station with a set point for each station, and determining a change to an RF adjuster to adjust the RF power parameter at each station such that the difference between the measurement and set point is reduced..

[0004] In some other or additional implementations, operation (i) may include measuring impedance as seen by a source of the RF power and operation (ii) may include determining a change to the frequency of the RF power such that the change to the frequency would result in a phase of the impedance as seen by the source of the RF power having zero value..

[0005] In some other or additional implementations, the RF power at each station during the depositing operation may be substantially the same.

[0006] In some other or additional implementations, the RF power distributed may be at a fixed frequency. In some such implementations, the fixed frequency may be a frequency of about 13.56 MHz. In some other or additional such implementations, the fixed frequency may be a preset frequency. In some such implementations, operation (i) may include measuring impedance as seen by a source of the RF power and the preset frequency may be a frequency calculated to result in a magnitude of the impedance as seen by the source of the RF power having a value of about 50 ohms.

[0007] In some other or additional implementations, tuning the frequency of the RF power may be performed over a duration of 10 seconds or less, 1 second or less, 500 milliseconds or less, or 150 milliseconds or less.

[0008] In some other or additional implementations, the thin film may be produced during a single ALD cycle. In some such implementations, operations (a) through (d) may be repeatedly performed, each time during a new ALD cycle. In some such implementations, the station-to-station distribution of the RF power parameter may not be changed over the multiple ALD cycles. In some other or additional such implementations, the tuning in operation (c) may produce a first RF power frequency in one ALD cycle and a second RF power frequency in another ALD cycle, such that the first and second RF power frequencies are different.

[0009] In certain implementations, a method of plasma-assisted semiconductor deposition in multiple stations may be provided. The method may include: providing a substrate at each of the

sensor configured to measure plasma impedance, a RF frequency tuner configured to tune the RF power's frequency, one or more RF power adjusters configured to adjust the RF power distributed to the multiple deposition stations and thereby reduce station to station variations, and one or more controllers. Each of the deposition stations may include at least one wafer support and is configured to receive at least one substrate. The multiple deposition stations may be within a chamber. The one or more controllers, the power source, the impedance sensor, the RF frequency ~~adjuster~~tuner, and the RF power adjusters may be communicatively connected. The controller may be configured to tune the RF power frequency and instruct the one or more RF power adjusters to adjust the RF power distributed to each station to reduce station-to-station variations. Tuning the RF power frequency may include: i) determining the impedance of the plasma via the plasma impedance measured by the impedance sensor, ii) determining, according to the impedance measured in operation (i), a change to the frequency of the RF power, and iii) adjusting the frequency of the RF power via the RF frequency tuner.

[0014] In some such implementations, operation (ii) may include determining a change to the frequency of the RF power such that the change to the frequency would result in a phase of the impedance having zero value.

[0015] In some other or additional implementations, the RF power adjuster may be selected from variable capacitors and variable coil inductors.

[0016] In some other or additional implementations, the impedance sensor may be configured to measure impedance as seen by the power source and operation (ii) may include determining a change to the frequency of the RF power such that the change to the frequency would result in a phase of the impedance as seen by the power source having zero value.

[0017] In some other or additional implementations, the RF power provided may be a fixed frequency. In some such implementations, the impedance sensor may be configured to measure impedance as seen by the power source and the fixed frequency is a frequency calculated to result in a magnitude of the impedance as seen by the power source having a value of about 50 ohms. In some such other or additional implementations, the fixed frequency is a frequency of about 13.56 MHz.

[0018] In some other or additional implementations, tuning the frequency of the RF power may be performed over a duration of 10 seconds or less, 1 second or less, 500 milliseconds or less, or 150 milliseconds or less. In certain implementations, an apparatus for plasma-assisted semiconductor depositions may be provided. The apparatus may include multiple deposition stations, a power source configured to provide RF power to the chamber to generate and maintain a plasma, an impedance sensor configured to measure plasma impedance, a RF frequency tuner configured to tune the RF power's frequency, one or more RF power adjusters configured to adjust the RF power distributed to the multiple deposition stations and thereby reduce station to station variations, and one or more controllers. Each of the deposition stations may include at least one wafer support and is configured to receive at least one substrate. The multiple deposition stations may be within a chamber. The one or more controllers, the power source, the impedance sensor, the RF frequency ~~adjuster~~tuner, and the RF power adjusters may be communicatively connected. The controller may be configured to: perform at least a first and a second deposition process to produce first and second layers having different materials with different values of intrinsic properties such that the first deposition process is performed according to a first recipe having a first station-to-station adjustment of the RF power distributed and the second deposition process is performed according to a second recipe having a second station-to-station adjustment of the RF power distributed, tune the RF power frequency, and instruct the one or more RF power adjusters to adjust the RF power distributed to each station to reduce station-to-station variations. Tuning the RF power frequency may include: i) determining the impedance of the plasma via the plasma impedance measured by the impedance sensor, ii) determining, according to the plasma impedance measured in operation (i), a change to the frequency of the RF power, and iii) adjusting the frequency of the RF power via the RF frequency tuner. The first adjustment for the RF power distributed according to the first recipe is different from the second adjustment for the RF power distributed according to the second recipe.

BRIEF DESCRIPTION OF THE DRAWINGS

deposition process, Figure 4B describes a process utilizing only RF frequency tuning during the deposition process.

[0083] Process flow diagram of Figure 4B may be a process utilized for a deposition process utilizing RF frequency tuning. Certain implementations may use the process illustrated in ~~Process~~ Figure 4B for an individual deposition process of a semiconductor processing operation that includes multiple different deposition processes. The multiple different deposition processes may deposit different materials as described herein. In other embodiments, only a single deposition process is used. Either way, the station-to-station RF power adjustment is fixed and may be set prior to the deposition process. Typically, the process does not employ feedback of an RF power parameter to determine appropriate RF power adjustment during deposition.

[0084] In process flow diagram 420 of Figure 4B, operations 421 and 423 are similar to operations 401 and 403 of Figure 4A, respectively. In operation 425 of Figure 4B, RF adjustments for the multiple stations are determined. The RF adjustments for the multiple stations are determined prior to generation of RF power and the processing of the substrates. The RF adjustments may be determined via historical data, calculations, or trial and error.

[0085] After the RF adjustment has been performed in operation 425, the process may proceed to operation 427. Operations 427, 429, and 431 are similar to operations 405, 407, and 408 of Figure 4A, respectively. In operation 433, the current cycle is processed for each station and the process is then repeated for the desired number of cycles. During each of the desired number of cycles, operations 427, 429 and 431 are repeated so that the RF power frequency is continuously tuned according to the requirements of the impedance measured. The RF power frequency may be tuned according to the techniques described elsewhere in this disclosure herein.

[0086] Various other configurations and apparatus for power balancing for multi-station semiconductor processing apparatuses are described in U.S. Patent No. 8,282,983, issued October 9, 2012, which is incorporated herein by reference in its entirety.

16. The method of claim 14, wherein i) comprises measuring impedance as seen by a source of the RF power and ii) comprises determining a change to the frequency of the RF power such that the change to the frequency would result in a phase of the impedance as seen by the source of the RF power having zero value.

17. The method of claim 14, wherein the first and second deposition processes are ALD deposition processes.

18. An apparatus for plasma-assisted semiconductor depositions, the apparatus comprising:

multiple deposition stations, wherein each of deposition stations includes at least one wafer support and is configured to receive at least one substrate, and wherein the multiple deposition stations are within a chamber;

a power source configured to provide RF power to the chamber to generate and maintain a plasma;

an impedance sensor configured to measure plasma impedance;

a RF frequency tuner configured to tune the RF power's frequency;

one or more RF power adjusters configured to adjust the RF power distributed to the multiple deposition stations and thereby reduce station to station variations; and

one or more controllers, wherein the one or more controllers, the power source, the impedance sensor, the RF frequency ~~adjuster~~tuner, and the RF power adjusters are communicatively connected and the controller is configured to:

tune the RF power frequency, wherein tuning the RF power frequency includes:

i) determining the impedance of the plasma via the plasma impedance measured by the impedance sensor;

ii) determining, according to the impedance measured in (i), a change to the frequency of the RF power; and

iii) adjusting the frequency of the RF power via the RF frequency tuner, and

instruct the one or more RF power adjusters to adjust the RF power distributed to each station to reduce station-to-station variations.

19. The apparatus of claim 18, wherein ii) comprises determining a change to the frequency of the RF power such that the change to the frequency would result in a phase of the impedance having zero value.

20. The apparatus of claim 18, wherein the RF power adjuster is selected from the group consisting of: variable capacitors and variable coil inductors.

21. The apparatus of claim 18, wherein the impedance sensor is configured to measure impedance as seen by the power source and ii) comprises determining a change to the frequency of the RF power such that the change to the frequency would result in a phase of the impedance as seen by the power source having zero value.

22. The apparatus of claim 18, wherein the RF power provided is at a fixed frequency.

23. The apparatus of claim 22, wherein the impedance sensor is configured to measure impedance as seen by the power source and the fixed frequency is a frequency calculated to result in a magnitude of the impedance as seen by the power source having a value of about 50 ohms.

24. The apparatus of claim 22, wherein the fixed frequency is a frequency of about 13.56 MHz.

25. The apparatus of claim 18, wherein tuning the frequency of the RF power is performed over a duration of 10 seconds or less.

26. An apparatus for plasma-assisted semiconductor depositions, the apparatus comprising:

multiple deposition stations, wherein each of deposition stations includes at least one wafer support and is configured to receive at least one substrate, and wherein the multiple deposition stations are within a chamber;

a power source configured to provide RF power to the chamber to generate and maintain a plasma;

an impedance sensor configured to measure plasma impedance;

a RF frequency tuner configured to tune the RF power's frequency;

one or more RF power adjusters configured to adjust the RF power distributed to the multiple deposition stations and thereby reduce station to station variations; and

one or more controllers, wherein the one or more controllers, the power source, the impedance sensor, the RF frequency ~~adjuster~~tuner, and the RF power adjusters are communicatively connected and the controller is configured to:

perform at least a first and a second deposition process to produce first and second layers having different materials with different values of intrinsic properties, wherein the first deposition process is performed according to a first recipe having a first station-to-station adjustment of the RF power distributed, and the second deposition process is performed according to a second recipe having a second station-to-station adjustment of the RF power distributed, and

instruct the one or more RF power adjusters to adjust the RF power distributed to each station to reduce station-to-station variations, wherein the first adjustment for the RF power distributed according to the first recipe is different from the second adjustment for the RF power distributed according to the second recipe.