**CLAIMS**

1. A metrology system comprising an x-ray scatterometer comprising:

an illumination source that provides a first amount of illumination radiation to one or more subsequent instances of a complex semiconductor structure after a critical process step of a semiconductor fabrication process flow;

a detector that detects a first amount of radiation from the one or more subsequent instances of the complex semiconductor structure in response to the first amount of illumination radiation and generates a first amount of measurement data in response to the first amount of detected radiation;

a computing system configured to:

estimate a value of a structural parameter of interest of the one or more subsequent instances of the complex semiconductor structure based on the first amount of measurement data and a second amount of measurement data indicative of a measurement of one or more prior instances of the complex semiconductor structure by the x-ray scatterometer before the critical process step of the fabrication process flow;

combine the first amount of measurement data with the second amount of measurement data to generate an amount of combined measurement data, wherein the estimating of the value of the structural parameter of interest is based on the amount of combined measurement data; and

generate a geometrically parameterized measurement response model including one or more geometric features affected by the critical process step and not including one or more geometric features not affected by the critical process step, wherein the estimating of the structural parameter of interest involves minimizing an

objective function that includes a difference between the combined measurement data and simulated data resulting from the geometrically parameterized measurement model.

2. The metrology system of Claim 1,

wherein the illumination source is further configured to provide a second amount of illumination radiation to one or more subsequent instances of the complex semiconductor structure having known values of the structural parameter of interest after the critical process step of the semiconductor fabrication process flow,

wherein the detector is further configured to detect a second amount of radiation from the one or more subsequent instances of the complex semiconductor structure in response to the second amount of illumination radiation and generate Design Of Experiments (DOE) measurement data in response to the second amount of detected radiation, and

wherein the computing system is further configured to:

combine the DOE measurement data with a second amount of DOE measurement data to generate an amount of combined DOE measurement data, the second amount of DOE measurement data indicative of a measurement of one or more prior instances of the complex semiconductor structure having known values of the structural parameter of interest by the x-ray scatterometer before the critical process step of the fabrication process flow, and

train a signal response metrology model based on the amount of combined DOE measurement data and the known values of the structural parameter of interest.

3. The metrology system of Claim 2, wherein the amount of combined measurement data is provided as input to the trained signal response metrology model, and wherein an output of the trained signal response metrology model corresponding to the

amount of combined measurement data provided as input is the value of the structural parameter of interest.

4. The metrology system of Claim 1, the computing system further configured to:

normalize the first and second amounts of measurement data based on values of one or more system parameters associated with measurement of the first and second amounts of measurement data, respectively.

5. The metrology system of Claim 4, wherein the combining of the first amount of measurement data with the second amount of measurement data to generate the amount of combined measurement data involves determining a difference between the first amount of measurement data and the second amount of measurement data on a pixel by pixel basis.

6. The metrology system of Claim 1, wherein the second amount of measurement data is generated by a measurement of the one or more prior instances of the complex semiconductor structure by the x-ray scatterometer before the critical process step of the fabrication process flow.

7. The metrology system of Claim 1, wherein the second amount of measurement data is generated by deleting a region of interest from the first amount of measurement data and replacing the deleted region of interest with signals generated by a patch matching algorithm.

8. The metrology system of Claim 1, wherein the illumination source provides the first amount of illumination radiation at a plurality of different orientations with respect to the complex semiconductor structure.

9. The metrology system of Claim 1, wherein the critical process step is any of a lithographic process step, a deposition process step, and an etch process step.

10. The metrology system of Claim 1, wherein the structural parameter of interest is any of a film thickness after a deposition process step and a material recess depth after an etch process step.

11. A method comprising:

providing a first amount of illumination radiation to one or more subsequent instances of a complex semiconductor structure after a critical process step of a semiconductor fabrication process flow;

detecting a first amount of radiation from the one or more subsequent instances of the complex semiconductor structure in response to the first amount of illumination radiation;

generating a first amount of measurement data in response to the first amount of detected radiation;

estimating a value of a structural parameter of interest of the one or more subsequent instances of the complex semiconductor structure based on the first amount of measurement data and a second amount of measurement data indicative of a measurement of one or more prior instances of the complex semiconductor structure by the x-ray scatterometer before the critical process step of the fabrication process flow;

combining the first amount of measurement data with the second amount of measurement data to generate an amount of combined measurement data, wherein the estimating of the value of the structural parameter of interest is based on the amount of combined measurement data; and

generating a geometrically parameterized measurement response model including one or more geometric features

affected by the critical process step and not including one or more geometric features not affected by the critical process step, wherein the estimating of the structural parameter of interest involves minimizing an objective function that includes a difference between the combined measurement data and simulated data resulting from the geometrically parameterized measurement model.

12. The method of Claim 11, wherein the combining of the first amount of measurement data with the second amount of measurement data to generate the amount of combined measurement data involves determining a difference between the first amount of measurement data and the second amount of measurement data on a pixel by pixel basis.

13. The method of Claim 11, further comprising:

normalizing the first and second amounts of measurement data based on values of one or more system parameters associated with measurement of the first and second amounts of measurement data, respectively.

14. A metrology system comprising:

an x-ray scatterometer comprising:

an illumination source that provides a first amount of illumination radiation to one or more subsequent instances of a complex semiconductor structure after a critical process step of a semiconductor fabrication process flow; and

a detector that detects a first amount of radiation from the one or more subsequent instances of the complex semiconductor structure in response to the first amount of illumination radiation and generates a first amount of measurement data in response to the first amount of detected radiation; and

a non-transitory, computer-readable medium, comprising code for causing a computing system to:

estimate a value of a structural parameter of interest of the one or more subsequent instances of the complex semiconductor structure based on the first amount of measurement data and a second amount of measurement data indicative of a measurement of one or more prior instances of the complex semiconductor structure by the x-ray scatterometer before the critical process step of the fabrication process flow;

combine the first amount of measurement data with the second amount of measurement data to generate an amount of combined measurement data, wherein the estimating of the value of the structural parameter of interest is based on the amount of combined measurement data; and

generate a geometrically parameterized measurement response model including one or more geometric features affected by the critical process step and not including one or more geometric features not affected by the critical process step, wherein the estimating of the structural parameter of interest involves minimizing an objective function that includes a difference between the combined measurement data and simulated data resulting from the geometrically parameterized measurement model.