

CLAIMS

What is claimed is:

1. An apparatus to estimate parameters of a radio frequency (RF) signal coupled
5 to an integrated circuit fabrication chamber, comprising:
a voltage sensor configured to provide an indication of a voltage of the RF signal;
a current sensor configured to provide an indication of a current conducted by the RF
signal;
an analog-to-digital converter configured to receive outputs from the voltage sensor
10 and the current sensor and configured to provide digital representations of the voltage of the
RF signal and the current conducted by the RF signal based on the inputs from the voltage
sensor and the current sensor; and
one or more processors configured to determine, based on the digital representations
of the voltage and the current of the RF signal: a peak voltage associated with the digital
15 representation of the voltage, a peak current associated with the digital representation of the
current, and power characteristics associated with the RF signal.
2. The apparatus of claim 1, wherein the one or more processors are further
configured to determine phases associated with the digital representations of the voltage and
20 the current.
3. The apparatus of claim 2, wherein the power characteristics are based on the
determined phases.
- 25 4. The apparatus of any one of claims 1-3, wherein the one or more processors
are further configured to determine an impedance based on the peak voltage and the peak
current.
5. The apparatus of any one of claims 1-3, wherein the apparatus further
30 comprises:
a plurality of voltage sensors included the voltage sensor and a plurality of current
sensors associated with the current sensor; and
a multiplexer configured to:

select a voltage sensor of the plurality of voltage sensors and a current sensor of the plurality of current sensors; and

provide outputs of the selected voltage sensor and the selected current sensor to the analog-to-digital converter.

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6. The apparatus of any one of claims 1-3, wherein the voltage sensor comprises a capacitive voltage sensor.

7. The apparatus of any one of claims 1-3, wherein the current sensor comprises
10 an inductive transformer.

8. The apparatus of any one of claims 1-3, wherein the RF signal is provided by an RF power generator that provides at least 2 frequency components.

9. The apparatus of any one of claims 1-3, wherein the RF signal is provided by
15 an RF power generator that provides one frequency component.

10. The apparatus of any one of claims 1-3, wherein the one or more processors
comprise a Field Programmable Gate Array (FPGA).

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11. The apparatus of any one of claims 1-3, wherein the digital representations are at a sampling rate typically greater than about 100 MHz.

12. The apparatus of any one of claims 1-3, wherein the power characteristics
25 comprise a power factor.

13. The apparatus of any one of claims 1-3, wherein the one or more processors are further configured to communicate data via a serial communication protocol, via Ethernet., or via another digital communication protocol.

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14. The apparatus of any one of claims 1-3, wherein the one or more processors are further configured to provide outputs to an Ethernet for Control Automation Technology (EtherCAT) system.

15. The apparatus of claim 14, wherein the EtherCAT system is configured to provide instructions to one or more elements in a matching network or other RF distribution system.

5 16. The apparatus of any one of claims 1-3, wherein the one or more processors are configured to: 1) provide calibration coefficients to the voltage sensor for storage in memory associated with the voltage sensor; or 2) provide calibration coefficients to the current sensor for storage in memory associated with the current sensor.

10 17. The apparatus of claim 16, wherein the calibration coefficients are determined for a plurality of RF signal frequencies.

18. The apparatus of claim 16, wherein the calibration coefficients are determined using a modular calibration method that comprises: determining an effect of one or more
15 cables that electrically couple the voltage sensor and the current sensor to the analog-to-digital converter; or determining an effect of a controller that receives outputs from the voltage sensor and the current sensor via the one or more cables.

19. The apparatus of claim 16, wherein the calibration coefficients are determined
20 using an end-to-end calibration method that comprises determining transformation functions that relate outputs of the one or more processors to characteristics of the RF signal.

20. The apparatus of any one of claims 1-3, wherein: 1) the voltage sensor is configured to provide identifying information to the one or more processors; or 2) the current
25 sensor is configured to provide identifying information to the one or more processors.

21. The apparatus of claim 20, wherein the identifying information comprises the calibration coefficients.

30 22. The apparatus of claim 20, wherein 1) the voltage sensor is configured to provide identifying information to the one or more processors at a system power on time or a system reset time; or 2) the current sensor is configured to provide identifying information to the one or more processors at the system power on time or the system reset time.

23. A method for identifying anomalous conditions associated with a process chamber, comprising:

obtaining indications of one or more trigger events;

detecting occurrence of a trigger event of the one or more trigger events;

5 in response to detecting occurrence of the one or more trigger events, obtaining samples of one of: RF voltage signals from a voltage sensor or samples of RF current signals from a current sensor;

determining a frequency domain representation of the samples of RF voltage signals or of the samples of RF current signals;

10 identifying an anomaly in the frequency domain representation; and causing an indication of the anomaly to be stored in a log.

24. The method of claim 23, wherein the one or more trigger events comprise at least one of: a powering on of an RF signal generator, a change in a process condition, a
15 voltage measured by the voltage sensor exceeding a voltage threshold, or a current measured by the current sensor exceeding a current threshold.

25. The method of any one of claims 23 or 24, wherein determining the frequency domain representation comprises determining a Fast Fourier Transform (FFT) of the samples
20 of the RF voltage signals or the samples of the RF current signals.

26. The method of any one of claims 23 or 24, wherein the samples are obtained for a predetermined time period subsequent to detection of the trigger event.

25 27. The method of claim 26, wherein the predetermined time period is within a range of about 10 milliseconds – 1 second.

28. The method of any one of claims 23 or 24, wherein the anomaly in the frequency domain representation comprises excess energy in a frequency band.

30 29. The method of claim 28, wherein the frequency band includes a harmonic of an RF signal generated by an RF signal generator.