- morphology

In the prior art, however, for the most part individual thin transparent or semi-transparent layers or two-layer systems are measured. If multilayer systems are investigated, then there is no structured surface present. Due to the complexity, in the prior art, either multilayer systems or periodic structures are measured. For multilayer systems, smooth surfaces are a prerequisite in the prior art. Further problems in the prior art are often an inadequate accuracy of the simulations from the measurement of complex samples. It is even more difficult if the structures also have even more complex structural forms. Then, adaptation of measurement and simulation is still a problem.

Embodiments of the present invention provide an improved method and an improved device for measuring a multilayered substrate.

All combinations made up of at least two features specified in the description, the claims and/or the figures also fall within the scope of the invention. When value ranges are specified, values lying within the limits mentioned should also be disclosed as limit values and be claimable in any desired combination.

According to a first aspect of the present invention, there is provided a method for measuring a substrate having a plurality of layers, the method including: producing the substrate with the plurality of layers, wherein the dimensions of the plurality of layers are known, measuring the substrate using ellipsometry to obtain measurement results, creating a simulation of the substrate using the measurement results from the measuring of the substrate, comparing the measurement results with simulation results from the simulation of the substrate, optimizing the simulation of the substrate and renewing creation of a simulation of the substrate using the measurement results from the measuring of the substrate, in the event that there is a deviation of the measurement results from the simulation results obtained from the simulation of the substate, or calculating parameters of further substrates, in the event that the measurement results correspond to the simulation results obtained from the simulation of the substate.

Advantageously, the simulation created can be used for the optimization of desired layer thicknesses, structures and materials.

According to a second aspect of the present invention, there is provided a device for measuring a substrate having a plurality of layers, the device including: at least one optical device configured to measure the substrate using ellipsometry to obtain measurement results, means for creating a simulation of the substrate using the measurement results from the at least one optical device, means for comparing the measurement results with simulation results from the simulation of the substrate, means for optimizing the simulation of the substrate and renewing creation of a simulation of the substrate using the measurement results from the at least one optical device, and means for analysing and optimizing further substrates by reconstructing layer and/or structure parameters with the use of the simulation of the surface , on the basis of measurement results from measuring the further substrates using the at least one optical device.

Advantageously, thin transparent or semi-transparent layers or two-layer systems or multilayer systems can be measured, wherein structured surfaces can also

be measured. Thus, complex substrates can be measured with high accuracy.

In particular, it is suggested to offer a simultaneous reconstruction of the layer and structure parameters by means of a combination of measurement and simulation. The information content is increased by adding a plurality of measurement variables and/or a plurality of measuring methods. One such combined measuring method is preferably used with RCWA as a calculation method and enables a characterization of complex samples which contain a plurality of layers and structures by obtaining information about diffraction and phase and topographical information. The newly used methods deliver results with a realistic computing power and in an acceptable short computing time in process monitoring.

Alternative calculation methods for electromagnetic simulations for example are the FDTD (Finite Difference Time Domain) method and the finite element method (FEM).

Preferably, the measuring technology is at least one, preferably exactly one, of the following technologies:

- VUV/UV/VIS/NIR variable angle spectral ellipsometry (VASE) in reflection or transmission mode. The measuring range extends from vacuum ultraviolet (VUV), ultraviolet/visual (UV/VIS), through to in the near infrared (NIR), from 146 nm to 1700 nm.
- IR variable angle spectral ellipsometry (VASE) in reflection or transmission mode. Here, the spectral measuring range extends from 1.7 µm to 30 µm.
- (polarized) reflectometry
- (polarized) scatterometry
- UV/VIS spectroscopy
- THz spectroscopy

These measuring technologies are known in the prior art and are not explained in more detail. Specifically in the IR or mid IR (MIR) range, in addition to reflection or transmission measurements, measurements with attenuated total reflection are also possible in the ATR (attenuated total reflection) mode (ATR spectroscopy).

CLAIMS

1. A method for measuring a substrate (1, 1‘, 1‘‘) having a plurality of layers, the method comprising:

producing (110) the substrate (1, 1‘, 1‘‘) with the plurality of layers (2, 3, 4, 5, 6, 6‘, 6‘‘), wherein the dimensions of the plurality of layers are known,

measuring (120) the substrate (1, 1‘, 1‘‘) using ellipsometry to obtain measurement results,

creating (130) a simulation of the substrate using the measurement results from the measuring of the substrate (1, 1‘, 1‘‘),

comparing (140) the measurement results with simulation results from the simulation of the substrate (1, 1‘, 1‘‘),

optimizing the simulation (130) of the substrate and

renewing creation (130) of a simulation of the substrate using the measurement results from the measuring of the substrate (1, 1‘, 1‘‘), in the event that there is a deviation of the measurement results from the simulation results obtained from the simulation of the substate, or

calculating (150) parameters of further substrates, in the event that the measurement results correspond to the simulation results obtained from the simulation of the substate.

2. The method according to Claim 1, wherein the ellipsometry is at least one of:

VUV/UV/VIS/NIR variable angle spectral ellipsometry (VASE) in reflection or transmission mode, wherein a measuring range extends from vacuum ultraviolet (VUV), ultraviolet/visual (UV/VIS), through to near infrared (NIR), from 146 nm to 1700 nm, and

IR variable angle spectral ellipsometry (VASE) in reflection or transmission mode, wherein a spectral measuring range extends from 1.7 µm to 30 µm.

3. The method according to one of the preceding claims, wherein one or more of an angle of incidence, a wavelength, or a polarization state is/are varied and measured when measuring the substrate.

4. The method according to one of the preceding claims, wherein mathematical algorithms are used for the creation of the simulation of the substrate.

5. The method according to claim 1, wherein the substrate having the plurality of layers includes at least one structure.

6. The method according to claim 5, wherein the at least one structure is a surface structure.

7. The method according to claim 6, wherein the surface structure is on an uppermost layer of the plurality of layers.

8. The method according to claim 4, wherein mathematical algorithms include rigorous coupled-wave analysis (RWCA).

9. A device for measuring a substrate (1, 1‘, 1‘‘) having a plurality of layers, the device comprising:

at least one optical device (120) configured to measure the substrate (1, 1‘, 1‘‘) using ellipsometry to obtain measurement results,

means for creating (130) a simulation of the substrate using the measurement results from the at least one optical device (120),

means for comparing (140) the measurement results with simulation results from the simulation of the substrate (1, 1‘, 1‘‘),

means for optimizing the simulation (130) of the substrate (1, 1‘, 1‘‘) and renewing creation (130) of a simulation of the substrate using the measurement results from the at least one optical device (120), and

means for analysing and optimizing further substrates (1, 1‘, 1‘‘) by reconstructing layer and/or structure parameters with the use of the simulation of the surface, on the basis of measurement results from measuring the further substrates (1, 1‘, 1‘‘) using the at least one optical device (120).

10. The device according to claim 9, wherein the device further comprises:

at least one data processing unit and at least one data processing system for processing and saving data obtained from the at least one optical device (120).

11. The device according to claim 9 or 10, wherein the at least one optical device (120) has:

at least one radiation source, at least one monochromator, at least one polarizer, at least one compensator, at least one substrate holder, at least one analyser, and at least one detector, wherein the at least one polarizer enables the setting of selected elliptical polarization states.

12. The device according to claim 9, 10 or 11, wherein the device includes a plurality of optical devices configured to measure the substrate, all of the optical devices are arranged in the device.

13. The device according to claim 9, wherein the substrate having the plurality of layers includes at least one structure.

14. The device according to claim 11, wherein the at least one radiation source includes a laser or wide-band radiation source.

15. The device according to claim 11, wherein the at least one polarizer enables the setting of selected linear or circular elliptical polarization states.