CLAIMS

What is claimed is:

1. A method comprising, by an X-ray inspection system:

capturing one or more X-ray images for one or more samples of interest that have been processed by a first tool, wherein the X-ray inspection system is inline with the first tool, and wherein the X-ray inspection system has an inspection speed of 300 mm^2 per minute or greater;

determining, in real-time, metrology information related to the one or more samples of interest based on the one or more X-ray images, wherein the metrology information indicates that a sample parameter associated with the one or more samples of interest is outside of a pre-determined threshold range associated with the sample parameter; and

providing, responsive to the real-time determination that the sample parameter is outside of the pre-determined threshold range, instructions or data to the first tool or one or more second tools to adjust one or more process parameters associated with the respective first tool and the one or more second tools based on the metrology information related to the one or more samples of interest, wherein the adjusted process parameters reduces a processing error probability, of the respective first tool and the one or more second tools for processing subsequent samples, related to the sample parameter being outside of the pre-determined threshold range.

2. The method of Claim 1, wherein the X-ray inspection system has an inspection speed of 1000 mm^2 per minute or greater.

3. The method of Claim 1, wherein the X-ray inspection system has an inspection speed of 3000 mm^2 per minute or greater.

4. The method of Claim 1, wherein the one or more X-ray images are captured with a field of view of 12 million pixels or greater.

5. The method of Claim 1, wherein the metrology information determined based on the one or more X-ray images comprises measurement information associated with one or more structural features measured with a spatial resolution of 5 microns or less.

6. The method of Claim 1, wherein the X-ray inspection system inspects the one or more samples of interest at a first speed faster than or equal to a second speed for the first tool or the one or more second tools to process the one or more samples of interest.

7. The method of Claim 1, further comprising:

determining that the one or more samples of interest have one or more defects based on the metrology information, wherein the instructions or data provided to the first tool are generated based on the one or more defects of the one or more samples of interest.

8. The method of Claim 1, wherein the one or more second tools are associated with one or more subsequent processes for processing or re-processing the one or more samples of interest and the subsequent samples.

9. The method of Claim 8, further comprising:

determining that the one or more subsequent processes for processing the one or more samples of interest are redundant based on the metrology information related to the one or more samples of interest; and

providing instructions or data to the one or more second tools to exclude the one or more subsequent processes from a manufacturing process associated with the one or more samples of interest.

10. The method of Claim 1, wherein the one or more samples of interest are inspected in situ to the first tool for processing the one or more samples of interest, and wherein the X-ray inspection system is integrated with the first tool.

11. The method of Claim 1, wherein the metrology information determined based on the one or more X-ray images comprises one or more of:

shape information of solder balls;

dimensional information of solder balls;

defect information;

alignment information of an integrated circuit die to an interposer;

warpage information;

a uniformity metric associated with a solder contact external size;

a solder joint diameter;

a darkness metric of a contact pad area;

a uniformity metric for a darkness coverage of a contact pad area;
a continuous signal variation over a location of a contact pad;
a bright signal ring connecting a ball and solder;
a small dark and uniform coverage over the contact pad area;
parameter deviations from a product specification;
a tilt angle of a die with respect to an interposer; or
a tilt angle of a die with respect to a substrate.

12. The method of Claim 11, wherein the metrology information is generated by a computer vision algorithm or a machine-learning model trained by historical data.

13. The method of Claim 1, wherein the first tool is an assembling tool for assembling the one or more samples of interest and the subsequent samples.

14. The method of Claim 13, wherein the assembling tool is a bonding tool comprising a placement tool and a mass reflow device.

15. The method of Claim 13, wherein the assembling tool is a thermo-compression bonding tool or a hybrid bonding tool.

16. The method of Claim 1, wherein the one or more process parameters of the first tool being adjusted comprise one or more of:
a chemical-mechanical polishing parameter;
an alignment of an integrated circuit die;
an alignment of an interposer;
a bonding force;
a bonding temperature;
a rate of heating;
a rate of cooling; or
a time duration after being assembled and before being heated.

17. The method of Claim 1, wherein the one or more samples of interest are re-processed by the first tool to make one or more adjustments to the one or more samples of interest, and wherein the one or more

adjustments to the one or more samples of interest are made based on the metrology information of the one or more samples of interest.

18. The method of Claim 1, wherein the one or more samples inspected by the X-ray inspection system are of a subset of a sample population processed by the first tool.

19. One or more computer-readable non-transitory storage media embodying software that is operable when executed to:

capture one or more X-ray images with an X-ray inspection system for one or more samples of interest that have been processed by a first tool, wherein the X-ray inspection system is inline with the first tool, and wherein the X-ray inspection system has an inspection speed of 300 mm^2 per minute or greater;

determine, in real-time, metrology information related to the one or more samples of interest based on the one or more X-ray images, wherein the metrology information indicates that a sample parameter associated with the one or more samples of interest is outside of a pre-determined threshold range associated with the sample parameter; and

provide, responsive to the real-time determination that the sample parameter is outside of the pre-determined threshold range, instructions or data to the first tool or one or more second tools to adjust one or more process parameters associated with the respective first tool or the one or more second tools based on the metrology information related to the one or more samples of interest, wherein the adjusted process parameters reduces a processing error probability, of the respective first tool or the one or more second tools for processing subsequent samples, related to the sample parameter being outside of the pre-determined threshold range.

20. A system comprising: one or more processors; and one or more computer-readable non-transitory storage media coupled to one or more of the processors and comprising instructions operable when executed by one or more of the processors to cause the system to:

capture one or more X-ray images with an x-ray inspection system for one or more samples of interest that have been processed by a first tool, wherein the X-ray inspection system is inline with the first tool, and wherein the X-ray inspection system has an inspection speed of 300 mm^2 per minute or greater;

determine, in real-time, metrology information related to the one or more samples of interest based on the one or more X-ray images, wherein the metrology information indicates that a sample parameter associated with the one or more samples of interest is outside of a pre-determined threshold range associated with the sample parameter; and

provide, responsive to the real-time determination that the sample parameter is outside of the pre-determined threshold range, instructions or data to the first tool or one or more second tools to adjust one or more process parameters associated with the respective first tool or the one or more second tools based on the metrology information related to the one or more samples of interest, wherein the adjusted process parameters reduces a processing error probability, of the respective first tool or the one or more second tools for processing subsequent samples, related to the sample parameter being outside of the pre-determined threshold range.