

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Figure 1A is a graph of signal strength as a function of wavelength.

[0012] Figure 1B is a graph illustrating signal transmission strength of SiN material.

5 [0013] Figure 1C is a graph illustrating signal strength for a defect in the presence of SiN material.

[0014] Figure 2 is a flow chart illustrating an inspection process in accordance with one embodiment of the present invention.

10 [0015] Figure 3 is a diagrammatic representation of an example inspection system in accordance with a specific implementation of the present invention.

[0016] Figure 4 is a diagrammatic representation of another example inspection apparatus in accordance with an alternative implementation of the present invention.

15 DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

[0017] In the following description, numerous specific details are set forth in order to provide a thorough understanding of the present invention. The present invention may be practiced without some or all of these specific details. In other instances, well known component or process operations have not been described in detail to not unnecessarily obscure the present invention. While the invention will be described in conjunction with these specific embodiments, it will be understood that it is not intended to limit the invention to these embodiments.

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[0018] The conditions can generally be optimized during wafer inspection for achieving the best signal to noise ratio (SNR) from a defect in a wafer structure.

25 The detected signal from a defect area at a specific wafer location may be compared to a corresponding reference area in which a defect is not present. First, the light or electromagnetic field (e-field) must reach the defect location in

[0024] Thus, in some cases, it may be desirable to have wavelengths of inspection above 230 nm (or at a signal peak wavelength range) when SiN (other wavelength ranges for other material types) is involved. Having an inspector with a broadband spectrum that includes wavelengths above and below the absorption edge of about 230 nm from SiN is desirable to maximize the detected signal, which is dependent upon the materials that are present. Similarly, the presence of SiN can affect the noise that is detected in the inspection such that having wavelengths above and below the 230 nm absorption edge allows the most flexibility in maximizing the signal-to-noise ratio. Other absorption edges can be used to affect the wavelength selection in the presence of other types of material, besides SiN. Although the following embodiments are described in relation to the presence or absence of SiN, these techniques can be easily altered and applied to other absorber types of materials. Alternative example absorber materials, to which embodiments of the present invention may be applied, may include copper indium gallium diselenide (CIGS), CdTe amorphous silicon, SiO₂, etc.

[0025] In general, different wavelength ranges for different sample layers of interest are selected on an inspection tool based on whether such different layers of interest have an absorber type material, such as SiN, present within or near such layers of interest. On the inspection tool, the different wavelength ranges are directed towards the different layers of interest of one or more samples and, in response, output signals or images are collected from each of the different layers of interest. The collected output signals or images from each of the different layers of interest can then be analyzed to detect defects in such different layers of interest.

[0026] Figure 2 is a flow chart illustrating an inspection process 200 in accordance with one embodiment of the present invention. Initially, a wafer with an associated layer of interest may be provided for inspection in operation 202. For instance, the layer of interest may be comprised of SiN. For another wafer or layer of interest for a same wafer, SiN may be near the layer of interest, but not actually present in the layer of interest. In a specific example, the targets or

applying across the wavelength range for each of the long and short wavelength paths.

5 [0044] Use of short and long wavelengths (either independently or simultaneously) allow the capture of (i) defects in the absence of an absorber material, such as SiN, (ii) defects in the presence of an absorber material below the layer of interest, (iii) defects in the presence of an absorber material in the layer of interest, (iv) defects in the presence of an absorber material above the layer of interest, (v) surface defects in a vertical stack structure with shorter wavelengths, (vi) both surface defects and buried defects in a vertical stack by
10 the use of longer wavelengths, and (vii) only the buried defects in a vertical stack by using a difference of the shorter and longer wavelength defect reports.

[0045] Figure 3 is a diagrammatic representation of an example inspection system 300 in accordance with a specific implementation of the present invention. As shown, the system 300 includes a broadband light source (e.g.,
15 illuminator 304) which generates illumination light 305. Examples of light sources include a laser-driven light source, a high-power plasma light source, a transillumination light source (e.g., halogen or Xe lamp), a filtered lamp, LED light sources, etc. The inspection system may include any suitable number and type of additional light sources, besides broadband light sources.

20 [0046] The incident beam from the light source may generally pass through any number and type of lenses which serve to relay (e.g., shape, focus or adjust focus offset, filter/select wavelengths, filter/select polarization states, resize, magnify, reduce distortion, etc.) the beam towards a sample.

[0047] The illuminator 304 may include any suitable optical elements for
25 generating an incident beam having a shorter wavelength range beam and a longer wavelength range beam. For example, the illuminator 304 may include a filter wheel 301 with selectable bandpass filters that are individually selectably inserted (or rotated) into the illumination path to change the wavelength of the illumination beam.

aberration. In an alternative embodiment, the objective lens 332 may be an all reflective objective or refractive or a combination (catadioptric) configuration.

[0052] The resulting output beam reflected or scattered from the sample may then be received by another dichroic beam splitter 337, which may be arranged to insert an autofocus into the objective lens 332 via auto-focus system 335. The autofocus beam may have a wavelength that is separated from the different inspection bands. The wavelength for the autofocus can be varied as long as it is not in the inspection wavebands for any of the shorter or longer wavelength ranges, and it does not necessarily need to be in between the inspection bands. Cost and availability of components can affect where the auto-focus insertion is located.

[0053] In one embodiment, the autofocus wavelength is between the longer and shorter wavelength ranges. Alternatively, the autofocus wavelength may be above both the longer and shorter wavelength range. The autofocus wavelength band may be 40 nm or less to minimize focus plane change due to wafer material response. For instance, the auto-focus system 335 may use an LED light source. The dichroic beam splitter 337 may be arranged to reflect the autofocus waveband and transmit all light above and below that region. The 50-50 beam splitter 328 can also be configured to pass the autofocus light with high efficiency (e.g., by use of a coating). This element may improve the light efficiency of the auto-focus by nearly 4x.

[0054] If the autofocus wavelength is much higher than both the longer and shorter wavelength ranges, the autofocus beam will be affected by different thermally induced focus change than the inspection imaging system. The system may include mechanisms to provide feedback on the focus change due to environment (temperature, pressure), lens heating, etc. By way of examples, the auto-focus system 335 may include feedback mechanisms in the form of temperature and pressure sensors and a calibration wafer installed on the side of the wafer chuck for evaluating the focal plane change. Based on feedback, the auto-focus system 335 may adjust one or more of the lens elements (such as by

moving lenses to form an adjustable air gap) to introduce focus correction. The frequency of the correction can also be determined based on such feedback.

5 **[0055]** The output beam may be directed and shaped by any suitable number and type of collection optics, such as pupil relay (lens group 340) and, mirror 338, a polarizer 307, aperture 309, and optics elements 310 and 312 for zooming and focusing the output beam onto sensor 354. By way of example, the sensor 354 may be in the form of a CCD (charge coupled device) or TDI (time delay integration) detector, photomultiplier tube (PMT), or other sensor.

10 **[0056]** The pupil relay 340 may be designed to form an image of the system pupil (at the objective lens 332) for the purpose of inserting specific apertures (309) in the collection path so as to optimize the inspection sensitivity for each wavelength range. Different aperture settings may be selected so as to achieve different angles of incidence on the sample. A polarizing filter (306 or 307) may be positioned in the illumination or collection path for the purpose of also
15 optimizing the inspection sensitivity.

20 **[0057]** The long wavelength band pass may be between about 230 nm and 950 nm and the short wavelength may be less than about 230 nm. Sub-band spectral filters (not shown) can be used to optimize the inspection sensitivity for either the buried defects in the long wavelength path or for surface defects, such as particles, in the short wavelength path.

25 **[0058]** In another system embodiment, two simultaneous shorter and longer wavelength paths are produced. Such a simultaneous wavelength system may be used to locate defects in a 3D vertical stack structure, as well as accounting for the presence or absence of absorbing type materials. As further described above, incident light having a shorter wavelength range (e.g., a red-visible, ultraviolet and/or a deep ultraviolet range) is used to detect defects on a surface of the 3D stack structure, while incident light having a longer wavelength range (e.g., a blue-visible, infrared, and/or near infrared range) is used to detect defects on both the surface and throughout a depth of the vertical stack. Further spectral
30 selection can be used for locations having SiN or Poly Si.