

Claims

1. A method comprising:
 - applying a multi-mode pulsing process to a selected wafer in a plasma process chamber, the multi-mode pulsing process including a plurality of cycles, each one of the plurality of cycles including a plurality of different phases;
 - collecting at least one process output variable for a phase of the plurality of phases during the plurality of cycles for the selected wafer;
 - comparing a plurality of trajectories of the at least one process output variable for the phase across the plurality of cycles;
 - calculating a distance from a point on a first one of the trajectories for a first one of the cycles to a point on a second one of the trajectories for a second one of the cycles; and
 - determining based on the distance whether an endpoint of the multi-mode pulsing process is reached.
2. The method of claim 1, wherein collecting the at least one process output variable for the phase during the plurality of cycles for the selected wafer includes collecting the at least one process output variable at a sampling rate of between 1 hertz and 10,000 hertz.
3. The method of claim 1, wherein the at least one process output variable is at least one of an optical emission spectrum emitted from plasma during the multi-mode pulsing process or a reflected spectrum reflected from a top surface of the selected wafer during the multi-mode pulsing process.
4. The method of claim 1, wherein the at least one process output variable is varied in each of the plurality of different phases.
5. The method of claim 1, wherein each of the plurality of different phases has a duration of between 2 seconds and 20 seconds.
6. The method of claim 1, wherein the at least one process output variable includes a plurality of wavelengths of light.

7. The method of claim 1, wherein a process changes for each of the plurality of different phases.
8. The method of claim 1, wherein the at least one process output variable includes an emitted spectrum, or a reflected spectrum, or an RF harmonic, or an RF voltage, or an RF current, or an RF impedance, or a process chamber temperature, or a process chamber pressure.
9. The method of claim 1, further comprising:
analyzing the at least one process output variable; and
identifying a selected process point from the at least one process output variable.
10. The method of claim 9, wherein identifying the selected process point includes identifying the endpoint of the multi-mode pulsing process.
11. The method of claim 9, further comprising:
differentiating the second trajectory of the phase in the second cycle that contains the selected process point from the plurality of trajectories, wherein differentiating includes:
calculating a multivariate analysis statistic for the second trajectory; and
identifying the selected process point when the multivariate analysis exceeds a threshold value.
12. The method of claim 9, wherein analyzing the at least one process output variable includes determining an envelope of the at least one process output variable and wherein the determined envelope includes a trend of the at least one process output variable prior to the selected process point.
13. The method of claim 12, wherein identifying the selected process point from the at least one process output variable includes identifying a multi-mode pulsing process point from the envelope of the at least one process output variable.

14. The method of claim 12, wherein identifying the selected process point from the at least one process output variable includes identifying the selected process point corresponding to a selected trend in a slope of the envelope.
15. The method of claim 9, wherein analyzing the at least one process output variable includes identifying a template for the selected process point of the multi-mode pulsing process, and wherein identifying the selected process point from the at least one process output variable includes matching the template for the selected process point to the at least one process output variable.
16. The method of claim 15, wherein identifying the template for the selected process point of the multi-mode pulsing process includes identifying a curve corresponding to the selected process point during the multi-mode pulsing process for a plurality of wafers.
17. The method of claim 16, wherein the curve corresponding to the selected process point during the multi-mode pulsing process for a plurality of wafers is a unique curve.