CLAIMS

1. A chemical mechanical polishing apparatus comprising:

a platen having a top surface to hold a polishing pad having a polishing surface;

a carrier head to hold a substrate against the polishing surface of the polishing pad during a polishing process;

a temperature monitoring system including a non-contact thermal imaging camera positioned above the platen to have a field of view of a portion of the polishing surface of the polishing pad on the platen; and

a controller configured to

set a rotating speed to a specified rotating speed from a polishing recipe and a carrier head chamber pressure to a specified carrier head chamber pressure from the polishing recipe for the polishing process,

receive a thermal image from the temperature monitoring system during the polishing process,

use the thermal image as the only input for a machine learning model trained by training examples to determine a diagnosis for a cause of a process excursion,

receive from the machine learning model the diagnosis, wherein the cause of the process excursion is an actual platen rotating speed departing from the specified rotating speed in the polishing recipe or an actual carrier head chamber pressure departing from the specified rotating speed in the polishing recipe, and

in response to receiving the diagnosis for the cause of the process excursion, adjusting the polishing process.

2. The apparatus of claim 1, wherein the machine learning model is trained by the training examples to determine an indication for a presence of a process excursion.

3. The apparatus of claim 1, wherein the machine learning model is trained by the training examples to determine an indication for a substrate state.

4. The apparatus of claim 3, wherein the machine learning model is trained by the training examples to determine a state selected from one or more of a group consisting of an underpolished state, an overpolished state, and a normal state.

5. The apparatus of claim 1, wherein the machine learning model comprises an artificial neural network.

6. The apparatus of claim 5, wherein the artificial neural network comprises an input layer having a plurality of input nodes to receive intensity values from the thermal image, an output layer having an output node to output a value indicative of indication, and one or more hidden layers between the input layer and the output layer.

7. The apparatus of claim 1, wherein the controller is configured to dimensionally reduce the thermal image and to input the dimensionally reduced thermal image to the machine learning model.

8. A computer program product comprising a non-transitory machine readable storage medium comprising instructions to cause one or more computers to:

set a rotating speed to a specified rotating speed from a polishing recipe and a carrier head chamber pressure to a specified carrier head chamber pressure from the polishing recipe for a polishing process;

receive a thermal image from a temperature monitoring system during the polishing process;

use the thermal image as the only input for a machine learning model trained by training examples to determine a diagnosis for a cause of a process excursion;

receive from the machine learning model the diagnosis, wherein the cause of the process excursion is an actual platen rotating speed departing from the specified rotating speed in the polishing recipe or an actual carrier head chamber pressure departing from the specified rotating speed in the polishing recipe; and

in response to receiving the diagnosis for the cause of the process excursion, adjusting the polishing process.

9. The computer program product of claim 8, wherein the machine learning model is trained by the training examples to determine an indication for a presence of a process excursion.

10. The computer program product of claim 8, wherein the machine learning model is trained by the training examples to determine an indication for a substrate state.

11. The computer program product of claim 10, wherein the machine learning model is trained by the training examples to determine a state selected from one or more of a group consisting of an underpolished state, an overpolished state, and a normal state.

12. The computer program product of claim 8, wherein the machine learning model comprises an artificial neural network.

13. The computer program product of claim 12, wherein the artificial neural network comprises an input layer having a plurality of input nodes to receive intensity values from the thermal image, an output layer having an output node to output a value indicative of indication, and one or more hidden layers between the input layer and the output layer.

14. The computer program product of claim 8, comprising instructions to dimensionally reduce the thermal image and to input the dimensionally reduced thermal image to the machine learning model.

15. A method of operating a polishing apparatus, comprising:

setting a rotating speed to a specified rotating speed from a polishing recipe and a carrier head chamber pressure to a specified carrier head chamber pressure from the polishing recipe;

polishing a substrate with a polishing pad having a polishing surface according to the polishing recipe;

obtaining a thermal image of a portion of the polishing surface of the polishing pad during polishing;

using the thermal image as the only input for a machine learning model trained by training examples to determine a diagnosis for a cause of a process excursion;

receiving from the machine learning model the diagnosis, wherein the cause of the process excursion is an actual platen rotating speed departing from the specified rotating speed in the polishing recipe or an actual carrier head chamber pressure departing from the specified rotating speed in the polishing recipe; and

in response to receiving the diagnosis for the cause of the process excursion, adjusting the polishing recipe.

16. The method of claim 15, wherein the machine learning model is trained by the training examples to determine an indication for a presence of a process excursion.

17. The method of claim 15, wherein the machine learning model is trained by the training examples to determine an indication for a substrate state.

18. The method of claim 15, wherein the machine learning model comprises an artificial neural network.

19. The method of claim 18, wherein the artificial neural network comprises an input layer having a plurality of input nodes to receive intensity values from the thermal image, an output layer having an output node to output a value indicative of indication, and one or more hidden layers between the input layer and the output layer.