CLAIMS

What is claimed is:

1. A system for estimating a position of an image relative to a substrate, the system comprising:

projection optics configured to project the image;

a metrology plate that is mechanically decoupled from the projection optics;

first and second sensors coupled to the metrology plate, the first and second sensors being configured to sense positions of the metrology plate relative to the substrate and the image, respectively; and

a processor operably coupled to the first and second sensors, the processor configured to estimate a position of the image relative to the substrate based on the positions of the metrology plate relative to the substrate and the image.

2. A system as in claim 1, further including plural sets of projection optics.

3. A system as in claim 2, wherein the plural sets of projection optics are configured to project plural images.

4. A system as in claim 1, wherein the metrology plate is disposed in an optical path between the projection optics and the substrate.

5. A system as in claim 1, wherein the image is an image of a production pattern disposed on a reticle.

6. A system as in claim 1, wherein the image is generated using a scanning beam or a modulated light source.

7. A system as in claim 1, further including:

a stage configured to support the substrate and mechanically decoupled from the metrology plate.

8. A system as in claim 7, further including:

a third sensor configured to sense a position of the metrology plate relative to the stage.

9. A system as in claim 1, wherein position errors induced by the metrology plate are smaller than position errors monitored by the first and second sensors.

10. A system as in claim 1, wherein the metrology plate is coupled to a bridge of the system, a base of the system, or a structure external from the system.

11. A system as in claim 1, wherein the first sensor is configured to determine the position of the metrology plate relative to the substrate by detecting a reflection from the substrate.

12. A system as in claim 1, wherein the second sensor is configured to determine the position of the metrology plate relative to the image by detecting light transmitted through the projection optics.

13. A system as in claim 12, further including:

reference marks in an object plane associated with the image, the second sensor being configured to detect images of the reference marks, wherein detected images of the reference marks indicate the position of the metrology plate relative to the image.

14. A system as in claim 13, further including:

additional reference marks in a plane equivalent to a plane of the image, and wherein the second sensor is configured to detect a fringe pattern produced by projection of the reference marks in the object plane onto the

additional reference marks, the fringe pattern indicating the position of the metrology plate relative to the image.

15. A system as in claim 13, wherein the reference marks and the object are disposed on a reticle.

16. A system as in claim 1, wherein the processor is further configured to estimate, based on data from the first and second sensors, at least one parameter associated with the image, including, but not limited to: transverse position, rotational position, focus, magnification, astigmatism, anamorphicity, aberration, and distortion.

17. A system as in claim 1, wherein the processor is further configured to estimate field curvature of the image based on measurements of astigmatism of the image.

18. A system as in claim 1, further including:

a controller operably coupled to the processor and configured to adjust the position of at least one of the image and the substrate with a compensation element based on input from the processor.

19. A system as in claim 18, wherein the controller is configured to adjust at least one parameter associated with the image based on input from the processor, and wherein the parameters include, but are not limited to: transverse position, rotational position, focus, magnification, astigmatism, anamorphicity, aberration, distortion, and field curvature.

20. A method of estimating a position of an image relative to a substrate, the method comprising:

projecting an image via projection optics;

sensing a position of a metrology plate relative to the image, the metrology plate being mechanically decoupled from the projection optics;

sensing a position of the metrology plate relative to the substrate; and

estimating a position of the image relative to the substrate based on the positions of the metrology plate relative to the substrate and the image.

21. A method as in claim 20, further including projecting plural images with plural sets of projection optics.

22. A method as in claim 20, wherein the metrology plate is disposed in an optical path between the image and the substrate.

23. A method as in claim 20, wherein the image is an image of a production pattern disposed on a reticle.

24. A method as in claim 20, further including:

generating the image with a scanning beam or a modulated light source.

25. A method as in claim 20, further including:

supporting the substrate with a stage that is mechanically decoupled from the metrology plate.

26. A method as in claim 25, further including:

sensing a position of the metrology plate relative to the stage.

27. A method as in claim 20, wherein position errors induced by the metrology plate are smaller than position errors monitored by the first and second sensors.

28. A method as in claim 20, wherein the metrology plate is coupled to a bridge, a base, or an external structure.

29. A method as in claim 20, wherein sensing the position of the metrology plate relative to the substrate includes detecting a reflection from the substrate.

30. A method as in claim 20, wherein sensing the position of the metrology plate relative to the image includes detecting light transmitted through the projection optics.

31. A method as in claim 30, wherein sensing the position of the metrology plate relative to the image includes detecting images of reference marks in an object plane associated with the image, and wherein detected images of the reference marks indicate the position of the metrology plate relative to the image.

32. A method as in claim 31, wherein sensing the position of the metrology plate relative to the image includes detecting a fringe pattern produced by projection of the reference marks in the object plane onto additional reference marks, the fringe pattern indicating the position of the metrology plate relative to the image.

33. A method as in claim 20, further including:

estimating, based on the position of the metrology plate relative to the image and the substrate, at least one parameter associated with the image, including, but not limited to: transverse position, rotational position, focus, magnification, astigmatism, anamorphicity, aberration, and distortion.

34. A method as in claim 20, further including:

estimating field curvature of the image based on measurements of astigmatism of the image.

35. A method as in claim 20, further including:

adjusting the position of at least one of the image and the substrate with a compensation element based on the position estimated of the image relative to the substrate.

36. A method as in claim 35, wherein the adjusting the position of at least one of the image and the substrate includes changing at least one parameter associated with the image, including, but not limited to: transverse position, rotational position, focus, magnification, astigmatism, anamorphicity, aberration, distortion, and field curvature.

37. A method of making a semiconductor or thin-film transistor device, the method comprising:

projecting an image associated with the semiconductor or thin-film transistor device via projection optics;

sensing a position of a metrology plate relative to the image, the metrology plate being mechanically decoupled from the projection optics;

sensing a position of the metrology plate relative to a substrate;

estimating a position of the image relative to the substrate based on the positions of the metrology plate relative to the image and the substrate;

if necessary, adjusting the position of the image relative to the surface; and

illuminating the substrate with the image associated with the semiconductor or thin-film transistor device.

38. A system for estimating a position of an image relative to a substrate, the projection system comprising:

means for projecting the image;

a metrology plate that is mechanically decoupled from the projection optics;

means for sensing the positions of the metrology plate relative to the substrate and the image, respectively; and

means for estimating the position of the image relative to the substrate based on the positions of the metrology plate relative to the substrate and the image.

39. An apparatus for estimating field curvature of an image, the apparatus comprising:

an aerial image sensor configured to detect sagittal and tangential foci of the image and to provide information about the sagittal and tangential foci; and

a processor operably coupled to the aerial image sensor and configured to estimate field curvature based on the information about the sagittal and tangential foci.

40. An apparatus as in claim 39, wherein the aerial image sensor is disposed on a metrology plate.

41. An apparatus as in claim 39, further including:

a height sensor configured to detect a distance from the aerial image sensor to a surface.

42. An apparatus as in claim 39, further including;

a servo configured to adjust optics in response to actuation from the processor based on the information about the sagittal and tangential foci.

43. An apparatus as in claim 39, wherein the processor is further configured to estimate a shape of the image.

44. An apparatus as in claim 39, wherein the processor is further configured to estimate a best-fit plane that corresponds to an optimum fit between the image and a substrate.

45. A method for estimating field curvature of an image, the method comprising:

detecting sagittal and tangential foci of the image; and

estimating field curvature of the image based on information about the sagittal and tangential foci.

46. A method as in claim 45, wherein detecting the sagittal and tangential foci and estimating field curvature occur during exposure of a substrate positioned at or near an image plane associated with the image.

47. A method as in claim 45, further including:

mapping an image plane associated with the image to provide a baseline field curvature before detecting the sagittal and tangential foci.

48. A method as in claim 45, further including:

detecting a distance from the aerial image sensor to a substrate.

49. A method as in claim 45, further including:

adjusting at least one of a lens and a stage based on information about the sagittal and tangential foci.

50. A method as in claim 45, further including:

estimating a shape of the image based on information about the sagittal and tangential foci.

51. A method as in claim 45, further including:

estimating a best-fit plane that corresponds to an optimum fit between the image and a substrate.

52. An apparatus for estimating field curvature of an image, the apparatus comprising:

means for detecting sagittal and tangential foci of the image and for providing information about the sagittal and tangential foci; and

means for estimating field curvature based on the information about the sagittal and tangential foci.

53. A method of making a semiconductor or thin-film transistor device, the method comprising:

detecting sagittal and tangential foci of an image associated with the semiconductor or thin-film transistor device;

estimating field curvature of the image based on information about the sagittal and tangential foci;

if necessary, adjusting the image based on estimated field curvature; and

illuminating a substrate with the image associated with the semiconductor or thin-film transistor device.

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a metrology plate that is mechanically decoupled from the projection optics;

first and second sensors coupled to the metrology plate, the first and second sensors being configured to sense positions of the metrology plate relative to the substrate and the image, respectively; and

a processor operably coupled to the first and second sensors, the processor configured to estimate a position of the image relative to the substrate based on the positions of the metrology plate relative to the substrate and the image.

2. A system as in claim 1, further including plural sets of projection optics.

3. A system as in claim 2, wherein the plural sets of projection optics are configured to project plural images.

4. A system as in claim 1, wherein the metrology plate is disposed in an optical path between the projection optics and the substrate.

5. A system as in claim 1, wherein the image is an image of a production pattern disposed on a reticle.

6. A system as in claim 1, wherein the image is generated using a scanning beam or a modulated light source.

7. A system as in claim 1, further including:

a stage configured to support the substrate and mechanically decoupled from the metrology plate.

8. A system as in claim 7, further including:

a third sensor configured to sense a position of the metrology plate relative to the stage.

9. A system as in claim 1, wherein position errors induced by the metrology plate are smaller than position errors monitored by the first and second sensors.

10. A system as in claim 1, wherein the metrology plate is coupled to a bridge of the system, a base of the system, or a structure external from the system.

11. A system as in claim 1, wherein the first sensor is configured to determine the position of the metrology plate relative to the substrate by detecting a reflection from the substrate.

12. A system as in claim 1, wherein the second sensor is configured to determine the position of the metrology plate relative to the image by detecting light transmitted through the projection optics.

13. A system as in claim 12, further including:

reference marks in an object plane associated with the image, the second sensor being configured to detect images of the reference marks, wherein detected images of the reference marks indicate the position of the metrology plate relative to the image.

14. A system as in claim 13, further including:

additional reference marks in a plane equivalent to a plane of the image, and wherein the second sensor is configured to detect a fringe pattern produced

by projection of the reference marks in the object plane onto the additional reference marks, the fringe pattern indicating the position of the metrology plate relative to the image.

15. A system as in claim 13, wherein the reference marks and the object are disposed on a reticle.

16. A system as in claim 1, wherein the processor is further configured to estimate, based on data from the first and second sensors, at least one parameter associated with the image, including, but not limited to: transverse position, rotational position, focus, magnification, astigmatism, anamorphicity, aberration, and distortion.

17. A system as in claim 1, wherein the processor is further configured to estimate field curvature of the image based on measurements of astigmatism of the image.

18. A system as in claim 1, further including:

a controller operably coupled to the processor and configured to adjust the position of at least one of the image and the substrate with a compensation element based on input from the processor.

19. A system as in claim 18, wherein the controller is configured to adjust at least one parameter associated with the image based on input from the processor, and wherein the parameters include, but are not limited to: transverse position, rotational position, focus, magnification, astigmatism, anamorphicity, aberration, distortion, and field curvature.

20. A method of estimating a position of an image relative to a substrate, the method comprising:

projecting an image via projection optics;

sensing a position of a metrology plate relative to the image, the metrology plate being mechanically decoupled from the projection optics;

sensing a position of the metrology plate relative to the substrate; and

estimating a position of the image relative to the substrate based on the positions of the metrology plate relative to the substrate and the image.

21. A method as in claim 20, further including projecting plural images with plural sets of projection optics.

22. A method as in claim 20, wherein the metrology plate is disposed in an optical path between the image and the substrate.

23. A method as in claim 20, wherein the image is an image of a production pattern disposed on a reticle.

24. A method as in claim 20, further including:

generating the image with a scanning beam or a modulated light source.

25. A method as in claim 20, further including:

supporting the substrate with a stage that is mechanically decoupled from the metrology plate.

26. A method as in claim 25, further including:

sensing a position of the metrology plate relative to the stage.

27. A method as in claim 20, wherein position errors induced by the metrology plate are smaller than position errors monitored by the first and second sensors.

28. A method as in claim 20, wherein the metrology plate is coupled to a bridge, a base, or an external structure.

29. A method as in claim 20, wherein sensing the position of the metrology plate relative to the substrate includes detecting a reflection from the substrate.

30. A method as in claim 20, wherein sensing the position of the metrology plate relative to the image includes detecting light transmitted through the projection optics.

31. A method as in claim 30, wherein sensing the position of the metrology plate relative to the image includes detecting images of reference marks in an object plane associated with the image, and wherein detected images of the reference marks indicate the position of the metrology plate relative to the image.

32. A method as in claim 31, wherein sensing the position of the metrology plate relative to the image includes detecting a fringe pattern produced by projection of the reference marks in the object plane onto additional reference marks, the fringe pattern indicating the position of the metrology plate relative to the image.

33. A method as in claim 20, further including:

estimating, based on the position of the metrology plate relative to the image and the substrate, at least one parameter associated with the image, including, but not limited to: transverse position, rotational position, focus, magnification, astigmatism, anamorphicity, aberration, and distortion.

34. A method as in claim 20, further including:

estimating field curvature of the image based on measurements of astigmatism of the image.

35. A method as in claim 20, further including:

adjusting the position of at least one of the image and the substrate with a compensation element based on the position estimated of the image relative to the substrate.

36. A method as in claim 35, wherein the adjusting the position of at least one of the image and the substrate includes changing at least one parameter associated with the image, including, but not limited to: transverse position, rotational position, focus, magnification, astigmatism, anamorphicity, aberration, distortion, and field curvature.

37. A method of making a semiconductor or thin-film transistor device, the method comprising:

projecting an image associated with the semiconductor or thin-film transistor device via projection optics;

sensing a position of a metrology plate relative to the image, the metrology plate being mechanically decoupled from the projection optics;

sensing a position of the metrology plate relative to a substrate;

estimating a position of the image relative to the substrate based on the positions of the metrology plate relative to the image and the substrate;

if necessary, adjusting the position of the image relative to the surface; and

illuminating the substrate with the image associated with the semiconductor or thin-film transistor device.

38. A system for estimating a position of an image relative to a substrate, the projection system comprising:

means for projecting the image;

a metrology plate that is mechanically decoupled from the projection optics;

means for sensing the positions of the metrology plate relative to the substrate and the image, respectively; and

means for estimating the position of the image relative to the substrate based on the positions of the metrology plate relative to the substrate and the image.