comprising an on-off switch and a calibration~~
- 25 device connected between the current measurement device and the voltage supply, wherein the calibration device is connected to the current measurement device through the via an ~~on-off switch and configured to connect to the voltage supply.~~
- 3.2. The system of Claim 1, wherein the voltage supply outputs non-negative voltage.
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- 4.3. The system of Claim 1, wherein the current measurement device is an amp meter and/or comprises an operational amplifier.
5. 5.4. The system of Claim 21, wherein the calibration device comprises a calibration heater, a calibrated temperature meter and a calibration diode whose anode is connected to the current measurement device through the on-off switch and whose cathode is configured to connect to the voltage supply.
- 10 6.5. The system of Claim 54, wherein the calibration diode of the calibration device is identical to the diodes connected to the planar heater zones in the heating plate.
- 15 7.6. The system of Claim 1, wherein a size of each of the planar heater zones is from 16 to 100 cm².
- 8.7. The system of Claim 1, wherein the heating plate comprises 10-100, 100-200, 200-300 or more planar heating zones.
- 20 9.8. A plasma processing apparatus comprising a substrate support assembly and the system of Claim 1, wherein the system is operable to measure temperatures of and control each heater zone of the multi-zone heating plate in the substrate support assembly used to support a semiconductor substrate in the semiconductor processing apparatus.
- 25 10.9. The plasma processing apparatus of Claim 98, wherein the plasma processing apparatus is a plasma etching apparatus.
- 30 11.14. A method of measuring temperatures of and maintaining a desired temperature profile across the system of Claim 1, comprising a temperature measurement step including:
connecting the power supply line connected to one of the planar heater zones to the current measurement device,

connecting all the other power supply line(s) to electrical ground,
 connecting the power return line connected to the planar heater zone to the
 voltage source,
 connecting all the other power return line(s) to ~~an~~ the first electrically
 5 isolated terminal; and
 taking a current reading of a reverse saturation current of the diode serially
 connected to the planar heater zone, from the current measurement device,
 calculating the temperature T of the planar heater zone from the current
 reading,
 10 deducing a setpoint temperature T_0 for the planar heater zone from a desired
 temperature profile for the entire heating plate,
 calculating a time duration t such that powering the planar heater zone with
 the power supply for the duration t changes the temperature of the planar heater zone
 from T to T_0 .
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~~12.15.~~ The method of Claim ~~11~~14, further comprising a powering step after the
 current measurement step, the powering step including:
 maintaining a connection between the power supply line connected to the
 planar heater zone and the power supply and a connection between the power return
 20 line connected to the planar heater zone and electrical ground for the time duration t .

~~13.16.~~ The method of Claim ~~12~~15, further comprising repeating the temperature
 measurement step and/or the powering step on each of the planar heater zones.

25 ~~14.17.~~ The method of Claim ~~11~~14, further comprising an optional discharge step
 before conducting the temperature measurement step on the planar heater zone, the
 discharge step including:
 connecting the power supply line connected to the planar heater zone to
 ground to discharge the junction capacitance of the diode connected to the planar
 30 heater zone.

15.18. The method of Claim 14, further comprising a zero point correction step before conducting the temperature measurement step on a planar heater zone, the zero point correction step including:

- connecting the power supply line connected to the planar heater zone to the current measurement device,
- connecting all the other power supply line(s) to the electrical ground,
- connecting the power return line connected to the planar heater zone to the electrical ground,
- connecting each of the other power return lines to ~~an~~ the first electrically isolated terminal,
- taking a current reading (zero point current) from the current measurement device.

16.19. The method of Claim 15, wherein the current measurement step further includes subtracting the zero point current from the current reading of the reverse saturation current before calculating the temperature T of the planar heater zone.

17.10. A method of calibrating the diodes in the system of Claim 6, comprising:

- disconnecting all power supply lines and power return lines from the current measurement device,
- closing the on-off switch,
- heating the calibration diode with the calibration heater to a temperature in a working temperature range of the diodes,
- measuring the temperature of the calibration diode with the calibrated temperature meter,
- measuring the reverse saturation current of the calibration diode, and
- determining at least one of parameters A and γ from $I_r = A \cdot T^{3+\gamma/2} \cdot e^{-E_g/kT}$

(Eq. 1) wherein A is the area of the junction in the diode, T is the temperature in Kelvin of the diode, γ is a constant, E_g is the energy gap of the material composing the junction ($E_g=1.12\text{eV}$ for silicon), k is Boltzmann's constant for each diode based on the measured temperature and measured reverse saturation current.

- ~~18.11.~~ A method of processing a semiconductor substrate in the plasma etching apparatus of Claim ~~109~~, comprising: (a) supporting a semiconductor substrate on the substrate support assembly, (b) creating a desired temperature profile across the heating plate by powering the planar heater zones therein with the system, (c) energizing a process gas into a plasma, (d) etching the semiconductor substrate with the plasma, and (e) during etching the semiconductor substrate with the plasma maintaining the desired temperature profile using the system.
- 10 ~~19.12.~~ The method of Claim ~~1811~~, wherein, in step (e), the system maintains the desired temperature profile by measuring a temperature of each planar heater zone in the heating plate and powering each planar heater zone based on its measured temperature.
- 15 ~~20.13.~~ The method of Claim ~~1912~~, wherein the system measures the temperature of each planar heater zone by taking a current reading of a reverse saturation current of the diode serially connected to the planar heater zone.