CLAIMS

1. A metrology system comprising:

an imaging sub-system configured to image a metrology target buried in a sample on a detector based on light collected from an objective lens, wherein the sample is formed from a first substrate and a second substrate bonded to the first substrate at an interface, the sample further including the metrology target located at the interface, wherein the metrology target includes a first target structure on the first substrate and a second target structure on the second substrate;

an illumination sub-system comprising:

an illumination source;

one or more illumination optics configured to illuminate the metrology target with illumination from the illumination source through the objective lens;

an illumination field stop located at a field plane conjugate to the metrology target, wherein the illumination field stop includes a field-stop aperture, wherein at least one of a size or shape of the field-stop aperture is selected to provide that a projected size of the field-stop aperture on a measurement plane corresponding to the metrology target matches a field of view of the detector at the measurement plane; and

an illumination pupil located at a pupil plane, wherein the illumination pupil includes a central obscuration in a center of the pupil plane, wherein at least one of a size or shape of the central obscuration is selected to provide oblique illumination of the metrology target with angles greater than a cutoff angle, wherein the cutoff angle is selected, based on at least one of a size of the field of view of the detector at the measurement plane, a thickness of the first substrate, or a thickness of the second substrate, to prevent reflections of the illumination from the illumination source off of at least one of a top surface or a bottom surface of the sample from reaching the detector; and

a controller communicatively coupled to the detector, wherein the controller includes one or more processors configured to execute program instructions causing the one or more processors to:

receive one or more images of the metrology target from the sample; and

generate one or more metrology measurements of the sample based on the one or more images.

2. The metrology system of claim 1, further comprising:

a sample positioning sub-system including a translation stage communicatively coupled to the controller, wherein the one or more processors are further configured to execute program instructions causing the one or more processors to:

receive sample positioning data from the sample positioning sub-system; and

direct the translation stage, through one or more control signals, to align the metrology target to the measurement plane prior to receiving the one or more images of the metrology target.

3. The metrology system of claim 2, wherein the sample positioning sub-system further comprises:

at least one of an interferometer or a parallax positioning sub-system.

4. The metrology system of claim 2, wherein the sample positioning sub-system further comprises:

a beamsplitter configured to split sample-positioning illumination from the illumination source into a measurement arm and a reference arm, wherein the measurement arm includes the objective lens configured to direct the sample positioning illumination to the sample, wherein the reference arm includes a reference objective lens configured to direct the sample-positioning illumination to a reference sample; and

a photodiode configured to receive light from the beamsplitter associated with interference of light in the measurement arm with light from the reference arm, wherein the photodiode generates the sample positioning data.

5. The metrology system of claim 4, wherein the sample-positioning illumination includes the illumination from the illumination source.

6. The metrology system of claim 4, wherein the sample-positioning illumination includes the illumination from an additional illumination source.

7. The metrology system of claim 4, wherein the sample positioning data includes an interference signal generated as the translation stage translates the sample along an optical axis of the objective lens.

8. The metrology system of claim 7, wherein a location of the metrology target is determinable based on a position of a peak of the interference signal.

9. The metrology system of claim 4, wherein the reference sample is formed from one or more reference substrates.

10. The metrology system of claim 9, wherein the reference sample further comprises:

a reflective layer on at least one of a back surface or an interface between two reference substrates.

11. The metrology system of claim 1, wherein at least one of the one or more metrology measurements comprises:

an overlay measurement between the first substrate and the second substrate.

12. The metrology system of claim 1, wherein the cutoff angle is further selected to prevent reflections from outer surfaces of the sample from reaching the detector.

13. The metrology system of claim 1, wherein the field-stop aperture is circular with a radius of r_f, wherein the central obscuration of the illumination pupil is sized to block illumination from the illumination source having a numerical aperture smaller than $n \cdot \sin\left(\operatorname{atan}\left(\frac{r_f}{W}\right)\right) \cdot (1-k)$, wherein n is a refractive index of the first substrate, r_f is the

projected size of the field-stop aperture on the measurement plane, *W* is the thickness of the second substrate, and k is a tolerance factor.

14. The metrology system of claim 1, wherein providing that the projected size of the field-stop aperture on the measurement plane corresponding to the metrology target matches the field of view of the detector at the measurement plane prevents reflections of illumination from the illumination source from reflecting off of a top surface of the sample and being captured by the detector.

15. The metrology system of claim 1, wherein providing that the projected size of the field-stop aperture on the measurement plane corresponding to the metrology target matches the field of view of the detector at the measurement plane prevents reflections of illumination from the illumination source from reflecting off of the bottom surface of the sample and propagating through the field of view of the detector at the measurement plane.

16. The metrology system of claim 1, wherein the detector has a rectangular sensor with a known aspect ratio, wherein the shape of the field-stop aperture is selected to be rectangular with the known aspect ratio.

17. The metrology system of claim 16, wherein a size of the field-stop aperture along a first direction, $d_{X,f}$, is selected to be $d_{X,f} = a \cdot (Mag_{ill}/Mag_{coll}) \cdot l_p(1 + k\ \ )$, where a is a number of square pixels of size l_p in the detector along the first direction, Mag_{ill} is a magnification of the illumination sub-system, Mag_{coll} is a magnification of a collection pathway, and k is a tolerance factor, wherein the size of the field-stop aperture along a second direction, $d_{Y,f}$, is selected to be $d_{Y,f} = b \cdot (Mag_{ill}/Mag_{coll}) \cdot l_p(1 + k\ \ )$, where b is a number of square pixels of size l_p in the detector along the second direction.

18. The metrology system of claim 17, wherein k is in a range from 0 to 0.05.

19. The metrology system of claim 1, wherein the detector has a rectangular sensor with a known aspect ratio, wherein the shape of the field-stop aperture is selected to be circular, wherein the projected size of the field-stop aperture on the measurement plane encapsulates the field of view of the detector at the measurement plane.

20. The metrology system of claim 19, wherein the detector has a size of $(n \times m)$ square pixels of size l_p, wherein the field-stop aperture has a radius of $r = \sqrt{n^2 + m^2} \cdot (Mag_{ill}/Mag_{coll}) \cdot \left(l_p/2\right) \cdot (1 + k)$, where Mag_{ill} is a magnification of the illumination sub-system, Mag_{coll} is a magnification of a collection pathway, and k is a tolerance factor.

21. The metrology system of claim 20, wherein k is in a range from 0 to 0.3.

22. The metrology system of claim 1, wherein at least one of the first substrate or the second substrate has a thickness of at least one of 775 µm, 750 µm, 600 µm, 300 µm, or 100 µm.

23. The metrology system of claim 1, wherein at least one of the first substrate or the second substrate comprises:

a semiconductor wafer.

24. A metrology system comprising:

an imaging sub-system configured to image a metrology target buried in a sample on a detector based on light collected from an objective lens, wherein the sample is formed from a first substrate and a second substrate bonded to the first substrate at an interface, the sample further including the metrology target located at the interface, wherein the metrology target includes a first target structure on the first substrate and a second target structure on the second substrate;

a sample positioning sub-system including a translation stage to position the metrology target at a measurement plane of the detector;

an illumination sub-system comprising:

an illumination source;

one or more illumination optics configured to illuminate the metrology target with illumination from the illumination source through the objective lens; and

a pupil stop located at a pupil plane, wherein the pupil stop includes a central obscuration in a center of the pupil plane, wherein at least one of a size or shape of the central obscuration is selected to provide oblique illumination of the metrology target with angles greater than a cutoff angle, wherein the cutoff angle is selected, based on at least one of a size of a field of view of the detector at the measurement plane, a thickness of the first substrate, or a thickness of the second substrate, to prevent reflections of the illumination from the illumination source off of at least one of a top surface or a bottom surface of the sample from reaching the detector; and

a controller communicatively coupled to the detector, wherein the controller includes one or more processors configured to execute program instructions causing the one or more processors to:

receive one or more images of the metrology target from the sample; and

generate one or more metrology measurements of the sample based on the one or more images.

25. The metrology system of claim 24, wherein the sample positioning sub-system further comprises:

a beamsplitter configured to split sample-positioning illumination from the illumination source into a measurement arm and a reference arm, wherein the measurement arm includes the objective lens configured to direct the sample-positioning illumination to the sample, wherein the reference arm includes a reference objective lens configured to direct the sample-positioning illumination to a reference sample; and

a photodiode configured to receive light from the beamsplitter associated with interference of light in the measurement arm with light from the reference arm, wherein the photodiode generates sample positioning data.

26. The metrology system of claim 25, wherein the sample-positioning illumination includes the illumination from the illumination source.

27. The metrology system of claim 25, wherein the sample-positioning illumination includes the illumination from an additional illumination source.

28. The metrology system of claim 25, wherein the reference sample is formed from one or more reference substrates.

29. The metrology system of claim 28, wherein the reference sample further comprises:

a reflective layer on at least one of a back surface or an interface between two reference substrates.

30. The metrology system of claim 24, wherein the cutoff angle is further selected to prevent reflections from outer surfaces of the sample from reaching the detector.

31. The metrology system of claim 24, wherein at least one of the one or more metrology measurements comprises:

an overlay measurement between the first substrate and the second substrate.

32. The metrology system of claim 24, wherein at least one of the first substrate or the second substrate has a thickness of at least one of 775 µm, 750 µm, 600 µm, 300 µm, or 100 µm.

33. The metrology system of claim 24, wherein at least one of the first substrate or the second substrate comprises:

a semiconductor wafer.

34. A metrology system comprising:

an imaging sub-system configured to image a metrology target buried in a sample on a detector based on light collected from an objective lens, wherein the sample is formed from a first substrate and a second substrate bonded to the first substrate at an interface, the sample further including the metrology target located at the interface, wherein the metrology target includes a first target structure on the first substrate and a second target structure on the second substrate;

a sample positioning sub-system including a translation stage to position the metrology target at a measurement plane of the detector;

an illumination sub-system comprising:

an illumination source;

one or more illumination optics configured to illuminate the metrology target with illumination from the illumination source through the objective lens; and

an illumination field stop located at a field plane conjugate to the metrology target, wherein the illumination field stop includes a field-stop aperture, wherein at least one of a size or shape of the field-stop aperture is selected to provide that a projected size of the field-stop aperture on the measurement plane corresponding to the metrology target matches a field of view of the detector at the measurement plane; and

a controller communicatively coupled to the detector, wherein the controller includes one or more processors configured to execute program instructions causing the one or more processors to:

receive one or more images of the metrology target from the sample; and

generate one or more metrology measurements of the sample based on the one or more images.

35. The metrology system of claim 34, wherein the sample positioning sub-system further comprises:

a beamsplitter configured to split sample-positioning illumination from the illumination source into a measurement arm and a reference arm, wherein the measurement arm includes the objective lens configured to direct the sample-positioning

illumination to the sample, wherein the reference arm includes a reference objective lens configured to direct the sample-positioning illumination to a reference sample; and

a photodiode configured to receive light from the beamsplitter associated with interference of light in the measurement arm with light from the reference arm, wherein the photodiode generates sample positioning data.

36. The metrology system of claim 35, wherein the sample-positioning illumination includes the illumination from the illumination source.

37. The metrology system of claim 35, wherein the sample-positioning illumination includes the illumination from an additional illumination source.

38. The metrology system of claim 35, wherein the reference sample is formed from one or more reference substrates.

39. The metrology system of claim 38, wherein the reference sample further comprises:

a reflective layer on at least one of a back surface or an interface between two reference substrates.

40. The metrology system of claim 34, wherein at least one of the one or more metrology measurements comprises:

an overlay measurement between the first substrate and the second substrate.

41. The metrology system of claim 34, wherein at least one of the first substrate or the second substrate has a thickness of at least one of 775 µm, 750 µm, 600 µm, 300 µm, or 100 µm.

42. The metrology system of claim 34, wherein at least one of the first substrate or the second substrate comprises:

a semiconductor wafer.

43. A metrology method comprising:

illuminating a metrology target on a sample with an illumination sub-system, wherein the sample is formed from a first substrate and a second substrate bonded to the first substrate at an interface, the sample further including a metrology target located at the interface, wherein the metrology target includes a first target structure on the first substrate and a second target structure on the second substrate, wherein the illumination sub-system comprises:

an illumination source;

one or more illumination optics configured to illuminate the metrology target with illumination from the illumination source;

an illumination field stop located at a field plane conjugate to the metrology target, wherein the illumination field stop includes a field-stop aperture, wherein at least one of a size or shape of the field-stop aperture is selected to provide that a projected size of the field-stop aperture on a measurement plane corresponding to the metrology target matches a field of view of an imaging detector at the measurement plane; and

an illumination pupil located at a pupil plane, wherein the illumination pupil includes a central obscuration in a center of the pupil plane, wherein at least one of a size or shape of the central obscuration is selected to provide oblique illumination of the metrology target with angles greater than a cutoff angle, wherein the cutoff angle is selected based on at least one of a size of the field of view of the detector at the measurement plane, a thickness of the first substrate, or a thickness of the second substrate, to prevent reflections of the illumination from the illumination source off of at least one of a top surface or a bottom surface of the sample from reaching the detector;

generating one or more images of the metrology target on the imaging detector; and

generating one or more metrology measurements of the sample based on the one or more images.

44. The metrology method of claim 43, wherein generating one or more metrology measurements of the sample based on the one or more images comprises:

generating an overlay measurement between the first substrate and the second substrate based on the one or more images.

45. The metrology method of claim 44, wherein illuminating the metrology target on the sample with the illumination sub-system comprises: illuminating the metrology target on the sample with illumination from the illumination sub-system including one or more wavelengths in an infrared spectral range.

46. The metrology system of claim 11, wherein the illumination from the illumination source comprises: illumination including one or more wavelengths in an infrared spectral range.

47. The metrology system of claim 46, wherein the illumination from the illumination source comprises: illumination including one or more wavelengths in an infrared spectral range.

48. The metrology system of claim 47, wherein the illumination from the illumination source comprises: illumination including one or more wavelengths in an infrared spectral range.