Joint Special Interest Group meeting between euspen and ASPE
Advancing Precision in Additive Manufacturing
KU Leuven, Belgium, September 2023
www.euspen.eu

Lead-time reduction of the design and production of thermal tables

Kevin Raedts[1], Ton Peijnenburg[1], Jos de Klerk[1]

[1]VDL ETG T&D

1. Introduction

Semicon manufacturing equipment needs to thermally condition the wafers. This is usually realized by a combination of air showers and thermal conditioning tables. At VDL ETG we design and build equipment containing the high precision thermal tables. Due to the complex manufacturing process and strained supply chain, obtaining sufficient hardware for design validation and testing is a big challenge. Therefore, we investigated how additive manufacturing could reduce the lead-time during development and manufacturing in a practical way.

2. Current design

The design of the thermal table is currently made by stacking three stainless steel plates and a milled manifold. All the parts are then brazed to each other. This is done so that internal water and vacuum channels can be created with a limited amount of welding.

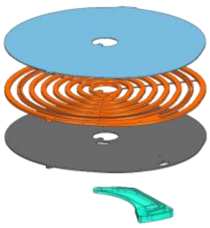

Figure 1: Stack of components of the Thermal table

After brazing, the table will be finished with vacuum grooves and with a diamond cutting process, a global surface flatness of 50um is reached. Then coatings are applied. This complete process takes about 42 weeks from start to finish.

3. Design and Functional prototypes

3.1. A new design

In to-be-designed tables, strongly warped wafers need to be handled. For this, a new clamping sequence and a different vacuum grooves pattern are needed. The question that needs to be answered is whether the clamping sequence and groove pattern are correct. As a first step, the clamping sequence is analysed based on a 1D and 3D simulation model. Results of these models needed to be compared with real measurement results.

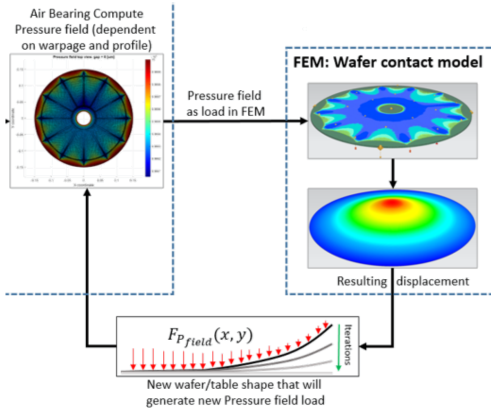

Figure 2: Theoretical clamping model

3.2. Functional prototypes

To test the clamping model, a prototype needs to be made and this would cost 40 weeks of time with conventional design techniques. To speed this up, as a first iteration, we selected SLA printing (Stereo Lithography Apparatus) with the material called TuskXC2700, which is a polycarbonate like material and is easily machinable. With a relative accurate way of printing and easy post processing, a delivery in 48 hours is possible.

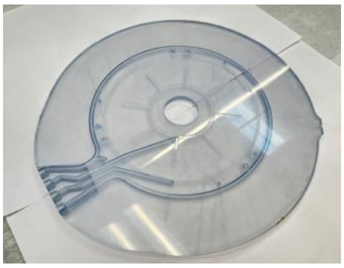

Figure 3: First SLA prototype

The design of the prototype is based on the thermal table as mentioned in section 2. The outline, external interfaces and the volume were unchanged insure the table can be mounted inside the available testrigs with minimal effort. By bringing all vacuum lines to the outside separately, multiple vacuum scenarios were tested in a single prototype. The only post processing needed on this table was the manual tapping of the threads and fly cutting the top surface to reach a sufficient surface flatness of 120um. Although the prototype was not ideal compared to the metal variant, valuable data were generated that validated the different vacuum patterns and clamping sequences of the theoretical model. Learning from each proto, we iterated the design four times over a span of only eighteen weeks until the limitations of the SLA print accuracy were reached.

By producing the final iteration of the design in Stainless steel 316 Manufactured by selective laser melting we were able to keep the functional advantages. Compared to the SLA prototypes, post processing was more complex due to CNC milling of the complete surface, vacuum pattern and external interfaces. Parts of the existing CNC programming and associated jigs where used during post processing and therefor saved time. This was possible because the design reused al the standard interfaces and remained inside the original volume. Over the span of 12 weeks, with 6 weeks for printing, we made one metal prototype that was machined three times to optimize the vacuum pattern and validated it to our theoretical model.

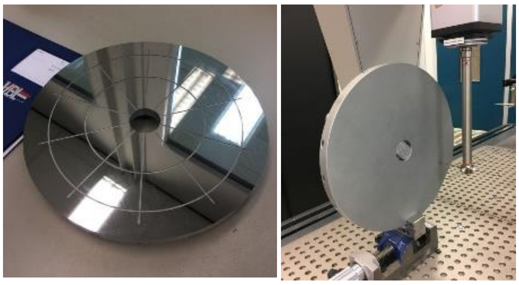

Figure 4: Example of an Al10SiMg Printed thermal table

3.3. Design consolidation

To end up with a fully functional thermal table more steps need to be taken as listed below.

<u>Thermal behaviour:</u>

- Water channels need to be incorporated to condition the wafer
- Compensate the thermal impact of changing from steel 304L to 316L
- Tune the pressure drop to be equal to the original for backwards compatibility

<u>Post processing:</u>

- Laser surface treatment of features on printed stainless steel
- Application of a wear resistant coatings on printed materials

<u>Cleaning</u>

- Post processing and cleaning internal vacuum and air channels to prevent contamination and particle generation on the backside of grippers.

All of the above points are currently under investigation.

4. Serial production

The lead time to produce the Brazing assembly for the thermal table currently takes 28 weeks in batch sizes of 6. This long lead time is caused by the different steps that need to end up with a functional product.

The following steps are involved:

- Ordering Base material: 2 thicknesses of Sheet metal and 1 cast block
- Rough machining: water jetting 3 sheet metal parts
- Fine machining:
    - Fine 3 axis milling 3 sheet metal parts
    - Fine 5 axis milling 1 manifold
- Brazing
- Heat treatment
- Milling and leak testing

When we would switch to a part made by selective laser melting the following production steps need to be done. Estimated Lead times are added for each step.

- Base Material: 0 weeks
    - Powder is handled as non-specific stock since only one powder type is allocated to the machine. Minimum stock level is always maintained
- Printing: 2 weeks
    - Printing is done in batch sizes of twelve items. With a four lasers machine this will take approximately 140 hours of printing. Together with work preparation, the lead time is rounded up to 2 weeks

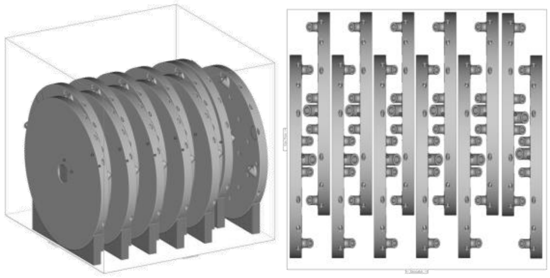

Figure 5: Optimal batch size estimate (420x420x400 buildchamber)

- Heat treatment: 4 weeks
    - Outsourced process
- Wire EDM for Build plate removal: 2 weeks
    - Dedicated machine for EDM build plates
- Milling and leak testing: 6 weeks

Sum of all the lead times give a total of 14 weeks for 12 assemblies. Compared to the conventional way that would mean 24 finished assemblies in 28 weeks and this results in a lead time improvement of 300% of parts that can be manufactured over the same time period.

5. Conclusion

There are cases where 3D printing is a viable alternative for the production thermal tables. Currently there are a couple of open items that need to be investigated to check whether all functions of the table can be performed by the redesigned version. First indications are very positive.

In the validation phase we proved that using additive manufacturing decreases the time to market in an early stage when rough design concepts need to be investigated.