euspen's 17th International Conference & Exhibition, Hannover, DE, May 2017

www.euspen.eu

How to qualify wafer thermal conditioning at milli-Kelvin resolution?

Marnix Tas[1], Roland Hanegraaf[1], Herman Verbeek[1], Willem Dijkstra[2]

[1] *Sioux CCM (www.sioux.eu), commissioned by VDL ETG (www.vdletg.com)*
[2] *VDL ETG (www.vdletg.com)*

marnix.tas@sioux.eu, roland.hanegraaf@sioux.eu, herman.verbeek@sioux.eu, willem.dijkstra@vdletg.com

Abstract

The next overlay nodes in the Semicon industry require accurate thermal conditioning of wafers in lithography scanners in order to control the thermal expansion of silicon wafers before exposure. High resolution temperature measurements are needed to qualify the thermal conditioning of wafers in lithography scanners of ASML. Commercially available wireless measurement wafers have a noise level that is 10 times too high for the qualification of the new developed wafer handler module. Therefor VDL ETG decided to develop a temperature measurement wafer with only 0.3 mK noise level. We call this measurement wafer: the ''mk-Wafer''. Standard components and processes were used to reduce development risk and costs.

Keywords: wafer thermal qualification milli kelvin wireless

1. Introduction

The next overlay nodes in the Semicon industry require accurate thermal conditioning of wafers in lithography scanners in order to control the thermal expansion of silicon wafers before exposure. The new wafer handler module in the ASML DUV scanner is able to perform this task. The evidence that wafer handler does the right job requires a tool with at least 5x higher sensitivity: that is in the sub-milli-Kelvin range!

The ultimo tool is a measurement wafer that can be handled like any other wafer in the scanner while measuring the wafer temperature in-line. Such measurement wafers are commercially available, but do not have the required perfor-mance. Therefor VDL ETG decided to develop a new high performance temperature measurement wafer. We call this measurement wafer: the ''mk-Wafer'' tool.

The mK-wafer is assembled from a standard 300mm silicon wafer substrate, using standard very low power electronic components and standard PCB technologies to reduce the development and manufacturing costs, see Figure 1. The electronics and sensors are mounted on the top side of the wafer, which limits the use of the wafer to the wafer handler module.

The mK-wafer is developed in close cooperation with Sioux CCM and Neways. Sioux CCM and VDL were responsible for the hardware and software design, Neways for the electronics manufacturing and VDL for the gluing technology.

In this paper the design of the mK-wafer tool is presented in chapter 2, followed by a short summary on calibration in chapter 3 and results in chapter 4.

2. Design of the milli-Kelvin wafer

A major constraint of the thermal measurement wafer is wireless, stand-alone operation. The confined spaces in the wafer handler module does not allow wires from the mK-Wafer to a controller. Hence the mK-wafer must execute a pre-programmed measurement sequence while transported and temperature conditioned in the wafer handler module. The measurement data is stored in local flash memory and is downloaded to a PC afterwards.

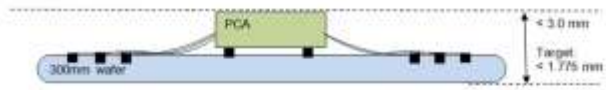

Figure 1. Concept of the mK-wafer

It is not only the average wafer temperature that is relevant. Also non-homogeneous temperature variation will negatively influence the overlay performance of the scanner. Therefore, a measurement grid of 63 NTC sensors is required, spread evenly over the surface area of the wafer.

The self heating of the measurement wafer by dissipation must be limited to a minimum. Wafer conditioning in the wafer handler module is done on water cooled tables with a good thermal contact to the wafer. At these positions, self heating is not a major problem. It is the wafer transport on a robot gripper that is critical. The robot grippers have a small contact area with the wafer, hence a low heat transfer coefficient. Self heating of the mK-wafer will disturb the measurement process of the wafer thermal interaction to its environment.

The major performance requirements for the mK-wafer are summarized in Table 1.

Table 1 : Major performance requirements for the mK-wafer

Performance	Requirement
Substrate silicon wafer, diameter	300 mm
Operation mode	wireless
Measurement time	> 20 min
Number of sensors, grid over wafer	32 to 64
Sample rate, selectable	1, 2, 4 or 8 Hz
Sensor noise level 3σ	< 0.3 mK
Self heating by dissipation	< 1 mK / 8 s

2.2. Thermal sensor design

The thermal sensors in mK-wafer has the goal to measure the temperature of a local spot on the silicon wafer without disturbing the thermal properties of this local spot. Several sensor types and mounting concepts have been investigated.

The chosen concept consists of wired NTC sensors with a diameter of only 0.4 mm, which are buried and glued in grooves in the silicon wafer for optimal contact between the silicon wafer and the sensors. The small mass of the NTC sensor gives a rapid thermal response of better than 0.5 s, the wires minimize the heat flux between the sensor and the PCB. The dis-advantage of the wired sensors are the labour costs to assemble the mK-wafer. This is taken as a penalty to meet the performance specifications.

2.3. Low power electronics

The PCB layout is optimized for minimal thermal impact on the NTC sensors. The PCB contains all elements that cause dissipation such as the battery, processor, analog/digital converters (ADC) and supply electronics. The distance between the ''warm'' PCB and the NTC sensors in the silicon wafer is made as large as possible. This explains the particular shape of the PCB with many cut-outs, see Figure 1.

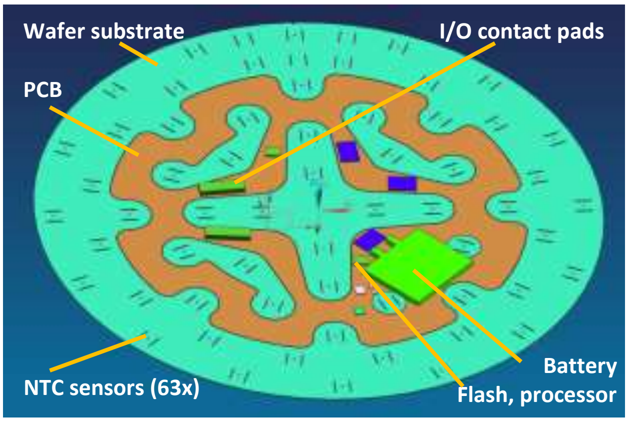

Figure 2. Design of the mK-wafer

Finally, the ADC and processor are selected to have a sleep or idle mode. The read-out of the 63 NTC sensors is done in a burst, bringing the ADC and processor back to idle mode directly after. This wake-up, read-out and sleep cycle is repeated at a frequency of maximal 8 Hz. A higher sample frequency is not needed because of the thermal response time of the wafer.

2.4. Wafer substrate

A standard 300m silicon wafer is used as substrate to mount all active components. Laser ablation is used to make grooves for the NTC sensors and a pothole for the PCB. The additional thermal mass of the PCB is compensated by removing silicon under the PCB from the wafer. The additional advantage is that the total height of the mK-wafer is also reduced which is important in the confined spaces of wafer handler.

2.5. Control architecture

The embedded software on the mK-wafer processor is kept as simple as possible. The embedded software mainly takes care of the communication to the internal and external hardware and executes the measurement sequence. The PC is used for the control, programming and data communication with the mK-wafer. Data post-processing is also done on the PC.

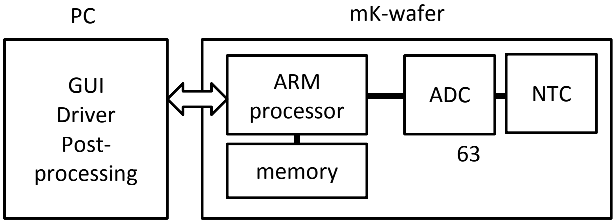

Figure 3. Control architecture of the mK-wafer

3. Sensor calibration

The sensor gain and offset is calibrated in a stable conditioned and isolated box, see Figure 4. The mK-wafer has a special operation mode for calibration which takes only 1 sample per minute to minimize the dissipation to the bare minimum.

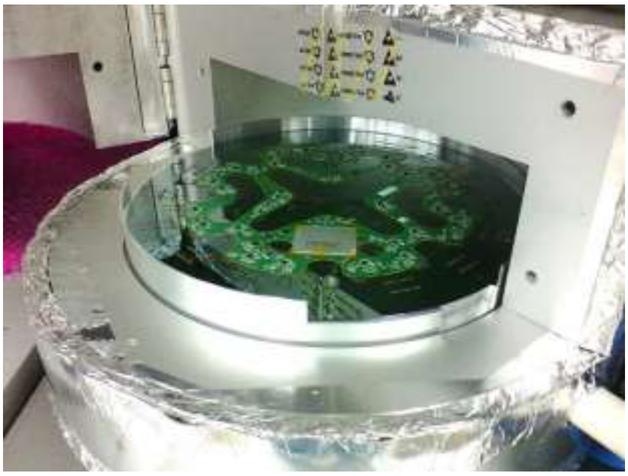

Figure 4. Calibration of the mK-wafer in a conditioned environment

4. Realization & test results

The first mk-Wafer is assembled first-time-right. The battery life exceeds 2 hours which is more than sufficient for thermal life of a wafer cycling measurements. The measurement noise 3σ of 0.3 mK per sensor is demonstrated which is according to our theoretical calculations.

5. Summary

The thermal performance of the mK-Wafer tool performs 10 times better than the commercially available measurement wafers. The thermal specifications are met in all aspects.

The thermal qualification of the new wafer handler module is done in the last quarter of 2016 with this mK-Wafer tool. The analysis of measurement data from the wafer handler showed unique details and understanding of its thermal behaviour. See abstract [1] for more details on the application of the mK-wafer for thermal qualification of wafer handler.

The mK-wafer tool architecture is well suited for other stand-alone sensor applications such as pressure, light, etc. Also applications in vacuum are possible, but this will require additional engineering effort.

References

[1] Tas M, et al. 2017 Euspen Hannover Abstracts ***ICE17329***