

Wafer warpage classification adapted to pragmatic equipment operation— Motoi Okada

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Abstract

We achieved a high precision wafer warpage detection inside a process chamber using Convolutional Neural Networks (CNN). Furthermore we developed a portable training system that can learn CNN models without expertise to adapt to chamber status variation, and also developed an inference system to execute wafer warpage detection in real time on an equipment controller.

1. Introduction

After a wafer is carried into a chamber, wafers get warped massively due to thermal nonuniformity at surface and inside and outside. The wafer warpage results to process nonuniformity and at some equipment it leads to wafer moving and followed serious incident. So, it is necessary to detect wafer warpage inside chamber at high precision before starting process.

The wafer warpage detection models need to be able to adapt to chamber status change with degradation of parts and depositions for a long equipment lifecycle. But we could not bring out the training data from customer fab. So, we need to update models at on-site.

In this work, our contributions are three points below.

- Achieved a high-precision wafer warpage detection using images inside chambers and applying CNN.
- Developed a system to train CNN models that could run at inside of customer fab and use without expertise.
- Developed a system to execute CNN inference on equipment controller in real time.

2. Experimental Result and Our System

We used images taken from a camera equipped to our chamber, and clipped it to 620 x 140 pixels around wafers (Fig. 1). We use 500 to 1500 images for each class (warpage/ flat), depends on dataset.

Networks including convolutional layers and full connection layers are trained using the training set and Adam optimizer as an image classification problem.

We executed training 10 times for each dataset and applied the trained model to the corresponding test dataset. Fig.2 shows a box plot of accuracies for several test datasets. It shows that the models could detect warpage at high-precision for each datasets. Fig 3 shows images that some models mispredicted and these images are in transition of warpage or may be labeled incorrectly.

As we mentioned in section 1, the equipment status changes and the background of images are also changes, so our CNN models should be updated inside customer's fab. To deal with this problem, we developed a CNN training system. Our system is stand-alone (not use cloud resources) and could train models from scratch or update a trained model.

To be operated by field engineer, the system has a very simple training configuration only to choose a dataset and a model template in minimum (Fig.4).

Also we developed a library to execute the trained model on an equipment controller and realized high-precision wafer warpage detection in real time.

3. Conclusion

We achieved a high precision wafer warpage detection using CNN. Furthermore we developed a training system that can learn CNN models without expertise, and inference system to execute wafer warpage detection in real time on equipment controller.

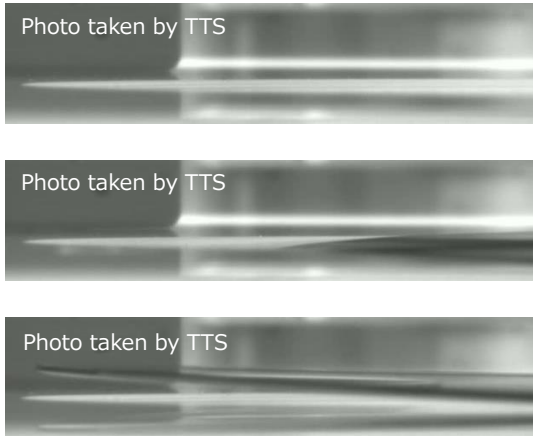


Fig. 1: Example images of left side of wafer. Top: no warpage (flat). Middle: warpage at center (right side of ROI). Bottom: warpage at left.

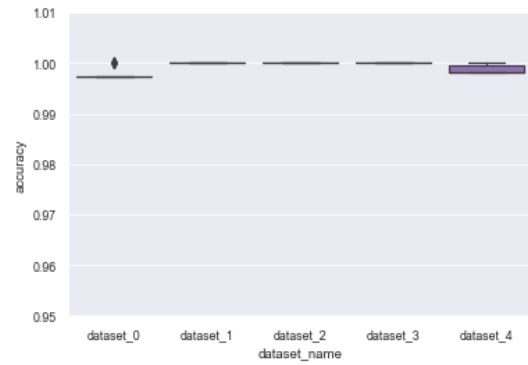


Fig. 2: 10 models are trained for each dataset 0 to 4, and execute inference with the corresponding test dataset.

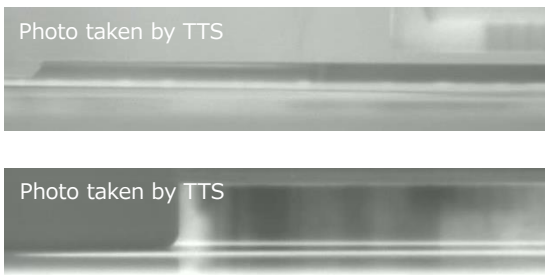


Fig. 3: The images that are mispredicted by some models. These images are labeled as no warpage (flat) but predicted as warpage. In both images, there is a little warpage in right side of image. Both images are in transition from flat to warpage or vice versa, and also very difficult to annotate for an expert engineer.

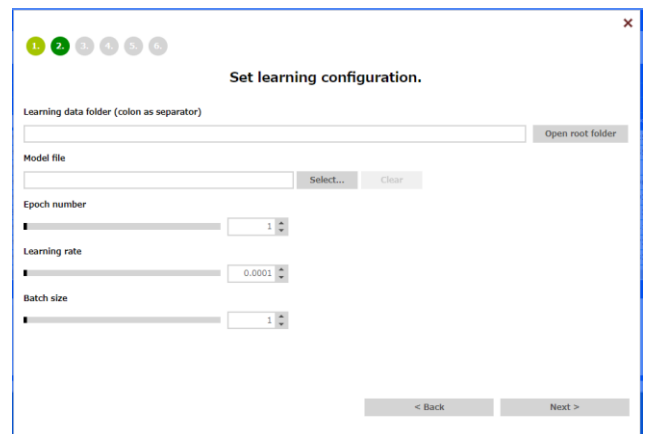


Fig. 4: Simple configuration window of our learning system.