

[0006] Alternatively, in-situ metrology devices (optical sensors) can be used to directly measure the etched layer during the etch process and provide feedback control for accurately stopping the etch process once a certain vertical feature has been attained. For example, in a generic spacer application the goal for an in-situ optical sensor for film thickness monitoring is to stop anisotropic oxide-etch at a few nm before touchdown (soft landing), then switch to isotropic etching to achieve an ideal spacer profile. Further, the in-situ metrology devices may be used for real-time actual measurement of the films and etch features during the etch process to determine information about the sizes of structures which can be used to control the etch process and/or to control subsequent processes (e.g., a process to compensate for a certain out-of-specification dimension).

[0007] The foregoing “Background” description is for the purpose of generally presenting the context of the disclosure. Work of the inventor, to the extent it is described in this background section, as well as aspects of the description which may not otherwise qualify as prior art at the time of filing, are neither expressly or impliedly admitted as prior art against the present invention.

SUMMARY

[0007a] According to a first aspect of the present invention, there is provided an apparatus for in-situ etching monitoring in a plasma processing chamber, the apparatus comprising:

- a continuous wave broadband light source;
- an illumination system configured to illuminate an area on a substrate with an incident light beam being directed from the continuous wave broadband light source at normal incidence to the substrate;
- a collection system configured to collect a reflected light beam being reflected from the illuminated area on the substrate, and to direct the reflected light beam to a first light detector;
- and

processing circuitry configured to process the detected reflected light beam to suppress background light, determine a property of the substrate or structures formed thereupon based on a reference light beam and the reflected light beam, and control an etch process based on the determined property,

5 wherein the reference light beam is generated by the illumination system by splitting a portion of the incident light beam through a beam splitter or using a mirror, thereafter directing the reference light beam to a second light detector.

[0007b] According to a second aspect of the present invention, there is provided a plasma processing system, the system comprising:

10 a plasma processing chamber; and

 a normal incidence reflectometer including

 a continuous wave broadband light source,

 an illumination system configured to illuminate an area on a substrate disposed in the plasma processing chamber with an incident light beam directed from the continuous wave broadband light source at normal incidence to the substrate;

15 a collection system configured to collect a reflected light beam being reflected from the illuminated area on the substrate, and to direct the reflected light beam to a first light detector; and

 processing circuitry configured to process the detected reflected light beam to suppress background light, determine a property of the substrate or structures formed thereupon based on reference light beam and the reflected light beam, and control an etch process based from the determined property,

20 wherein the reference light beam is generated by the illumination system by splitting a portion of the incident light beam through a beam splitter or using a mirror, thereafter directing the reference light beam to a second light detector.

25 [0008] There is provided an apparatus for in-situ etching monitoring in a plasma processing chamber. The apparatus includes a continuous wave broadband light source, an illumination system configured to illuminate an area on a substrate with an incident light beam being directed at normal incidence to the substrate, a collection system configured to collect a reflected light beam being reflected from the illuminated area on the substrate, and direct the reflected light beam to a detector, and processing circuitry. The processing circuitry is configured to process the reflected light beam to suppress (e.g., filter or subtract) background light, determine a property (e.g., thickness) of the substrate or structures formed thereupon,

based on reference light beam and the reflected light beam, and control an etch process based on the determined property.

5 [0009] There is provided a plasma processing system. The system includes a plasma processing chamber and a normal incidence reflectometer with zero degree AOI (angle of incidence). The normal incidence reflectometer includes a continuous wave broadband light source, a detector, an illumination system configured to illuminate an area on a substrate disposed in the plasma processing chamber with an incident light beam being directed at normal incidence to the substrate, a collection system configured to collect a reflected light beam being reflected from the illuminated area on the substrate, and direct the reflected light beam to the detector, and processing circuitry. The processing circuitry is configured to process the reflected light beam to suppress background light, determine a property of the substrate or structures formed thereupon based on reference light beam and the reflected light beam that are processed to suppress the background light, and control an etch process based on the determined property.

15 [0010] There is provided a method for in-situ etch monitoring. In the disclosed method, incident light beam is directed at normal incidence to a substrate disposed in a plasma processing chamber, and the incident light generates an illuminated area on surface of the substrate. In addition, a portion of the incident light beam is split to a detector to collect a reference light beam. Background light generated from the plasma and a reflected light beam is also collected from the illuminated area. Further, the reflected light beam is processed to suppress the background light. A property of the substrate or structures formed thereupon is determined based on the reference light beam and the reflected light beam by using an algorithm or a reference library, and the etch process is controlled based on the determined property.

WHAT IS CLAIMED IS:

1. An apparatus for in-situ etching monitoring in a plasma processing chamber, the apparatus comprising:
 - a continuous wave broadband light source;
 - an illumination system configured to illuminate an area on a substrate with an incident
 - 5 light beam being directed from the continuous wave broadband light source at normal incidence to the substrate;
 - a collection system configured to collect a reflected light beam being reflected from the illuminated area on the substrate, and to direct the reflected light beam to a first light detector;
 - and
 - 10 processing circuitry configured to process the detected reflected light beam to suppress background light, determine a property of the substrate or structures formed thereupon based on a reference light beam and the reflected light beam, and control an etch process based on the determined property,
 - wherein the reference light beam is generated by the illumination system by splitting a
 - 15 portion of the incident light beam through a beam splitter or using a mirror, thereafter directing the reference light beam to a second light detector.
2. The apparatus of claim 1, further comprising a shutter configured to periodically block the incident light beam from the continuous wave broadband light source to let the collection
- 20 system collect a background light from the plasma processing chamber.
3. The apparatus of claim 2, further comprising a step motor configured to move the shutter between two positions, wherein in a first position the shutter is configured to block the incident light beam from reaching the plasma processing chamber and the substrate, and in a second
- 25 position the shutter is configured to allow the incident light beam into the plasma processing chamber and towards the substrate.
4. The apparatus of claim 2, wherein the shutter is a chopper wheel.
- 30 5. The apparatus of claim 1, wherein the continuous wave broadband light source is laser-driven broadband light source with a wavelength range from 190 nm to 2000 nm.

6. The apparatus of claim 1, wherein the illumination system includes a first polarizer and the incident light beam is passed through the first polarizer before being directed to the substrate.
- 5 7. The apparatus of claim 1, wherein the collection system includes a second polarizer and the reflected light beam is passed through the second polarizer before being directed to the first light detector.
8. The apparatus of claim 1, wherein the illumination system includes a first off-axis parabolic
10 mirror and a beam splitter to direct the incident light beam to the substrate.
9. The apparatus of claim 1, wherein the collection system includes a second off-axis parabolic mirror and a fold mirror to direct the reflected light beam to the first light detector.
- 15 10. The apparatus of claim 1, wherein the first light detector is a dual-channel broad-band high SNR (signal to ratio) spectrometer including a measurement channel to receive the reflected light beam.
11. A plasma processing system, the system comprising:
- 20 a plasma processing chamber; and
 a normal incidence reflectometer including
 a continuous wave broadband light source,
 an illumination system configured to illuminate an area on a substrate disposed
in the plasma processing chamber with an incident light beam directed from the
25 continuous wave broadband light source at normal incidence to the substrate;
 a collection system configured to collect a reflected light beam being reflected
from the illuminated area on the substrate, and to direct the reflected light beam to a
first light detector; and
 processing circuitry configured to process the detected reflected light beam to
30 suppress background light, determine a property of the substrate or structures formed thereupon based on reference light beam and the reflected light beam, and control an etch process based from the determined property,

wherein the reference light beam is generated by the illumination system by splitting a portion of the incident light beam through a beam splitter or using a mirror, thereafter directing the reference light beam to a second light detector.

5 12. The system of claim 11, wherein the illumination system and the collection system are installed inside a tube.

13. The system of claim 12, wherein the tube is made of stainless steel or aluminum alloy and is inserted into the plasma processing chamber through a top wall of the plasma processing
10 chamber.

14. The system of claim 12, wherein the tube includes an upper window configured to serve as a vacuum seal and a lower window configured to prevent contamination.

15 15. The system of claim 12, wherein the tube includes a gas supply pipe configured to inject processing gas or a purge gas into the tube and the plasma processing chamber.

16. The system of claim 11, wherein the normal incidence reflectometer further comprises a shutter configured to periodically block the incident light beam from the continuous wave
20 broadband light source to let the collection system collect the background light from the plasma processing chamber.

17. The system of claim 11, wherein the illumination system includes a first polarizer and the incident light beam is passed through the first polarizer before being directed to the substrate.
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18. The system of claim 11, wherein the collection system includes a second polarizer and the reflected light beam is passed through the second polarizer before being directed to the first light detector.

30 19. The apparatus of claim 1, wherein the second light detector comprises a photodiode or a spectrometer.