BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The Figures described below depict various aspects of the systems and methods disclosed. Each Figure depicts an embodiment of a particular aspect of the disclosed systems and methods, and that each of the Figures is intended to accord with a possible embodiment . Further, wherever possible, the following description refers to the reference numerals included in the following Figures, in which features depicted in multiple Figures are designated with consistent reference numerals.

[0010] Figures 1A and 1B illustrate schematic representations of three crucibles without and with homogeneous cullet distribution

[0011] Figures 2A and 2B illustrate two views of silicon melt rings in crucibles.

[0012] Figure 3A illustrates an example view of a crucible in use.

[0013] Figure 3B illustrates an example labeling scheme for the crucible in use shown in Figure 3A.

[0014] Figures 4A and 4B illustrate example views of a crucible in use before and after the image has been segmented using the labeling scheme shown in Figure 3B.

[0015] Figures 5A-5D illustrate example stages of crystal growth.

[0016] Figures 6A-6D illustrate further example stages of crystal growth.

[0017] Figure 7 illustrates an example process of analyzing a Continuous Czochralski method.

[0018] Figure 8 illustrates an example system for performing the process shown in Figure 7.

one or models executed and used the pictures as inputs. Figure 2A is related to a picture 200 that was recognized as not optimal conditions and showing a “warning” message 205. Figure 2B is related to a picture 210 that that was recognized as having good cullet distribution without a liquid zone and showing a “pass” message 215. The goal is to prevent the picture 200 in Figure 2A because the portion of solid crystal growth could have incorporated micro-bubble of argon due the polysilicon discharge in the liquid zone.

[0042] Figures 2A and 2B represent two extreme opposite cases. Figure 2A shows a cullet island with closer a clear silicon liquid melt. Figure 2B shows a very compact cullet structure. In many cases, the real situation of cullet distribution could be much complicated than the two cases mentioned above. For example, there could be a lot of small islands of cullet with around liquid silicon zone, or there could be a compact cullet layer with small liquid zone above. A quantitative approach is necessary to calculate the percentage of liquid zone in the picture captured by the camera and processed by the AI models.

[0043] Figure 3A illustrates an example view of a crucible 100 (shown in Figure 1) in use. Figure 3B illustrates an example labeling scheme for the crucible 100 in use shown in Figure 3A.

[0044] The system uses semantic segmentation for a deep learning algorithm that associates a label or category to each pixel of an image. The segmentation is the process in which the image is divided into distinct regions which have common characteristics. The results of the segmentation process are an image with the same dimensions as the initial picture composed of solid-colored regions. The first step is the labeling process in which the goal was to obtain an equivalent image with the mask of each pixel marked according to the relevant class.

[0045] For this segmentation four different classes were chosen with four distinct colors: 1) Background (black); 2) Silicon melt liquid (blue); 3) Cullet (grey); and 4) Crucible (yellow). These colors were chosen for training and user

CLAIMS:

1. A computer device comprising at least one processor in communication with at least one memory device, wherein the at least one processor programmed to:

receive at least one image of a silicon melt of a crystal in a crucible;

execute a model trained to segment the at least one image into different classes;

analyze segmentation to determine a quality of the crystal; and

approve or reject the crystal based upon the analysis.

2. The computer device of Claim 1, wherein the silicon melt is associated with a Continuous Czochralski process.

3. The computer device of Claim 2, wherein the crucible is a triple crucible.

4. The computer device of Claim 1, wherein the model is trained to segment the at least one image pixel by pixel.

5. The computer device of Claim 4, wherein the model generates an output of a segmented image.

6. The computer device of Claim 5, wherein the at least one processor is further programmed to mask the segmented image to determine a percentage of area associated with one or more classifications.

7. The computer device of Claim 4, wherein the model is trained to segment the at least one image into a plurality of segments including, but not limited to, background, silicon melt liquid, cullet, and crucible.

8. The computer device of Claim 1, wherein the at least one processor is programmed to reject the crystal if an area of silicon melt liquid exceeds one fourth of a total surface area in the crucible.

9. The computer device of Claim 1, wherein the model is a semantic segmentation network, and wherein the at least one processor is further programmed to train the model with a plurality of pixel-labeled images for the model to classify pixels of images into pixel categories.

10. The computer device of Claim 9, wherein the at least one processor is further programmed to retrain the model with a subsequent plurality of pixel-labeled images.

11. The computer device of Claim 1, wherein the at least one processor is further programmed to approve or reject the crystal based upon a number of micro-voids predicted to occur in the crystal based upon the analysis.

12. The computer device of Claim 1, wherein the at least one image is received from a camera positioned perpendicular to an external silicon melt annulus.

13. A computer-implemented method performed by a computer system including at least one processor in communication with a chatbot and at least one memory device, the method comprising:

receiving at least one image of a silicon melt of a crystal in a crucible;

executing a model trained to segment the at least one image into different classes;

analyzing segmentation to determine a quality of the crystal; and

approving or rejecting the crystal based upon the analysis.

14. The computer-implemented method of Claim 13, wherein the silicon melt is associated with a Continuous Czochralski process.

15. The computer-implemented method of Claim 14, wherein the crucible is a triple crucible.

16. The computer-implemented method of Claim 13, wherein the model is trained to segment the at least one image pixel by pixel.

17. The computer-implemented method of Claim 16, wherein the model generates an output of a segmented image.

18. The computer-implemented method of Claim 17 further comprising masking the segmented image to determine a percentage of area associated with one or more classifications.

19. The computer-implemented method of Claim 16, wherein the model is trained to segment the at least one image into a plurality of segments including, but not limited to, background, silicon melt liquid, cullet, and crucible.

20. The computer-implemented method of Claim 13 further comprising rejecting the crystal if an area of silicon melt liquid exceeds one fourth of a total surface area in the crucible.

21. The computer-implemented method of Claim 13, wherein the model is a semantic segmentation network, and wherein the method further comprises training the model with a plurality of pixel-labeled images for the model to classify pixels of images into pixel categories.

22. The computer-implemented method of Claim 21 further comprising retraining the model with a subsequent plurality of pixel-labeled images.

23. The computer-implemented method of Claim 13 further comprising approving or rejecting the crystal based upon a number of micro-voids predicted to occur in the crystal based upon the analysis.

24. The computer-implemented method of Claim 13, wherein the at least one image is received from a camera positioned perpendicular to an external silicon melt annulus.