

CLAIMS

What is claimed is:

- 5 1. A method for automatically identifying an optimal endpoint algorithm for qualifying a process endpoint during substrate processing ~~in~~ within a plasma processing system, ~~the method comprising:~~
 - receiving sensor data from a plurality of sensors during substrate processing of at least one substrate ~~in~~ within said plasma processing system, wherein said sensor data
 - 10 includes a plurality of signal streams from a plurality of sensor channels;
 - identifying an endpoint domain, wherein said endpoint domain is an approximate period within which said process endpoint is expected to occur;
 - analyzing said sensor data to generate a set of potential endpoint signatures;
 - converting said set of potential endpoint signatures into a set of optimal endpoint
 - 15 algorithms; and
 - importing one optimal endpoint algorithm of said set of optimal endpoint algorithms into production environment, wherein said analyzing of said sensor data includes performing linear fitting on said sensor data to divide ~~dividing~~ each signal stream of ~~from~~ said plurality of signal streams into a plurality of segments based on
 - 20 time intervals;
 - ~~calculating a first set of slopes and a first set of corresponding slope noise values for said sensor data, wherein a slope and a corresponding slope noise value is calculated for each segment of said plurality of segments;~~
 - ~~calculating slope variances in said first set of slopes to identify a first set of~~
 - 25 ~~candidate signals from said plurality of signal streams, wherein said first set of candidate signals have higher slope variances than other signals in said plurality of signal streams;~~
 - ~~combining contiguous wavelength measurements in said sensor data that have similar slope variances into a first set of signal wavelength bands;~~
 - 30 ~~ranking said first set of candidate signals;~~
 - ~~ranking said first set of signal wavelength bands;~~

identifying a first set of potential endpoint signatures by applying a set of class features to at least part of said first set candidate signals and said first set of signal wavelength bands, wherein said set of class features include at least one of a peak feature, a valley feature, and an inflection feature;

5 converting said first set of potential endpoint signatures into a set of endpoint algorithms; and

importing an endpoint algorithm of said set of endpoint algorithms into a production environment as said optimal endpoint algorithm.

2. — The method of claim 1 wherein said sensor data is gathered from a plurality of substrates.

3. — The method of claim 1 wherein said dividing is performing by performing linear fitting on said sensor data.

4. — The method of claim 1 wherein segments of said plurality of segments have a uniform length.

5. — The method of claim 1 wherein said first set of candidate signals are ranked according to slope variances associated with candidate signals in said first set of candidate signals.

2. The method of claim 1 wherein each segment of said plurality of segments is uniform.

3. The method of claim 1 wherein said analyzing of said sensor data to generate a first set of potential endpoint signatures of said set of potential endpoint signatures includes

calculating a first set of slopes and a first set of corresponding slope noise values for said sensor data, wherein a slope and a corresponding slope noise value is calculated for each segment of said plurality of segments,

calculating slope variances in each slope to identify a set of high contrast signals from said plurality of signal streams, wherein said set of high contrast signals having high slope variance,

combining contiguous wavelengths with similar slope variance into a set of signal wavelength bands,

ranking said high contrast signals,

ranking said set of signal wavelength bands, and

identifying said first set of potential endpoint signatures by applying a set of class features to at least part of said high contrast signals and said set of signal wavelength bands, wherein said set of class features include at least one of peak, valley, and inflection.

5 6. ~~—The method of claim 1 further comprising:~~

~~identifying a second set of candidate signals from said plurality of signal streams, wherein said second set of candidate signals have higher slopes and lower slope variances than at least some signals in said plurality of signal streams;~~

10 ~~combining contiguous wavelength measurements in said second set of candidate signals that have similar slope variances into a second set of signal wavelength bands;~~

~~ranking said second set of candidate signals;~~

~~ranking said second set of signal wavelength bands; and~~

15 ~~applying a second set of class features to a ratio of said first set of candidate signals and said first set of signal wavelength bands to said second set of candidate signals and said second set of signal wavelength bands to generate a second set of potential endpoint signatures.~~

20 4. The method of claim 3 wherein said analyzing of said sensor data to generate a second set of potential endpoint signatures of said set of potential endpoint signatures includes

performing a multi-variate analysis by combining slopes scaled by corresponding slope noise values of said first set of slopes and said first set of corresponding slope noise values to generate a normalized set of slopes and a normalized set of corresponding slope noise values.

25 calculating slope variances in said normalized set of slopes to identify normalizing signals from said plurality of signal streams, wherein said normalizing signals having high slope and low variance,

combining contiguous wavelengths with similar slope variance into a set of normalizing signal wavelength bands,

30 ranking said normalizing signals,

ranking said set of normalizing signal wavelength bands, and

applying a set of class features to a ratio of said high contrast signals and a set of signal wavelength bands to said normalizing signals and said set of normalizing signal wavelength bands to generate said second set of potential endpoint signatures.

75. The method of claim 3 wherein said converting of said set of potential endpoint signatures into said set of optimal endpoint algorithms includes

combining a first potential endpoint signature and a second potential endpoint signature of said first set of potential endpoint signatures if said first potential endpoint signature and said second potential endpoint signature have having similar shapes and similar time periods,

performing a robustness test to remove potentially non-repeatable endpoint signatures from said first set of potential endpoint signatures,

performing a multi-variate correlation analysis to identify a set of optimal endpoint signatures of said first set of potential endpoint signatures,

converting said set of optimal endpoint signatures into a set of optimal real-time endpoint algorithms associated with minimal real-time delays, wherein said real-time delays being based on filter delays,

generating said set of optimal endpoint algorithms by performing at least one of removing a subset of optimal real-time endpoint algorithms associated with corresponding real-time delays greater than a predefined threshold, and

eliminating said real-time endpoint algorithms if said real-time endpoint algorithms fail to pass a robustness test, and

ranking each optimal endpoint algorithm of said set of optimal endpoint algorithms, wherein said ranking being based on at least one of fidelity ratio and said real-time delay.

86. The method of claim 4 wherein said converting of said set of potential endpoint signatures into said set of optimal endpoint algorithms includes

combining a first potential endpoint signature and a second potential endpoint signature of said set of potential endpoint signatures if said first potential endpoint signature and said second potential endpoint signature have having similar shapes and similar time periods,

performing a robustness test to remove potentially non-repeatable endpoint signatures from said set of potential endpoint signatures,

performing a multi-variate correlation analysis to identify a set of optimal endpoint signatures of said set of potential endpoint signatures,

converting said set of optimal endpoint signatures into a set of real-time endpoint algorithms ~~that minimizes~~ with minimal real-time delays, wherein said real-time delays being based on filter delays, and

generating said set of optimal endpoint algorithms by performing at least one of removing real-time endpoint algorithms with corresponding real-time delay greater than a predefined threshold, and

eliminating a subset of said set of real-time endpoint algorithms that if said real-time endpoint algorithms fails to pass an endpoint algorithm a robustness test, and

ranking each optimal endpoint algorithm of said set of optimal endpoint algorithms, wherein said ranking being based on at least one of fidelity ratio and said real-time delay.

97. The method of claim 1 wherein said importing is of said optimal endpoint algorithm being based on at least one of a ranking of said set of endpoint algorithms and a set of user-defined conditions.

8. The method of claim 1 wherein said sensor data is being gathered from more than one substrate.

109. A method for qualifying an endpoint during substrate processing ~~in~~ within a processing chamber, the method comprising:

executing a recipe on a substrate;

~~receiving sensor processing data from a set of sensors during processing said substrate, wherein said substrate processing;~~

analyzing said processing data by applying an optimal endpoint algorithm;

identifying a process endpoint;

stopping said substrate processing wherein said optimal ending algorithm is constructed by receiving sensor data from a plurality of sensors during processing of at least one substrate within a plasma processing system, said sensor data includes a plurality of signal streams from a plurality of sensor channels; identifying an endpoint domain, wherein said endpoint domain is an approximate period within which said process endpoint is expected to occur, analyzing said sensor data to generate a set of

potential endpoint signatures, converting said set of potential endpoint signatures into a set of optimal endpoint algorithms, importing one optimal endpoint algorithm of a set of optimal endpoint algorithms into production environment, said sensor data is being gathered from more than one substrate, said analyzing of said sensor data includes performing linear fitting on said sensor data to divide each signal stream from said plurality of signal streams into a plurality of segments based on time intervals

dividing each signal stream from said plurality of signal streams into a plurality of segments based on time intervals;

calculating a first set of slopes and a first set of corresponding slope noise values for said sensor data, wherein a slope and a corresponding slope noise value is calculated for each segment of said plurality of segments;

calculating slope variances in said first set of slopes to identify a first set of candidate signals from said plurality of signal streams, wherein said first set of candidate signals have higher slope variances than other signals in said plurality of signal streams;

combining contiguous wavelength measurements in said sensor data that have similar slope variances into a first set of signal wavelength bands;

ranking said first set of candidate signals;

ranking said first set of signal wavelength bands;

identifying a first set of potential endpoint signatures by applying a set of class features to at least part of said first set candidate signals and said first set of signal wavelength bands, wherein said set of class features include at least one of a peak feature, a valley feature, and an inflection feature;

identifying a process endpoint using at least one endpoint signature of said first set of potential endpoint signatures; and

stopping said substrate processing.

11. — The method of claim 10 wherein said calculating said slope variances is performed by a computing engine.

12. — The method of claim 10 further comprising identifying an endpoint domain, wherein said endpoint domain is an approximate period within which said process endpoint is expected to occur.

13. — ~~The method of claim 10 wherein said sensor data is gathered from a plurality of substrates.~~

14. — ~~The method of claim 10 wherein said dividing is performed by performing linear fitting on said sensor data.~~

15. — ~~The method of claim 10 wherein said first set of candidate signals are ranked according slope variances associated with candidate signals in said first set of said candidate signals.~~

16. — ~~The method of claim 10 further comprising:~~

~~identifying a second set of candidate signals from said plurality of signal streams, wherein said second set of candidate signals have higher slopes and lower variances than at least some signals in said plurality of signal streams;~~

~~combining contiguous wavelength measurements in said second set of candidate signals that have similar slope variances into a second set of signal wavelength bands;~~

~~ranking said second set of candidate signals;~~

~~ranking said second set of signal wavelength bands; and~~

~~applying a second set of class features to a ratio of said first set of candidate signals and said first set of signal wavelength bands to said second set of candidate signals and said second set of signal wavelength bands to generate a second set of potential endpoint signatures.~~

10. The method of claim 9 wherein said analyzing of said sensor data to generate a first set of potential endpoint signatures of said set of potential endpoint signatures includes

calculating a first set of slopes and a first set of corresponding slope noise values for said sensor data, wherein a slope and a corresponding slope noise value is calculated for each segment of said plurality of segments.

calculating slope variances in said first set of slopes to identify a set of high contrast signals from said plurality of signal streams, wherein said set of high contrast signals having high slope variance,

combining contiguous wavelengths with similar slope variance into a set of signal wavelength bands,

ranking said high contrast signals,

ranking said set of signal wavelength bands, and
identifying said first set of potential endpoint signatures by applying a set of
class features to at least part of said high contrast signals and said set of signal
wavelength bands, wherein said set of class features include at least one of peak, valley,
5 and inflection.

11. The method of claim 10 wherein said analyzing of said sensor data to generate
second set of potential endpoint signatures of said set of potential endpoint signatures
includes

10 performing a multi-variate analysis by combining slopes scaled by
corresponding slope noise values of said first set of slopes and said first set of
corresponding slope noise values to generate a normalized set of slopes and a
normalized set of corresponding slope noise values.

15 calculating slope variances in said normalized set of slopes to identify
normalizing signals from said plurality of signal streams, wherein said normalizing
signals having high slope and low variance.

combining contiguous wavelengths with similar slope variance into a set of
normalizing signal wavelength bands.

ranking said normalizing signals.

ranking said set of normalizing signal wavelength bands, and

20 applying a set of class features to a ratio of said high contrast signals and a set of
signal wavelength bands to said normalizing signals and said set of normalizing signal
wavelength bands to generate said second set of potential endpoint signatures.

1712. The method of claim 10 further comprising: wherein said converting of said set
of potential endpoint signatures into said set of optimal endpoint algorithms includes

25 combining a first potential endpoint signature and a second potential endpoint
signature of said first set of potential endpoint signatures if said first potential endpoint
signature and said second potential endpoint signature have having similar shapes and-
similar time periods;

30 performing a robustness test to remove potentially non-repeatable endpoint
signatures from said first set of potential endpoint signatures;

performing a multi-variate correlation analysis to identify a set of optimal
endpoint signatures of said first set of potential endpoint signatures;

converting said set of optimal endpoint signatures into a set of real-time endpoint algorithms-associated with minimal real-time delays, wherein said real-time delay being based on filter delays;

5 generating said set of optimal endpoint algorithms by performing at least one of
 removing a subset of real-time endpoint algorithms-associated with
 corresponding real-time delays greater than a predefined threshold, and
 eliminating said real-time endpoint algorithms if said real-time endpoint
 algorithms fail to pass a robustness test, and
 ranking each optimal endpoint algorithm of said set of optimal endpoint
10 algorithms, wherein said ranking being based on at least one of fidelity ratio and said
real-time delay.

13. The method of claim 10 ~~11~~ further comprising wherein said converting of said
set of potential endpoint signatures into said set of optimal endpoint algorithms
includes:

15 combining a first potential endpoint signature and a second potential endpoint
signature of said ~~first~~ set of potential endpoint signatures if said first potential endpoint
signature and said second potential endpoint signature ~~have~~ having similar shapes and
~~similar~~ time periods;

20 performing a robustness test to remove potentially non-repeatable endpoint
signatures from said set of potential endpoint signatures;

 performing a multi-variate correlation analysis to identify a set of optimal
endpoint signatures of said ~~first~~ set of potential endpoint signatures;

25 converting said set of optimal endpoint signatures into a set of real-time
endpoint algorithms-associated with minimal real-time delays, wherein said real-time
delay being based on filter delays; and,

generating said set of optimal endpoint algorithms by performing at least one of

removing real-time endpoint algorithms with corresponding real-time
delay greater than a predefined threshold, and

30 eliminating a subset of said set of real-time endpoint algorithms that if
said real-time endpoint algorithms fails to pass an endpoint algorithm a
robustness test, and

ranking each optimal endpoint algorithm of said set of optimal endpoint algorithms, wherein said ranking being based on at least one of fidelity ratio and said real-time delay.

5 ~~1914.~~ The method of claim-10 ~~9~~ further comprising wherein said importing-an of said optimal endpoint algorithm-associated with said at least one endpoint signature into a production environment being based on at least one of ranking and a set of user-defined conditions.

~~2015.~~ The method of claim-10 ~~9~~ wherein each segments of said plurality of segments-
have a is uniform-length.