divided into micro-defect inspection tools and macro-defect inspection tools.

Micro-defect inspection tools aim to detect deficiencies in the smallest manufactured microstructures having dimensions of 0.1 μm and below. An advantage of micro-defect inspection tools is that a geometry or other properties of a microstructure can be directly verified and that deficiencies in these microstructures can be directly shown. A disadvantage of micro-defect inspection tools is the long time needed for inspection and the high amount of generated data which have to be processed if the whole surface of the substrate is to be inspected. If only portions of the surface of the substrate are inspected due to time considerations, there is a risk that certain deficiencies are not detected.

Macro-defect inspection tools aim to achieve a high throughput at the cost of a lower sensitivity to defects and at lower spatial resolution of the generated images. Macro-defect inspection tools have an advantage in that large portions of the substrates or the complete substrates can be inspected within a short time, and they have a disadvantage in that the smallest manufactured microstructures are not directly imaged to detect deficiencies in those microstructures.

It is desirable to extend the applicability of macro-inspection tools and to obtain more detailed inspection information from a semiconductor wafer with a high throughput.

It is further desirable to use information obtained using a macro-defect inspection tool in a manufacturing process of semiconductor wafer.

SUMMARY

Embodiments of the present disclosure seek to provides methods of inspecting a semiconductor wafer which may allow to obtain valuable information about microstructures formed on the semiconductor wafer.

The semiconductor wafer may include a plurality of different regions in which microstructures are arranged according to different arrangement patterns. For example, microstructures can be arranged in a regular repetitive arrangement pattern, such that a repetition period can be identified for the arrangement in one or two directions. There can be different regions having different arrangement patterns having different repetition periods. Moreover, other regions may have arrangements of microstructures which are irregular or random.

According to a first aspect of the present invention, there is provided a method of manufacture of a semiconductor wafer, wherein the semiconductor wafer includes a plurality of regions in which microstructures are arranged according to different arrangement patterns, wherein in at least one selected region the microstructures are arranged according to a regular repetitive arrangement pattern having a smallest repetition period, and wherein the method comprises: imaging a full surface of the wafer onto an array of pixels of a detector, wherein an area of the wafer which is imaged onto one pixel of the detector has an extension of more than 5 times, more than 10 times or more than 50 times the smallest repetition period, and wherein each of the at least one selected regions is imaged onto a selected group of pixels; wherein imaging comprises a first imaging with a first light setting and a second imaging with a second light setting, the first light setting and the second light setting differ with respect to at least one of a polarization and a spectrum of the light used for imaging the wafer onto the camera, and wherein the wafer is maintained in a same position relative to an imaging optics used in the imaging while performing the first imaging and second imaging; collecting detection signals from pixels of the detector for the first imaging and the second imaging; and calculating at least one value for each group of plural groups of selected detection signals, wherein the selected detection signals of each group comprise collected detection signals from pixels which are members of at least one of the selected groups of pixels, and wherein a plurality of detection signals from pixels which are not members of any of the selected groups of pixels are not contained in any of the groups of selected detection signals.

According to a second aspect of the present invention, there is provided a method of manufacture of a semiconductor wafer, in particular in combination with the first aspect, the method comprising: positioning the wafer relative to an imaging optics and a camera such that a full surface of the wafer is imaged onto the camera by the imaging optics; directing illuminating light produced by a light source onto the wafer; providing a first light setting of light used for imaging the wafer onto the camera and recording a first image of the wafer with the camera using illuminating light reflected from the wafer; and providing a second light setting of light used for imaging the wafer onto the camera and recording a second image of the wafer with the camera using illuminating light reflected from the wafer; wherein the first and second light settings differ with respect to at least one of a polarization and a spectrum of the light used for imaging the wafer onto the camera, and wherein a position of the wafer relative to the imaging optics and camera is maintained constant between the recording of the first image and the recording of the second image.

In some embodiments, the disclosure provides an imaging of at least a portion of the semiconductor wafer onto an array of pixels of a detector. The imaging may include optical imaging, using imaging rays of light.

In certain embodiments, the disclosure provides for using light of a broad spectral range for the imaging. The spectral range may comprise visible light, infrared light and ultraviolet light.

In other certain embodiments, the disclosure provides for using light of a narrow spectral range for the imaging. The narrow spectral range may be within visible light, infrared light or ultraviolet light.

In certain embodiments, the imaging is performed using an optical system comprising lenses and/or mirrors.

In some embodiments, the disclosure provides an imaging such that an area of the semiconductor wafer which is imaged onto one pixel of the detector has an extension of more than five times, more than ten times or more than fifty times of a smallest repetition period at which microstructures are arranged in a region. This means that it is not possible to observe or detect a geometry or structure of the microstructures formed in those regions using the detector with the array of pixels. In other words, the microstructures are too small to be directly observed using the imaging. However, a selected region in which the microstructures are arranged according to a same regular

According to further exemplary embodiments herein, the inspecting can be performed according to a method illustrated above and involve calculating, for each recorded image, a value for a group of pixels of the respective image.

According to other exemplary embodiments herein, an image processing is applied to the recorded images to calculate a new image based on the recorded images, wherein at least one value is calculated for one or more groups of pixels of the new calculated image.

With such methods using more than one image of a same wafer recorded at different light settings it is possible to obtain information relating to the wafer which could not be obtained from a single image recorded at a single light setting.

Preferably~~According to exemplary embodiments~~, a position of the wafer relative to the imaging optics and camera is maintained constant between the recording of the first image and the recording of the second image, such that an image processing applied to the plural recorded images is facilitated and that results of image processing can be readily associated with particular locations and regions of the wafer.

According to some embodiments, the light with which the first image is recorded has a first spectral distribution and the light with which the second image is recorded has a second spectral distribution, and wherein the first and second light settings are configured such that a central wavelength of the first spectral distribution differs from a central wavelength of the second spectral distribution by more than 50 nm or more than 100 nm. The central wavelength can be calculated according to one of the methods known in the art. For example, the central wavelength can be calculated by determining a center of gravity of an area below a graph representing the spectral distribution of the light used.

According to some embodiments, a width of each of the first and second spectral distributions is smaller than 100 nm or smaller

settings are configured such that the first polarization direction differs from the second polarization direction by more than 10°, by more thanthat 20° or by more than 40°.. Herein, it is possible that the light is only partially polarized since a perfect linear polarization of 100% is difficult to obtain in practice. Moreover, according to further embodiments, the first polarization differs from the second polarization with respect to a degree of polarization. For example, the first image can be recorded using non-polarized light while the second image is recorded using light having a degree of polarization of, for example 60%.

According to some embodiments, the light setting is changed by changing a filter provided in an illumination beam path of an inspection system. According to other embodiments, the light setting is changed by changing a filter provided in an imaging beam path of an inspection system, and according to still further embodiments, the filter setting is changed by changing both a filter provided in an illumination beam path of an inspection system and a filter provided in an imaging beam path of the inspection system. The changing of the filter may include replacing a first filter having a first transmission characteristics positioned in the beam path with a second filter having a second transmission characteristics. The transmission characteristics may differ with respect to a spectral distribution of intensities and/or with respect to a polarization of the light transmitted trough or reflected from the filter.

According to some other embodiments, the light setting is changed by changing a light source generating the illumination light in an illumination beam path of an inspection system.

In some embodiments, the disclosure provides a method of imaging at least a portion of a substrate onto a detector. According to some embodiments herein, the complete surface of the substrate is imaged onto the detector.

In some embodiments, the disclosure provides a method of inspecting a semiconductor wafer, wherein at least a portion of