Claims

1. An inspection system comprising: an illumination source configured to generate an illumination beam; one or more illumination optics to direct the illumination beam to a sample; a first collection channel including at least a first detector to collect light from the sample in response to the illumination beam within a first range of solid angles, the first collection channel further including a first polarizer to control a polarization of the light from the sample incident on the first detector; a second collection channel including at least a second detector to collect light from the sample in response to the illumination beam from the illumination source within a second range of solid angles different than the first range of solid angles, the second collection channel further including a second polarizer to control a polarization of the light from the sample incident on the second detector; and a controller including one or more processors configured to execute program instructions causing the one or more processors to: receive two or more scattering signals, the two or more scattering signals including one or more scattering signals from the first collection channel based on one or more orientations of the first polarizer, the two or more scattering signals further including one or more scattering signals from the second collection channel based on one or more orientations of the second polarizer; and determine depths of one or more defects in the sample based on comparing the two or more scattering signals to training data, the training data including scattering signals from a training sample having known defects at known depths.

2. The inspection system of claim 1, wherein determining depths of one or more defects in the sample based on comparing the two or more scattering signals to the training data comprises: sorting the one or more defects in the sample into depth bins based on comparing the two or more scattering signals to the training data.

3. The inspection system of claim 2, wherein the depth bins comprise: two or more depth bins.

4. The inspection system of claim 2, wherein the depth bins comprise: a surface depth bin and two or more sub-surface depth bins.

5. The inspection system of claim 2, wherein the depth bins comprise: a surface depth bin and four or more sub-surface depth bins.

6. The inspection system of claim 1, wherein determining depths of one or more defects in the sample based on comparing the two or more scattering signals to training data comprises: generating one or more rules for determining defect depth based on the training data; and applying the one or more rules to the two or more scattering signals to determine the depths of the one or more defects in the sample.

7. The inspection system of claim 1, wherein determining depths of one or more defects in the sample based on comparing the two or more scattering signals to training data comprises: training a machine learning algorithm with the training data,

wherein the machine learning algorithm includes at least one of a supervised learning, semi-supervised learning or deep learning technique; providing the two or more scattering signals as inputs to the machine learning algorithm; and determining the depths of one or more defects in the sample based on an output of the machine learning algorithm.

8. The inspection system of claim 1, wherein the one or more defects comprise: one or more particles embedded in the sample.

9. The inspection system of claim 1, wherein the sample comprises: a semiconductor wafer.

10. The inspection system of claim 1, wherein the sample comprises: a film deposited on a substrate.

11. The inspection system of claim 1, wherein the sample comprises: a multilayer film stack deposited on a substrate.

12. The inspection system of claim 1, wherein the one or more illumination optics include an objective lens, wherein the first range of solid angles includes a first subset of solid angles within a numerical aperture of the objective lens, wherein the at least a second set of collection angles includes a second subset of solid angles within the numerical aperture of the objective lens.

13. The inspection system of claim 12, wherein the first and second collection channels are azimuthally symmetric.

14. The inspection system of claim 12, wherein the first range of solid angles comprises: a cone of solid angles ranging from a direction normal to the sample to a first solid angle, wherein the second range of solid angles comprises: an annular distribution of solid angles ranging from the first solid angle to a second solid angle larger than the first solid angle.

15. The inspection system of claim 14, wherein the one or more scattering signals from the second collection channel comprise: two scattering signals based on two orthogonal orientations of the second polarizer.

16. The inspection system of claim 15, wherein the one or more scattering signals from the first collection channel comprise: one scattering signal based on a single orientation of the first polarizer.

17. The inspection system of claim 14, wherein the one or more scattering signals from the first collection channel comprise: two scattering signals based on two orthogonal orientations of the first polarizer.

18. The inspection system of claim 1, wherein the one or more illumination optics direct the illumination beam from the illumination source to the sample at an oblique incidence angle.

19. The inspection system of claim 18, wherein at least one of the two or more scattering signals comprises: a dark-field scattering signal.

20. The inspection system of claim 1, wherein the one or more illumination optics direct the illumination beam from the illumination source to the sample at a normal incidence angle.

21. The inspection system of claim 20, wherein at least one of the two or more scattering signals comprises: a bright-field scattering signal.

22. The inspection system of claim 1, wherein the illumination source is configured to generate illumination including at least one of visible wavelengths, ultraviolet wavelengths, deep ultraviolet wavelengths, vacuum ultraviolet wavelengths, or extreme ultraviolet wavelengths.

23. The inspection system of claim 1, wherein the illumination source is configured to generate illumination including two wavelength ranges, wherein at least one wavelength range includes visible wavelengths.

24. The inspection system of claim 1, wherein the one or more illumination optics direct the illumination beam to the sample at a fixed focus height.

25. An inspection system comprising: a controller including one or more processors configured to execute program instructions causing the one or more processors to: receive one or more scattering signals from a first collection channel, the first collection channel including a first detector to collect light from a sample within a first range of solid angles in response to an illumination beam, the first collection channel further including a first adjustable polarizer to control a polarization of the light from the sample incident on the first detector, wherein the one or more scattering signals from the first collection channel are based on one or more polarization states of the first adjustable polarizer; receive one or more scattering signals from a second collection channel, the second collection channel including a second detector to collect light from the sample in response to the illumination beam within a second range of solid angles different than the first range of solid angles, the second collection channel further including a second adjustable polarizer to control a polarization of the light from the sample incident on the second detector, wherein the one or more scattering signals from the second collection channel are based on one or more polarization states of the second adjustable polarizer; and determine depths of one or more defects in the sample based on comparing the one or more scattering

signals from the first and second collection channels to training data, the training data including two or more training scattering signals as a function of defect depth from at least one training sample having known defects at known depths, the two or more training scattering signals including at least one training signal from the first collection channel and at least one training signal from the second collection channel.

26. The inspection system of claim 25, wherein determining depths of one or more defects in the sample based on comparing the two or more scattering signals to the training data comprises: sorting the one or more defects in the sample into depth bins based on comparing the two or more scattering signals to the training data.

27. The inspection system of claim 26, wherein the depth bins comprise: two or more depth bins.

28. The inspection system of claim 26, wherein the depth bins comprise: a surface depth bin and two or more sub-surface depth bins.

29. The inspection system of claim 26, wherein the depth bins comprise: a surface depth bin and four or more sub-surface depth bins.

30. The inspection system of claim 25, wherein determining depths of one or more defects in the sample based on comparing the two or more scattering signals to training data comprises: generating one or more rules for determining defect depth based on the training data; and applying the one or more rules to the two or more scattering signals to determine the depths of the one or more defects in the sample.

31. The inspection system of claim 25, wherein determining depths of one or more defects in the sample based on comparing the two or more scattering signals to training data comprises: training a machine learning algorithm with the training data, wherein the machine learning algorithm includes at least one of a supervised learning, semi-supervised learning or deep learning technique; providing the two or more scattering signals as inputs to the machine learning algorithm; and determining the depths of one or more defects in the sample based on an output of the machine learning algorithm.

32. The inspection system of claim 25, wherein the one or more defects comprise: one or more particles embedded in the sample.

33. The inspection system of claim 25, wherein the one or more illumination optics include an objective lens, wherein the first range of solid angles includes a first subset of solid angles within a numerical aperture of the objective lens, wherein the at least a second set of collection angles includes a second subset of solid angles

within the numerical aperture of the objective lens.

34. The inspection system of claim 33, wherein the first and second collection channels are azimuthally symmetric.

35. The inspection system of claim 34, wherein the one or more scattering signals from the second collection channel comprise: two scattering signals based on two orthogonal orientations of the second polarizer, wherein the one or more scattering signals from the first collection channel comprise: one scattering signal based on a single orientation of the first polarizer.

36. The inspection system of claim 25, wherein the one or more illumination optics direct the illumination beam from the illumination source to the sample at an oblique incidence angle.

37. The inspection system of claim 36, wherein at least one of the two or more scattering signals comprises: a dark-field scattering signal.

38. The inspection system of claim 25, wherein the one or more illumination optics direct the illumination beam from the illumination source to the sample at a normal incidence angle.

39. The inspection system of claim 38, wherein at least one of the two or more scattering signals comprises: a bright-field scattering signal.

40. An inspection method comprising: receiving one or more scattering signals from a first collection channel, the first collection channel including a first detector to collect light from a sample within a first range of solid angles in response to an illumination beam, the first collection channel further including a first adjustable polarizer to control a polarization of the light from the sample incident on the first detector, wherein the one or more scattering signals from the first collection channel are based on one or more polarization states of the first adjustable polarizer; receiving one or more scattering signals from a second collection channel, the second collection channel including a second detector to collect light from the sample in response to the illumination beam within a second range of solid angles different than the first range of solid angles, the second collection channel further including a second adjustable polarizer to control a polarization of the light from the sample incident on the second detector, wherein the one or more scattering signals from the second collection channel are based on one or more polarization states of the second adjustable polarizer; and determining depths of one or more defects in the sample based on comparing the one or more scattering signals from the first and second collection channels to training data, the training data including two or more training scattering signals as a function of defect depth from at least one training sample having known defects at known depths, the two or more training scattering

signals including at least one training signal from the first collection channel and at least one training signal from the second collection channel.

41. The inspection method of claim 40, wherein determining depths of one or more defects in the sample based on comparing the two or more scattering signals to the training data comprises: generating one or more rules for determining defect depth based on the training data; and applying the one or more rules to the two or more scattering signals to determine the depths of the one or more defects in the sample.

42. The inspection method of claim 40, wherein determining depths of one or more defects in the sample based on comparing the two or more scattering signals to training data comprises: training a machine learning algorithm with the training data, wherein the machine learning algorithm includes at least one of a supervised learning, semi-supervised learning or deep learning technique; providing the two or more scattering signals as inputs to the machine learning algorithm; and determining the depths of one or more defects in the sample based on an output of the machine learning algorithm.

43. The inspection system of claim 1, wherein each of the two or more scattering signals corresponds to a different combination of measurement parameters, wherein the measurement parameters include at least two of a wavelength of the illumination beam, a polarization of the illumination beam, a selected collection channel, or a polarization of light detected in the selected collection channel, wherein the selected collection channel includes one of the first collection channel or the second collection channel.

44. The inspection system of claim 25, wherein each of the two or more scattering signals corresponds to a different combination of measurement parameters, wherein the measurement parameters include at least two of a wavelength of the illumination beam, a polarization of the illumination beam, a selected collection channel, or a polarization of light detected in the selected collection channel, wherein the selected collection channel includes one of the first collection channel or the second collection channel.