In-situ warpage measurement of 300mm wafer with speckle-free digital image correlation method

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Background

Wafer Warpage: During the manufacturing process, wafer undergoes many microfabrication process steps, which would make wafer experience thermal cycles.

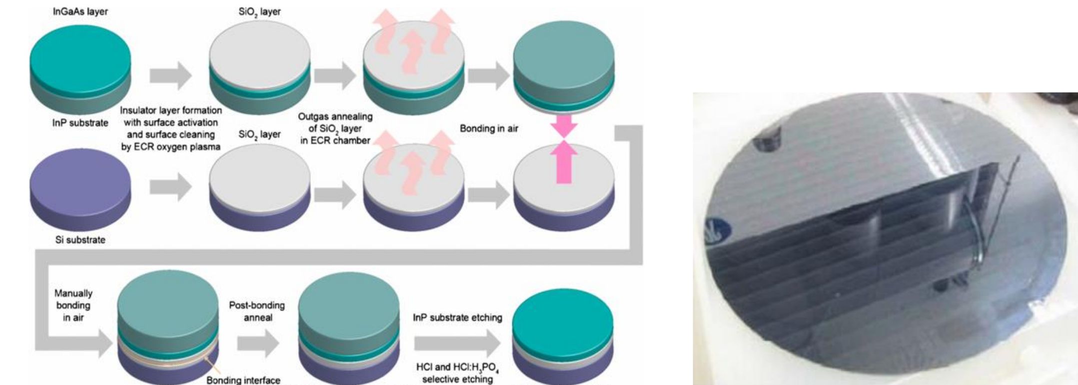

Figure 1. III-V-OI on Si wafer fabrication process flow chart

Digital Image Correlation:

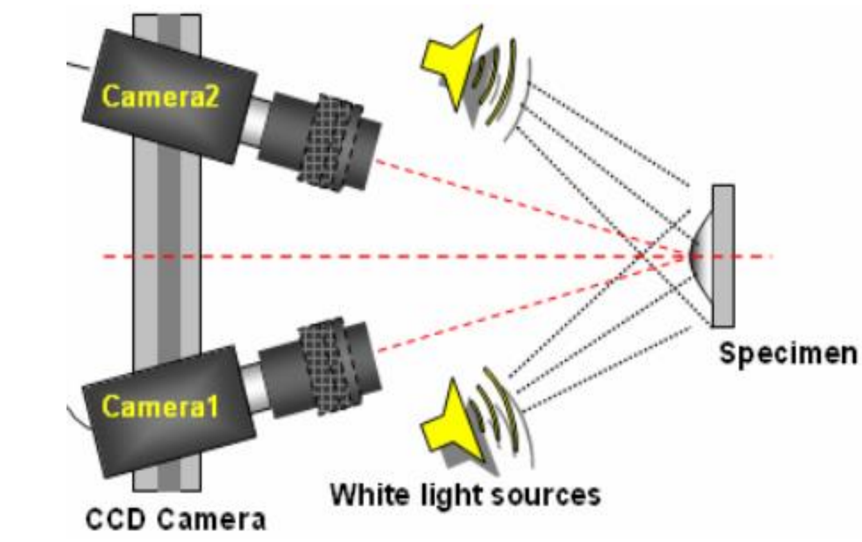

Figure 2. Schematic of 3D DIC

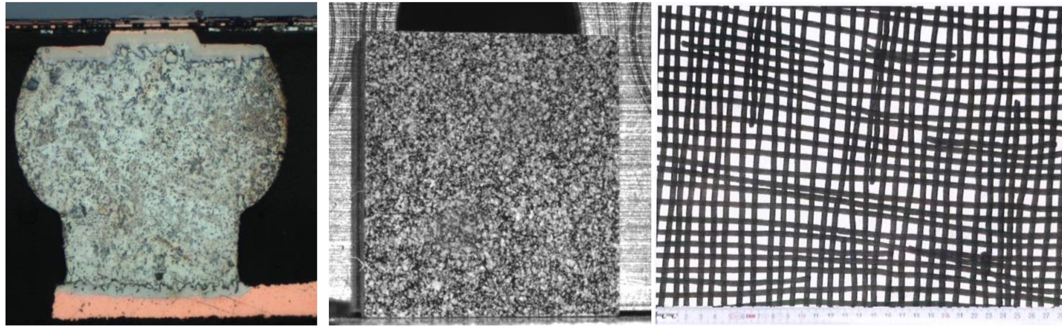

Figure 3. 3 DIC surface treatment methods: (a) etching; (b) spraying; (c) painting

Objectives

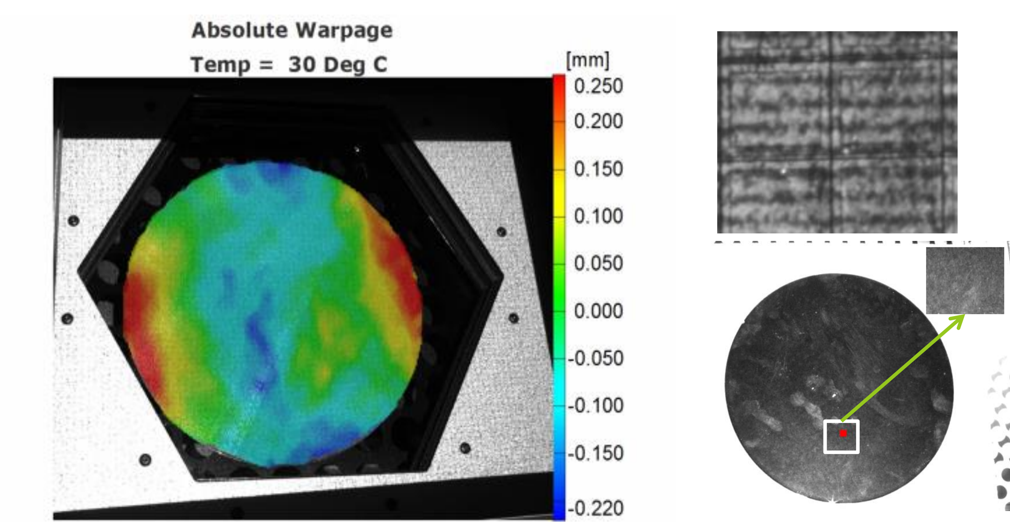

Figure 4. 300mm warpage contour & patterns projected on the wafer

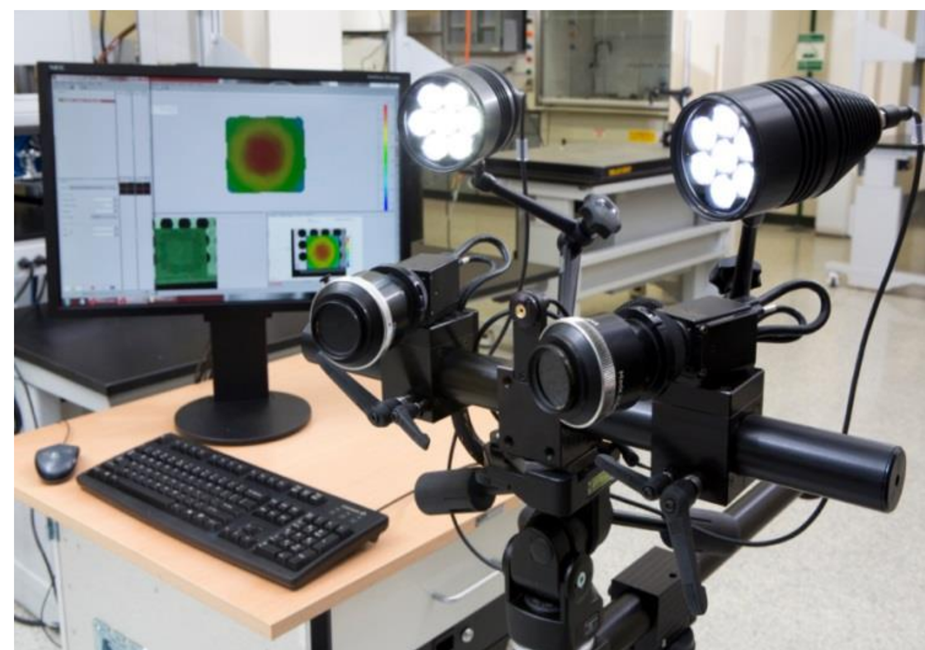

Figure 5. Digital Image Correlation System

Core Steps

Experiment Set-up

In project plan, two sets of sensors are applied for different field of view.

Sensor	Field of View (mm)	Measurement Sensitivity (μm)	Usage
Global Camera	350 x 280	11.67	Whole wafer
Local Camera	10 x 8	0.33	Microcircuits on the wafer

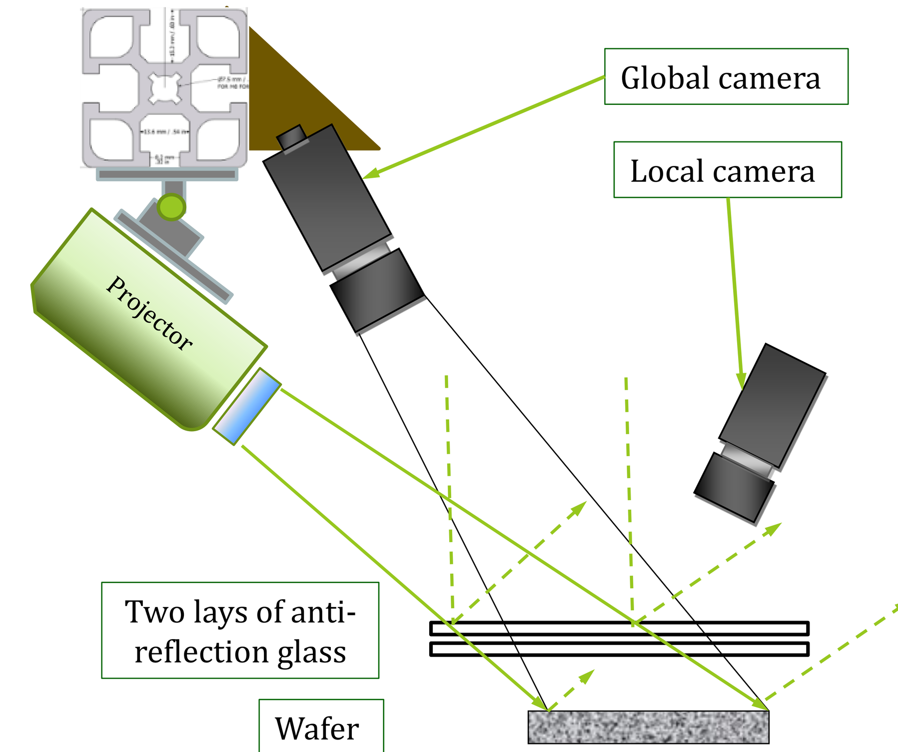

Figure 6. Schematic of speckle-free DIC

The thermal chamber provides the temperature range from -73°C to 315°C. High contrast ratio and resolution projector generates patterns on the wafer (fig. 4).

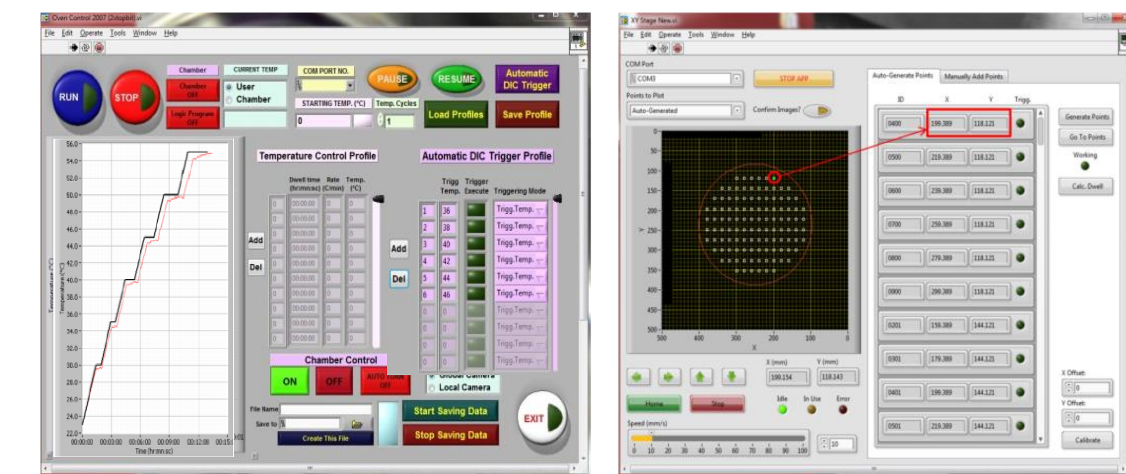

Figure 7. Control system for the experiment: (a) oven control program; (b) linear stage control program

Pattern Size and Density

Speckle-free method can adjust pattern parameters easily and achieve optimized speckle patterns.

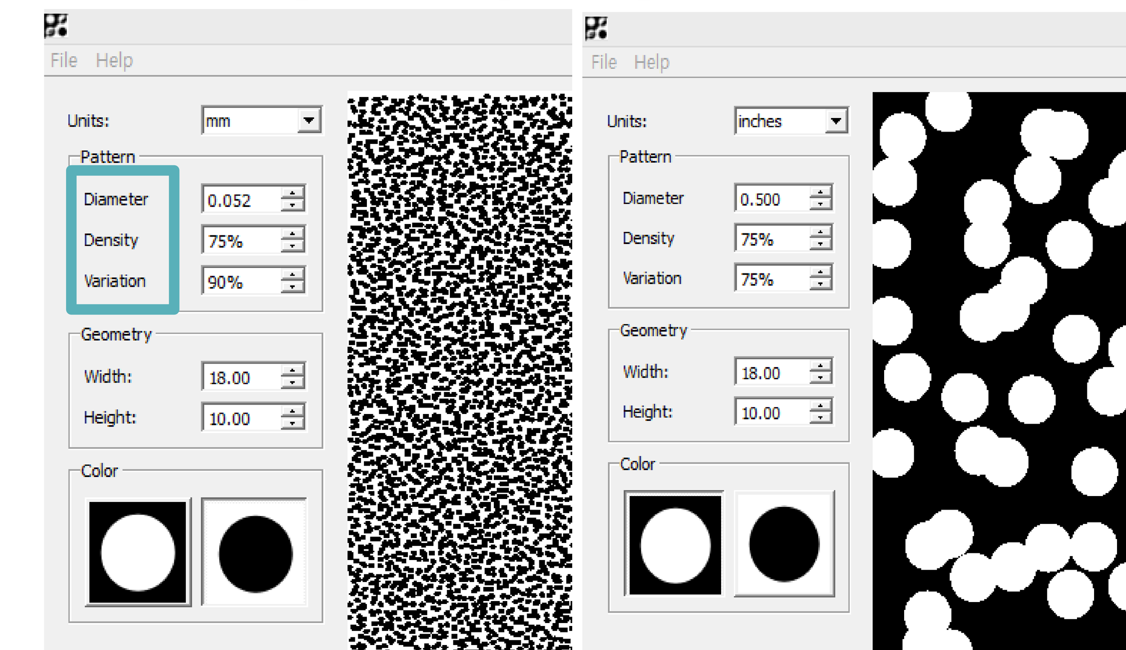

Figure 8. Pattern size and density effects: pattern generation program

Measurement Verification

Before the wafer measurement starts, two verification tests were done to verify the speckle-free method.

Warpage Test

A plastic package (fig. 9) with convex surface is selected for profiling. The surface is measured by both speckle-free DIC and Wyko (nanometers of measurement sensitivity).

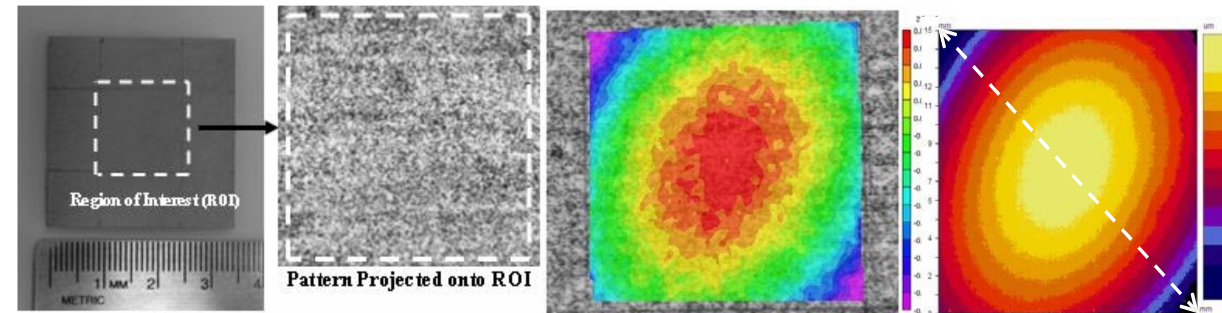

Figure 9. Plastic package

Figure 10. Warpage contour from DIC & Wyko

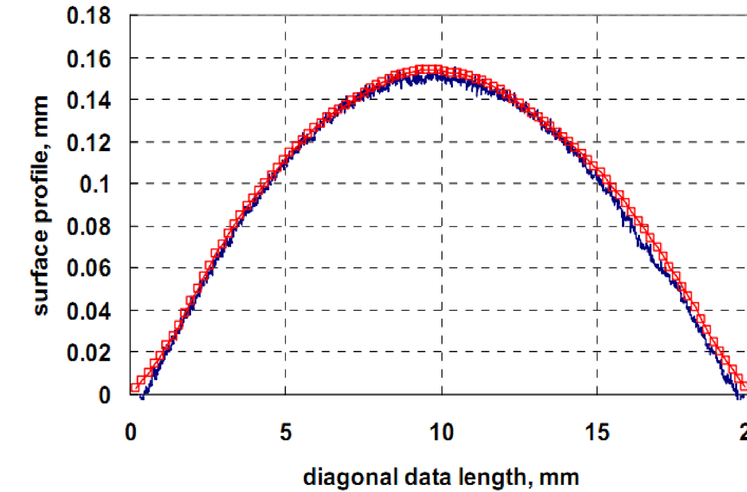

Figure 11. Comparison of surface profile between speckle-free DIC and Wyko Profiler

Surface Treatment Effect

For wafer level specimen, surface is flat and the surface treatment might influence the actual result. So an optical mirror was used to check the surface treatment effect.

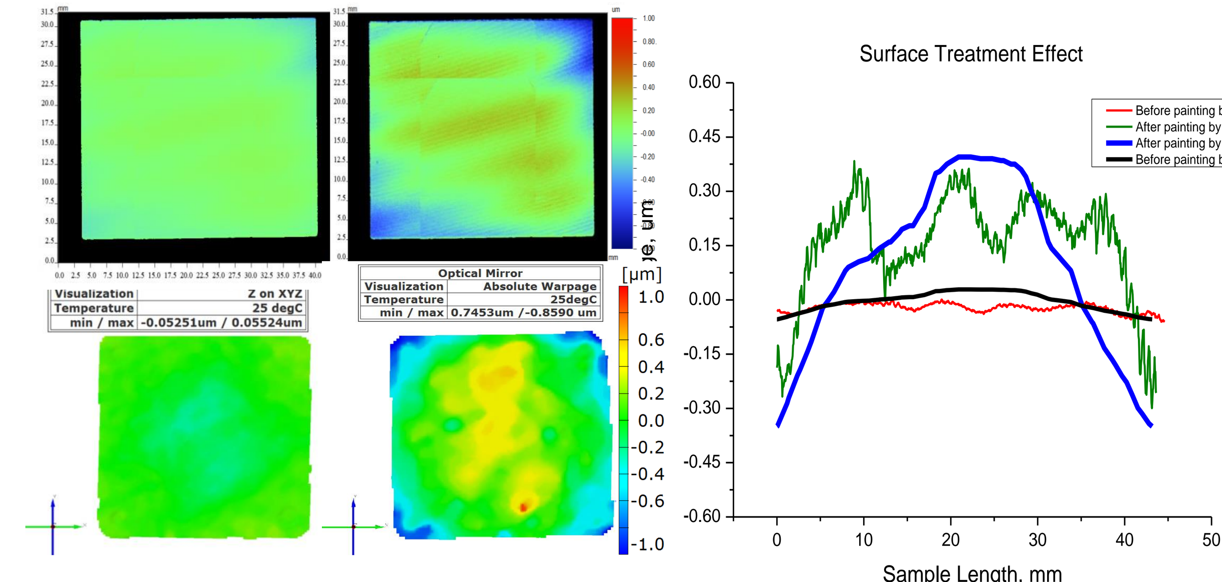

Figure 12. Comparison of surface treatment effect with optical mirror specimen

Wafer Warpage Measurement

Once the speckle-free DIC method solidified, the actual 300mm wafer was measured.

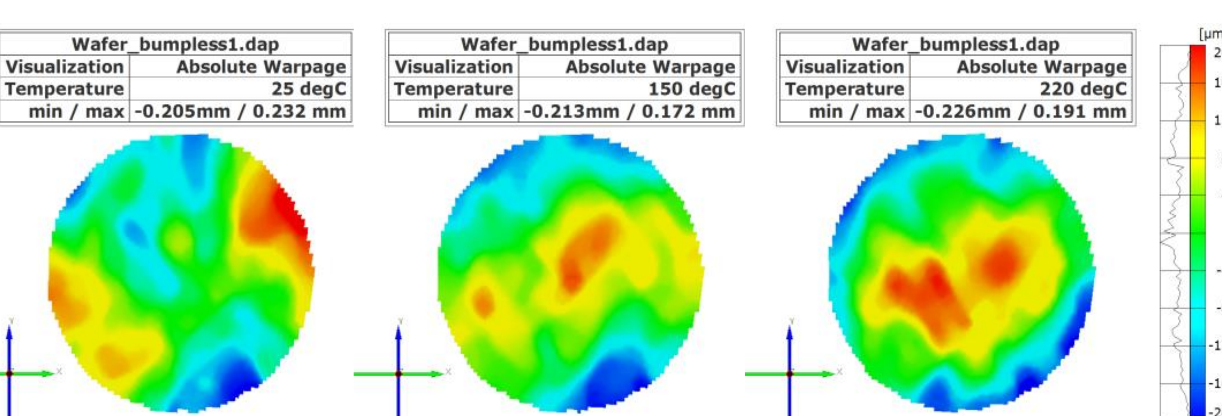

Figure 13. In-situ warpage measurement of 300mm wafer with speckle-free DIC method

Discussion

1. Conventional speckle method for wafer

Overall warpage contours were the same, but for microelectronic devices built on the wafer tiny warpage difference may lead to big problems.

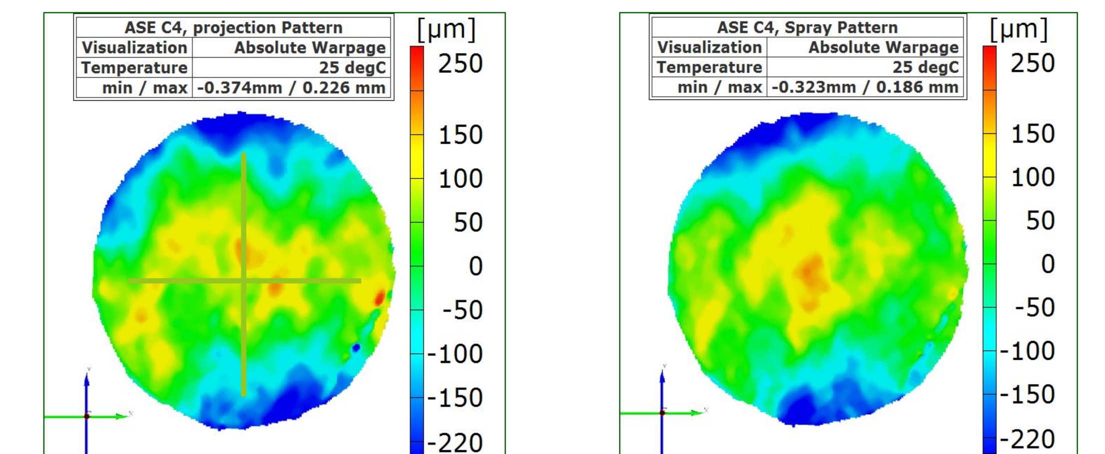

Figure 14. C4 wafer absolute warpage room temperature for two methods

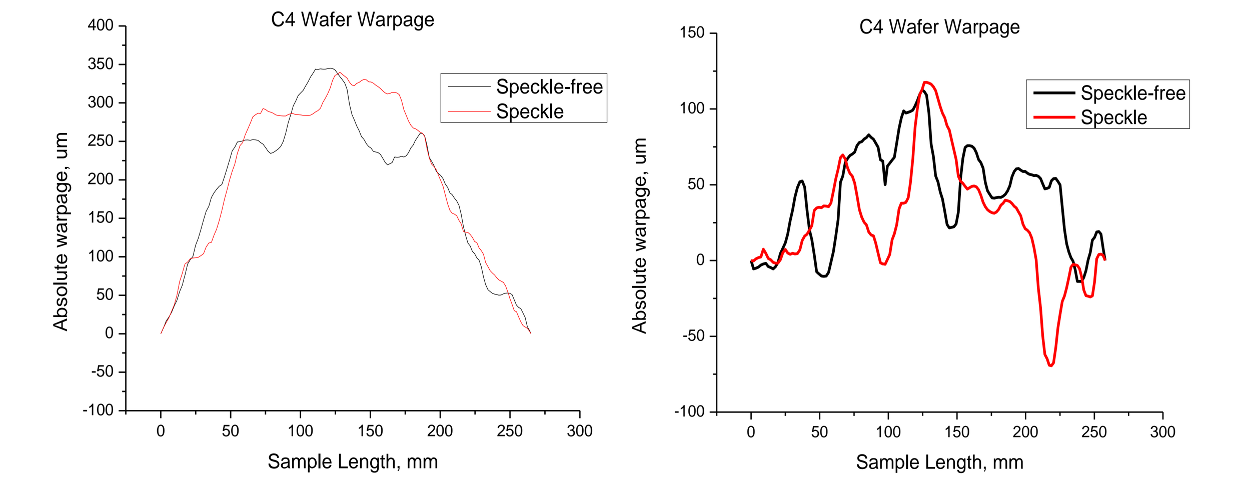

Figure 15. C4 wafer absolute warpage along the cross in fig. 14

2. Speckle-free DIC Method Limitation

For in plane displacement measurement, the correlation algorithm is based on the tracking of the grey value pattern G(x, y) in small local neighborhood facets.

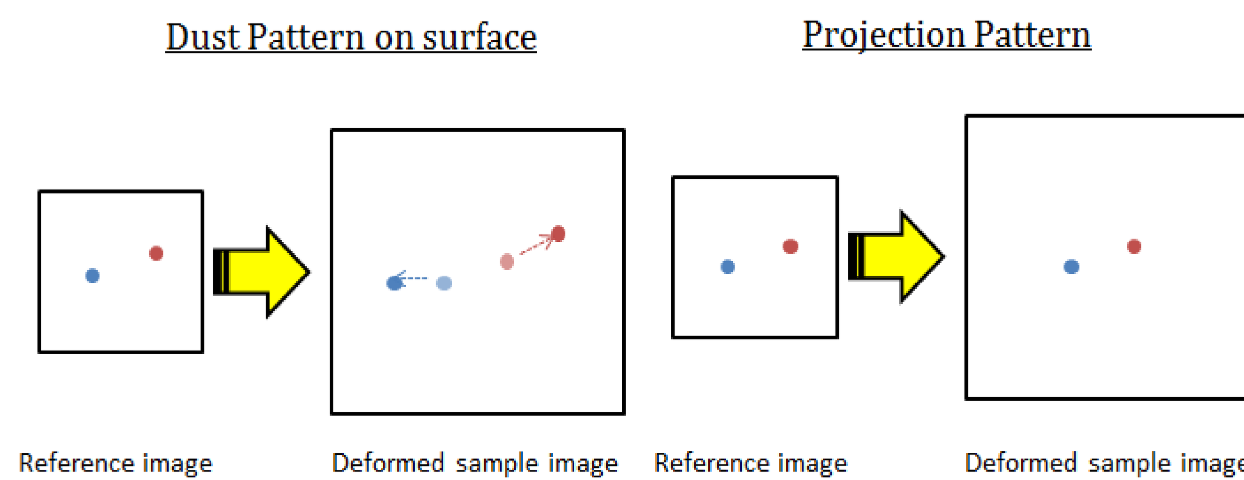

Figure 16. Schematic of speckle-free DIC method limitation

Conclusion