Claims

1. A system comprising: an optical subsystem comprising: an illumination subsystem that provides an amount of illumination light to a vertically stacked structure disposed on a substrate, the illumination subsystem comprising an illumination source, an illumination aperture subsystem and an illumination polarization subsystem; a collection subsystem that collects light from the vertically stacked structure in response to the amount of illumination light provided by the illumination subsystem, the collection subsystem comprising a collection aperture subsystem, wherein the optical subsystem generates a focused optical image at each of a plurality of focus planes located at a plurality of different depths of the vertically stacked structure; a detector configured to detect the light collected at each of the plurality of different depths and generate a plurality of output signals indicative of the amount of light collected at each of the plurality of different depths; and a computing system configured to: receive the plurality of output signals; communicate control commands to any of the illumination source, the illumination aperture subsystem, the collection aperture subsystem, and the illumination polarization subsystem that cause any of the illumination source to change a spectral range of the illumination light, the illumination aperture to change a shape of the illumination light provided to the substrate, the illumination polarization subsystem to change a polarization of illumination light provided to the substrate, and the collection aperture subsystem to change a shape of collected light at the detector to achieve a performance objective, wherein the performance objective is a minimization of a response of the vertically stacked structure in the three dimensional image, an enhancement of a defect signal in the three dimensional image, a minimization of wafer noise or one or more nuisance signals in the three dimensional image, a discrimination of the defect signal from wafer noise or the one or more nuisance signals in the three dimensional image, an improvement of an accuracy of an estimated physical location of the defect estimated from the three dimensional image, or any combination thereof; generate a

three dimensional image of an inspected volume spanned by the plurality of different depths of the vertically stacked structure based on the plurality of output signals; determine the presence of a defect within the inspected volume based on the three dimensional image; and classify the defect as a defect of interest based on the three dimensional image, wherein the determining and classifying of the defect involves generating a two dimensional cross-section of the three dimensional image and determining whether a measured signal visible in the two dimensional cross-section exceeds a predetermined threshold value.

2. The system of claim 1, wherein the computing system is further configured to: determine a location of the defect in three dimensions within the inspected volume of the vertically stacked structure.

3. The system of claim 2, wherein the determining of the location of the defect involves generating a two dimensional cross-section of the three dimensional image, and wherein the location of the defect is based on a depth associated with a value of the measured signal visible in the two-dimensional cross-section.

4. The system of claim 1, wherein the generating of the three dimensional image of the inspected volume involves aligning a plurality of images in two lateral dimensions each associated with different depths based on one or more alignment marks visible in each of the plurality of images.

5. The system of claim 1, wherein the computing system is further configured to: filter the three dimensional image of the inspected volume, wherein the determining and classifying of the defect within the inspected volume is based on the filtered three dimensional image.

6. The system of claim 1, wherein the determining and classifying of the defect involves a model-based analysis of the three dimensional image or a library-based analysis of the three dimensional image.

7. The system of claim 2, wherein the determining of the location of the defect involves a model-based analysis of the three dimensional image or a library-based analysis of the three dimensional image.

8. The system of claim 1, wherein the classifying of the defect involves any of a three dimensional filter, a clustering algorithm, and a deep learning algorithm.

9. The system of claim 1, the collection subsystem further comprising a Fourier filter subsystem and a collection polarization subsystem, wherein the computing system is further configured to communicate control commands to any of the Fourier filter subsystem and the collection polarization subsystem that cause any of the Fourier filter subsystem to change a spatial frequency content of the collected light and the collection polarization subsystem to select a polarization of collected light at the detector to achieve the performance objective.

10. The system of claim 1, wherein the illumination subsystem is further configured to provide the amount of illumination light at a plurality of incidence angles, a plurality of illumination wavelengths, or both, wherein the collection subsystem further configured to collect light from the vertically stacked structure at the plurality of incidence angles, the plurality of illumination wavelengths, or both, wherein the detector is further configured to detect light collected at each of the plurality of incidence angles, each of the plurality of illumination wavelengths, or both, and generate a plurality of output signals indicative of the amount of light collected at

each of the plurality of incidence angles, each of the plurality of illumination wavelengths, or both, and the computing system is further configured to generate an image of the inspected volume having more than three dimensions based on the plurality of output signals.

11. The system of claim 1, wherein the vertically stacked structure is a three dimensional NAND memory device.

12. The system of claim 1, wherein an illumination source of the illumination subsystem is a broadband laser sustained plasma light source.

13. The system of claim 1, wherein the illumination light includes wavelengths between 260 nanometers and 950 nanometers.

14. The system of claim 1, further comprising: a wafer positioning system configured to scan the substrate in a scanning motion in two dimensions parallel to a substantially flat surface of the substrate at a plurality of different positions in a direction normal to the substantially flat surface, the wafer positioning system further configured to fix a position of the substrate in the two dimensions parallel to the substantially flat surface and move the substrate in the direction normal to the substantially flat surface.

15. A method comprising: providing an amount of illumination light to a vertically stacked structure disposed on a substrate, the amount of illumination light generated by an illumination source; collecting light from the vertically stacked structure in response to the amount of illumination light, wherein the providing of the amount of illumination light and the collecting of light in response to the amount of illumination light generates a focused optical image at each of a plurality of focus planes located at a plurality of different depths of the vertically stacked structure; communicating control commands to

any of an illumination source, an illumination aperture subsystem, a collection aperture subsystem, and an illumination polarization subsystem that cause any of the illumination source to change a spectral range of the illumination light, the illumination aperture to change a shape of the illumination light provided to the substrate, the illumination polarization subsystem to change the polarization of illumination light provided to the substrate, and the collection aperture subsystem to change a shape of collected light at the detector to achieve a performance objective, wherein the performance objective is a minimization of a response of the vertically stacked structure in the three dimensional image, an enhancement of a defect signal in the three dimensional image, a minimization of wafer noise or one or more nuisance signals in the three dimensional image, a discrimination of the defect signal from wafer noise or the one or more nuisance signals in the three dimensional image, an improvement of an accuracy of an estimated physical location of the defect estimated from the three dimensional image, or any combination thereof; detecting the amounts of collected light at each of the plurality of different depths onto a detector; generating a three dimensional image of an inspected volume spanned by the plurality of focus planes at the plurality of different depths of the vertically stacked structure based on the detected amounts of collected light at each of the plurality of different depths; determining the presence of a defect within the inspected volume based on the three dimensional image; and classifying the defect as a defect of interest based on the three dimensional image, wherein the determining and classifying of the defect involves generating a two dimensional cross-section of the three dimensional image and determining whether a measured signal visible in the two dimensional cross-section exceeds a predetermined threshold value.

16. The method of claim 15, further comprising: determining a location of the defect in three dimensions within the inspected volume of the vertically stacked structure.

17. The method of claim 16, wherein the determining of the location of the defect involves generating a two dimensional cross-section of the three dimensional image and wherein the location of the defect is based on a depth associated with a value of a measured signal visible in the two-dimensional cross-section.

18. The method of claim 15, wherein the generating of the three dimensional image of the inspected volume involves aligning a plurality of images in two lateral dimensions each associated with different depths based on one or more alignment marks visible in each of the plurality of images.

19. The method of claim 15, further comprising: filtering the three dimensional image of the inspected volume, wherein the determining and classifying of the defect within the inspected volume is based on the filtered three dimensional image.

20. The method of claim 15, wherein the determining and classifying of the defect involves a model-based analysis of the three dimensional image or a library-based analysis of the three dimensional image.

21. The method of claim 16, wherein the determining of the location of the defect in three dimensions within the inspected volume of the vertically stacked structure involves a model-based analysis of the three dimensional image or a library-based analysis of the three dimensional image.

22. The method of claim 15, wherein the classifying of the defect involves any of a three dimensional filter, a clustering algorithm, and a deep learning algorithm.

23. The method of claim 15, further comprising: communicating control commands to any of a Fourier filter subsystem and a collection polarization subsystem that cause any of the Fourier filter subsystem to change a spatial frequency content of the collected light and the collection polarization subsystem to select the polarization of collected light at the detector to achieve the performance objective.

24. The method of claim 15, wherein the illumination subsystem is further configured to provide the amount of illumination light at a plurality of incidence angles, a plurality of illumination wavelengths, or both, wherein the collection subsystem is further configured to collect light from the vertically stacked structure at the plurality of incidence angles, the plurality of illumination wavelengths, or both, wherein the detector is further configured to detect light collected at each of the plurality of incidence angles, each of the plurality of illumination wavelengths, or both, and generate a plurality of output signals indicative of the amount of light collected at each of the plurality of incidence angles, each of the plurality of illumination wavelengths, or both, and further comprising determining an image of the inspected volume having more than three dimensions based on the plurality of output signals.

25. The method of claim 15, wherein the vertically stacked structure is a three dimensional NAND memory device.

26. An apparatus comprising: an optical subsystem comprising: an illumination subsystem that provides an amount of illumination light to a vertically stacked structure disposed on a substrate, the illumination subsystem comprising an illumination source, an illumination aperture subsystem and an illumination polarization subsystem; a collection subsystem that collects light from the vertically stacked structure in response to the amount of illumination light provided by the illumination subsystem, the

collection subsystem comprising a collection aperture subsystem, wherein the optical subsystem generates a focused optical image at each of a plurality of focus planes located at a plurality of different depths of the vertically stacked structure; a detector configured to detect the light collected at each of the plurality of different depths and generate a plurality of output signals indicative of the amount of light collected at each of the plurality of different depths; and a computing system comprising: one or more processors; and a non-transitory, computer-readable medium storing instructions, that when executed by the one or more processors, cause the apparatus to: receive the plurality of output signals; communicate control commands to any of the illumination source, the illumination aperture subsystem, the collection aperture subsystem, and the illumination polarization subsystem that cause any of the illumination source to change a spectral range of the illumination light, the illumination aperture to change a shape of the illumination light provided to the substrate, the illumination polarization subsystem to change a polarization of illumination light provided to the substrate, and the collection aperture subsystem to change a shape of collected light at the detector to achieve a performance objective, wherein the performance objective is a minimization of a response of the vertically stacked structure in the three dimensional image, an enhancement of a defect signal in the three dimensional image, a minimization of wafer noise or one or more nuisance signals in the three dimensional image, a discrimination of the defect signal from wafer noise or the one or more nuisance signals in the three dimensional image, an improvement of an accuracy of an estimated physical location of the defect estimated from the three dimensional image, or any combination thereof; generate a three dimensional image of an inspected volume spanned by the plurality of focus planes at the plurality of different depths of the vertically stacked structure based on the plurality of output signals; determine the presence of a defect within the inspected volume based on the three dimensional image; and classify the defect as a defect of interest based on

the three dimensional image, wherein the determining and classifying of the defect involves generating a two dimensional cross-section of the three dimensional image and determining whether a measured signal visible in the two dimensional cross-section exceeds a predetermined threshold value.

27. The apparatus of claim 26, the non-transitory, computer-readable medium further storing instructions, that when executed by the one or more processors, cause the apparatus to: determine a location of the defect in three dimensions within the inspected volume of the vertically stacked structure.