## TECHNICAL SPEC FOR Spectrometer

**System Model:**

**BIORAD QS 2200M**

**Tool was operational at shutdown**

**Wafer size: 6 inch**

**SECS/GEM: yes**

**Non-contact: yes**

**Nondestructive: yes**

**Vintage: 1998**

**Missing parts: none**

**Defected parts: none**

### Acce[tance report at installation :

**Description of equipment**

The BIORAD QS2200M we have installed in Fab 2, is a FT-IR spectrometer, capable of measuring EPI thickness and Boron – Phosphorous concentrations.
The second hand tool is only 1 year old and is installed by BIORAD itself.

Today, we will only use the tool for measuring EPI thickness.
We can't use the Boron-Phosphorous option, because the system is not calibrated to measure these concentrations. To do this calibration, we need a lot of boron and phosporous doped oxide wafers. This will result in a long downtime of our Watkins Johnson to create these wafers with a different doping concentration. Therefore we decided to wait with the calibration until the second Watkins Johnson is installed.

We also have a 1 year warranty on the tool starting from the date of signing the acceptance.

**Description of the acceptance test**

We've setted up an internal acceptance test together with the Biorad tests to determine the performance of the tool for EPI measurements.

We've organised the following test's :

**1 . MSA was performed on the following layers :**

3 µm EPI
4.2 µm EPI
14 µm EPI

The MSA test was done using the standard MSA template. 15 samples on 3 different wafers, 5 samples per wafer. These samples were taken over a 2 weeks time period.

**2. A short term stability test was done :**

A 3µm EPI wafer was measured 10 times in the center of the wafer, and the mean and the standard deviation was recorded.

**3. Measurement position accuracy check was done :**

A recipe TESTPAT5 was written to cycle a test wafer from the loading position of the stage, the stage movement where 5 sites were measured and returned to the loading position. A cycle includes :

- transporting the wafer to the measurement site
- mapping the wafer by moving to the site, measuring the thickness and returning the sample to the loading position.

**4. A long term reproducibility was done :**

We measured a wafer once everyday for a period of 2 weeks, with two different recipes. With the first recipe, we always took a new reference before we started the measurement, where we didn't take any reference using the second recipe.

**5. A correlation check was done :**

In this test we made a correlation between Nicolet (Fab2) – BIORAD (Fab1) – BIORAD (Fab2). For this correlation test, we used the 11 wafers with a known thickness, provided by Wacker.
Using this Wacker wafers we could also check our system versus an external standard.

**<u>Results of the acceptance tests</u>**

## 1. MSA Results

Attached to this report, you can find the data sheets with the raw data of the measurements during the MSA test.
In the table underneath, you can find an overview of the R&R results of this tests.

| Measurement | R&R |
|---|---|
| 3 µm EPI | 4 % |
| 4.2 µm EPI | 7 % |
| 14 µm EPI | 8 % |

For measurement systems whose purpose is to analyze a process (=Rudolph FE-IV), a general rule for measurement system acceptability is as follows :

| | | |
|---|---|---|
| R&R < 10 % | : | acceptable measurement |
| 10 % < R&R < 30 % | : | may be acceptable based upon importance of application, cost of measurement device,… |
| R&R > 30 % | : | considered not acceptable – every effort should be made to improve the measurement system |

## 2. Short term stability

We measured a 3 µm wafer 10 times in center.

Thickness = 3.51 µm
Precision = 0.002 µm (Spec +/- 0.02 µm)

The system passed the Short term stability test

## 3. Measurement positioning accuracy

In the table underneath, you can find the results of a 5 point measurement on a wafer. The same wafer was measured 10 times.

| Cycle # | Point 1 | Point 2 | Point 3 | Point 4 | Point 5 |
|---|---|---|---|---|---|
| 1 | 3.51 | 3.48 | 3.50 | 3.49 | 3.47 |
| 2 | 3.51 | 3.48 | 3.50 | 3.49 | 3.47 |
| 3 | 3.51 | 3.48 | 3.50 | 3.49 | 3.46 |
| 4 | 3.51 | 3.48 | 3.50 | 3.50 | 3.46 |
| 5 | 3.51 | 3.48 | 3.50 | 3.49 | 3.47 |
| 6 | 3.51 | 3.47 | 3.50 | 3.49 | 3.47 |
| 7 | 3.50 | 3.48 | 3.50 | 3.49 | 3.47 |
| 8 | 3.51 | 3.48 | 3.50 | 3.49 | 3.48 |
| 9 | 3.51 | 3.48 | 3.50 | 3.49 | 3.47 |
| 10 | 3.50 | 3.48 | 3.50 | 3.49 | 3.48 |
| **Thickness** | **3.507** | **3.479** | **3.502** | **3.493** | **3.467** |
| **Precision** | **0.002** | **0.003** | **0.003** | **0.002** | **0.003** |

The spec for precision +/- 0.05 µm is met, the system passes this test.

## 4. Long term reproducibility

A 3µm wafer was measured daily over a 2 weeks time period. The wafer was measured with 2 recipes :

- Recipe 'Acceptance' : before every measurement, a 16.8 µm reference sample is taken.
- Recipe 'Acceptance2': no reference is taken before the recipe.

| Acceptance | Acceptance2 |
|---|---|
| 3.487 | 3.481 |
| 3.481 | 3.483 |
| 3.478 | 3.484 |
| 3.489 | 3.485 |
| 3.475 | 3.486 |
| 3.484 | 3.483 |

| | |
|---|---|
| 3.479 | 3.486 |
| 3.475 | 3.482 |
| 3.483 | 3.483 |
| 3.489 | 3.485 |

At this test, we are looking at the maximum and minimum difference of this measurements. The difference should not exceed 1 % of the thickness of the measured sample.

Acceptance-recipe = 3.489 – 3.475 = 0.014 µm => **0.4 %**

Acceptance2-recipe = 3.486 – 3.481 = 0.005 µm => **0.14 %**

The system has passed the long term reproducibility check.

## 5. Correlation between the tools

A correlation check was done between the following tools :

- Nicolet ECO-8S in Fab2
- Biorad QS-2200M in Fab1
- Biorad QS-2200M in Fab2

For these correlation check, we used 11 wafers delivered from Wacker with a known thickness. We will use this wafers as an external standard for our tools.

Due to the software setup of the Nicolet, we used 2 different Nicolet recipes to make a correlation. We used the recipe (here named as "C05 EPI") used by quality, to measure the incoming wafers, and we used the recipe to measure our internally grown EPI (here named as "4.2M EPI").

In the following table, you can find an overview of the different measurements. We always measured the wafer on the centerpoint. The results, you can find in the Mean colum, is a mean value of 2 measurements.

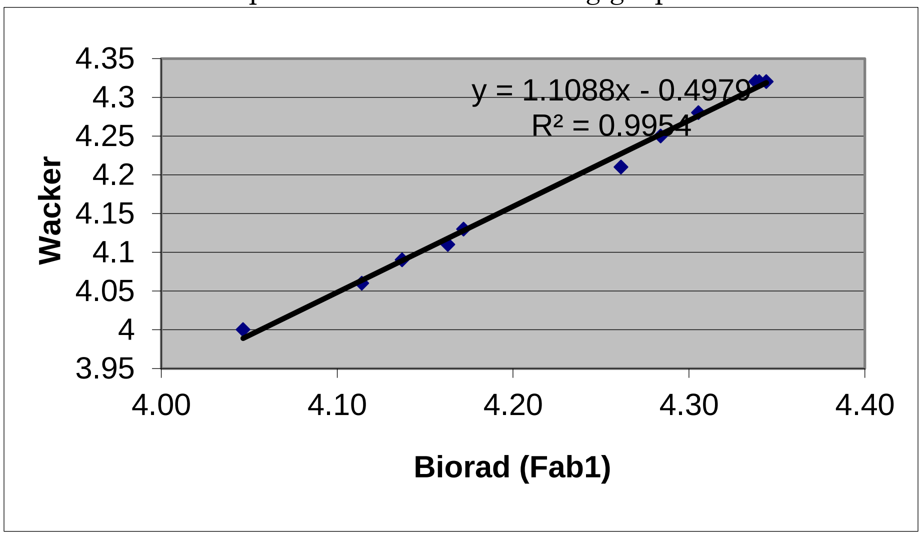
| Wacker | Biorad (Fab2) | | Nicolet 'C05 EPI' | | Nicolet '4.2M EPI' | | Biorad (Fab1) | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Offset | Mean | Offset | Mean | Offset | Mean | Offset |
| **4.06** | 4.09 | 0.03 | 4.03 | -0.03 | 3.94 | -0.12 | 4.11 | 0.05 |
| **4.09** | 4.11 | 0.02 | 4.06 | -0.03 | 3.97 | -0.12 | 4.14 | 0.05 |
| **4.32** | 4.34 | 0.02 | 4.27 | -0.05 | 4.17 | -0.15 | 4.34 | 0.02 |
| **4.21** | 4.30 | 0.09 | 4.18 | -0.03 | 4.08 | -0.13 | 4.26 | 0.05 |
| **4.25** | 4.27 | 0.02 | 4.20 | -0.05 | 4.10 | -0.15 | 4.28 | 0.03 |
| **4.11** | 4.10 | -0.01 | 4.08 | -0.03 | 3.98 | -0.13 | 4.16 | 0.05 |
| **4.13** | 4.12 | -0.01 | 4.10 | -0.03 | 4.00 | -0.13 | 4.17 | 0.04 |
| **4** | 4.04 | 0.04 | 3.98 | -0.02 | 3.88 | -0.12 | 4.05 | 0.05 |
| **4.32** | 4.30 | -0.02 | 4.27 | -0.06 | 4.17 | -0.15 | 4.34 | 0.02 |
| **4.28** | 4.30 | 0.02 | 4.23 | -0.05 | 4.13 | -0.15 | 4.31 | 0.03 |
| **4.32** | 4.31 | -0.01 | 4.27 | -0.05 | 4.17 | -0.15 | 4.34 | 0.02 |
| **Average** | **4.21** | **0.02** | **4.15** | **-0.04** | **4.05** | **-0.14** | **4.23** | **0.04** |
| **Average Offset in** | | **0.42%** | | **-0.91%** | | **-3.36%** | | **0.89%** |

As you can see, both Biorad tools are measuring very consistently, where we can find a big offset in our actual EPI measurement with our Nicolet tool.
Although the offset between the Biorad tools and the Wacker measurements is very small, I've tried to get it better by putting in a correlation curve for this recipe.

<u>Correlation curve for the Biorad (Fab1)</u>

When we look closer to the measurement results of the Biorad (Fab1), we can see that the offset between Wacker and Biorad is small, but always positive.

The measurements are presented in the following graph :




Through the measurement points, a line has been fitted with the following equation

**Y = 1.1088x – 0.4979**

The $R^2$ is 99.5 % , indicating a very good correlation between both measurements.
This equation has been putted in the Biorad recipe. The measurement results with this correlation curve are presented in the following table :

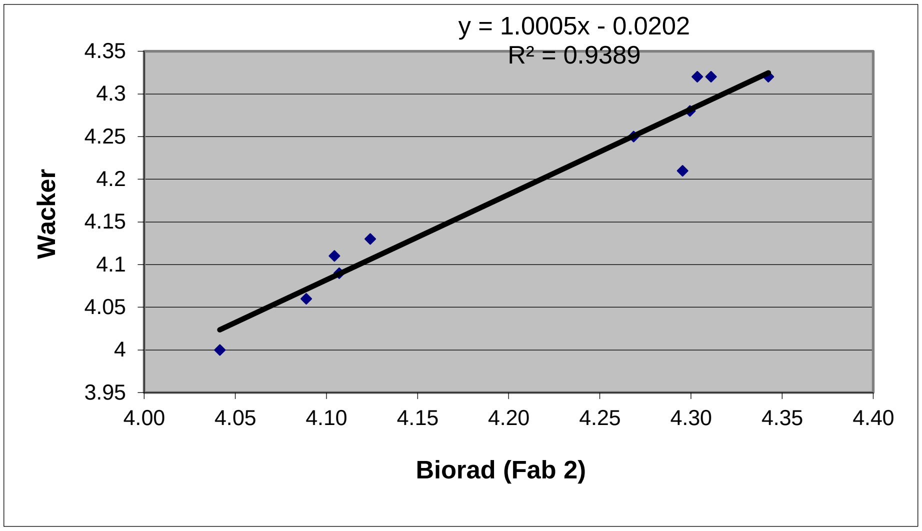
| Wacker | Biorad (Fab1) | |
|---|---|---|
| | Mean | Offset |
| **4.06** | 4.05 | -0.01 |
| **4.09** | 4.08 | -0.01 |
| **4.32** | 4.31 | -0.01 |
| **4.21** | 4.24 | 0.03 |
| **4.25** | 4.26 | 0.01 |
| **4.11** | 4.09 | -0.02 |
| **4.13** | 4.11 | -0.02 |
| **4** | 3.99 | -0.01 |
| **4.32** | 4.31 | -0.01 |
| **4.28** | 4.28 | 0.00 |
| **4.32** | 4.31 | -0.01 |
| Average | 4.18 | -0.01 |
| Average Offset in % | | -0.13% |

Now, the measurements are now matching very closely.

Correlation curve for the Biorad (Fab2)

When we look closer to the measurement results of the Biorad (Fab2),the offset between the 2 measurements have not always the same sign.

The measurements are presented in the following graph :




Through the measurement points, a line has been fitted with the following equation

$$\mathbf{Y = 1.0005x - 0.0202}$$

The $R^2$ is 93.8 % , which is lower then the Biorad (Fab1) result, but still good.
This equation has been putted in the Biorad (Fab2) recipe. The measurement results with this correlation curve are presented in the following table :

| **Wacker** | Biorad (Fab2) | |
|---|---|---|
| | Mean | Difference |
| **4.06** | 4.08 | 0.02 |
| **4.09** | 4.10 | 0.01 |
| **4.32** | 4.32 | 0.00 |
| **4.21** | 4.27 | 0.05 |
| **4.25** | 4.27 | 0.02 |
| **4.11** | 4.10 | -0.01 |
| **4.13** | 4.12 | -0.01 |
| **4** | 4.03 | 0.03 |
| **4.32** | 4.31 | -0.01 |
| **4.28** | 4.29 | 0.01 |
| **4.32** | 4.32 | 0.00 |
| Average | 4.20 | 0.01 |
| Average Offset in % | | 0.25% |

As with the Biorad (Fab1), the average offset here is also 0.01 µm, but with an opposite sign.

Monitoring the system stability in the future

To constantly monitor the stability of the tool the following checks will be carried out on a 2-daily basis:

- measuring the stability on a 3µm EPI wafer
- measuring the accuracy on a 4.2 µm EPI wafer
- measuring the accuracy on a 14 µm EPI wafer

The stability check will consist of a measurement, where we will measure the wafer 10 times in the centerpoint. The mean value and the standard deviation will be monitored.
The accuracy check will measure the wafers on 5 points close to the center. Also here, the mean and the standard deviation will be monitored.

## Conclusion

Out of all these tests, we can conclude that the system is ready to use for measuring EPI layers. It is far more reliable than our current Nicolet system.
The Biorad in Fab1 can act as a complete backup of our tool. All te recipes of our tool are also written in the Fab1 tool. Both tools have an offset of 0.02 µm between each other, where both tools have a 0.01 µm offset versus the Wacker standard wafers.