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WAFERMAP for Windows

APPLICATION NOTE 2: Difference/ Ratio Method

One of the best methods to compare different sets of wafer data (maps) are the difference and ratio methods. One map can be subtracted from another map by subtracting individual measurements point by point. The resulting map will visualize the difference between the two maps.

This is a simple method, however it often requires two maps, which are identical regarding the individual coordinates of sites. In WAFERMAP such differences can be calculated without the necessity of identical grids (only the wafer diameter must be the same). This is possible because different grids will be transformed to the grid with higher density of sites before comparison.

It is also possible to calculate the ratio between two files in the same way.

Using the difference or ratio method both maps should have almost the same mean value. Therefore, one map should possibly be normalized to the mean value of the second map (in WAFERMAP for Windows select "Edit" → „Operations" → select "Multiply" or "Divide" in the menu on the right → give the appropriate numerical value → click on "Perform Operation" → a preview will be shown → click on „OK").

On the next pages 3 different examples of these methods are shown together with actual test data.

- Comparison of pre- and postmaps
- Comparison of maps measured under different conditions
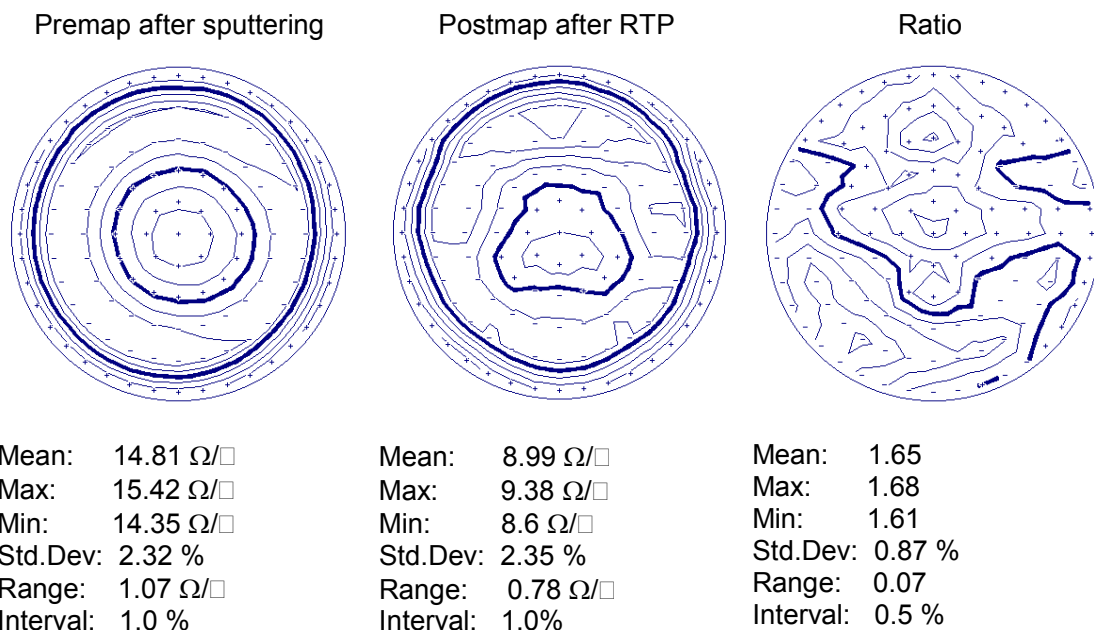- Comparison of different metrology tools

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Comparison of pre- and postmaps:

One application of interest is to compare so-called pre- and postmaps. E.g. in case of Ti deposition the sheet resistance after sputtering can be mapped and compared to the resulting sheet resistance distribution after a following Rapid Thermal Processing step. The ratio map will visualize the influence of the Rapid Thermal Processing equipment (and possibly other influences such as problems during wafer cleaning before sputtering).

Example:

Titanium was sputtered with 600 Å thickness on a 200 mm prime wafer. Then the wafer was annealed in an RTP chamber at approximately 700°C in pure nitrogen. The sheet resistance was mapped before („premap", Fig. 1) and after the RTP step („postmap", Fig. 2). The ratio was calculated between both maps (in WAFERMAP for Windows select „Multi-File-Operations"→ „Compare"→ select the files in the 2 windows on the left → choose „X/Y" in the center → click on „OK"). The result (Fig. 3) shows the characteristics of the RTP chamber.

Premap after sputtering	Postmap after RTP	Ratio

Mean: 14.81 Ω/□	Mean: 8.99 Ω/□	Mean: 1.65
Max: 15.42 Ω/□	Max: 9.38 Ω/□	Max: 1.68
Min: 14.35 Ω/□	Min: 8.6 Ω/□	Min: 1.61
Std.Dev: 2.32 %	Std.Dev: 2.35 %	Std.Dev: 0.87 %
Range: 1.07 Ω/□	Range: 0.78 Ω/□	Range: 0.07
Interval: 1.0 %	Interval: 1.0%	Interval: 0.5 %

Figs. 1-3

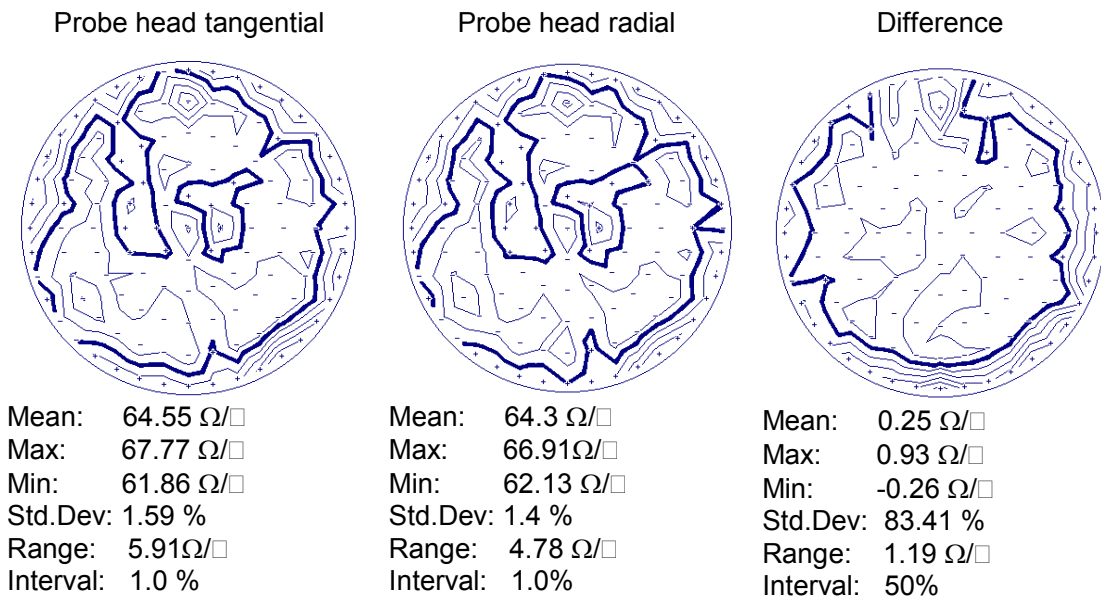**Comparison of maps measured under different conditions:**

Another application is the comparison of maps generated on metrology tools such as 4 point probes or ellipsometers using the same test wafer. The resulting map will visualize differences between these tools.

Example:

Sheet resistance measurement of a 200 mm As implant-annealed wafer is chosen. 121 sites with 5 mm edge exclusion are measured using an automated 4 point probe system. This tool allows for changing the direction of the probe head, so that the 4 points are arranged either radially or tangentially to the wafer periphery.

Shown below are two measurements on the same tool, using the same wafer, but with different adjustments of the probe direction (Figs. 4, 5). It is obvious, that there is almost no visible difference in the shape of the contour lines. Only the difference map (Fig. 6) is able to show the real difference (in WAFERMAP for Windows select „Multi-File-Operations"→ „Compare"→ select the two files in the 2 windows on the left → choose „X-Y" in the center → click on „OK").

The direction of the probe head arrangement has a direct influence mainly in the wafer edge region.

Probe head tangential	Probe head radial	Difference

Mean: 64.55 Ω/□	Mean: 64.3 Ω/□	Mean: 0.25 Ω/□
Max: 67.77 Ω/□	Max: 66.91Ω/□	Max: 0.93 Ω/□
Min: 61.86 Ω/□	Min: 62.13 Ω/□	Min: -0.26 Ω/□
Std.Dev: 1.59 %	Std.Dev: 1.4 %	Std.Dev: 83.41 %
Range: 5.91Ω/□	Range: 4.78 Ω/□	Range: 1.19 Ω/□
Interval: 1.0 %	Interval: 1.0%	Interval: 50%

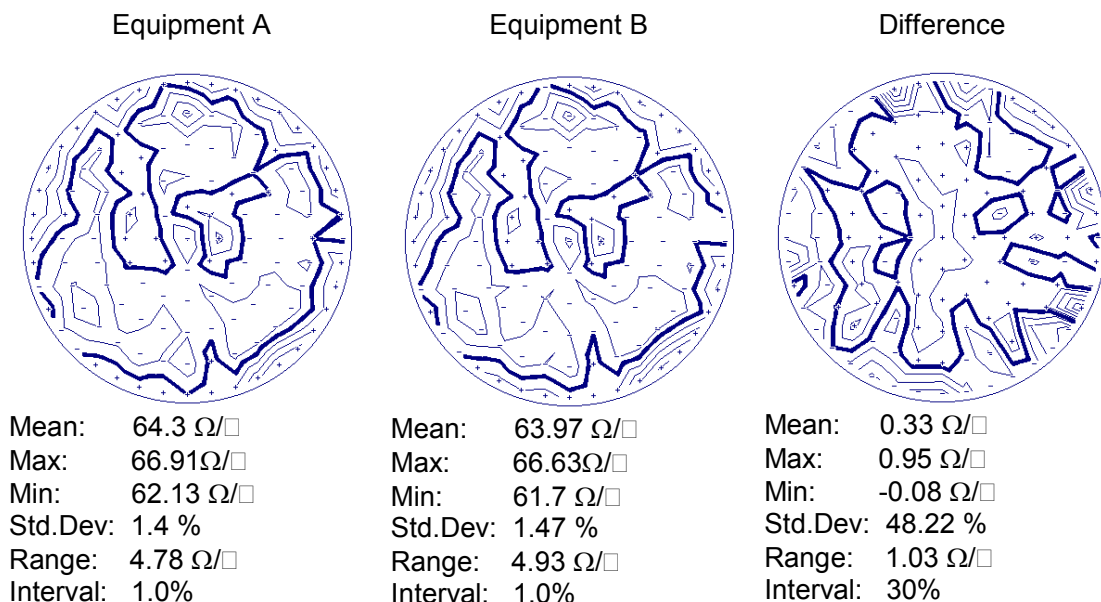Figs. 4-6

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Comparison of different metrology tools:

Another interesting application is the comparison of different metrology tools using the same test wafer. If both tools are in best conditions, the difference should be almost 0 and the resulting map should show statistically distributed differences. In other words, no distinct shape of the contour lines should be visible.

Example:

A 200 mm As implant-annealed wafer is chosen to measure the distribution of sheet resistance. 121 sites with 5 mm edge exclusion are measured. Two different 4 point probe measurement systems were used (A and B). Shown below are both maps (Figs. 7, 8) and the calculated difference between both (in WAFERMAP for Windows select „Multi-File-Operations"→ „Compare"→ select the two files in the 2 windows on the left → choose „X-Y" in the center → click on „OK", Fig. 9).

The mean value varies slightly, the standard deviation is almost the same. There is no obvious difference between both maps visible, especially the difference map shows no „signature".

Equipment A	Equipment B	Difference

	Equipment A		Equipment B		Difference
Mean:	64.3 Ω/□	Mean:	63.97 Ω/□	Mean:	0.33 Ω/□
Max:	66.91Ω/□	Max:	66.63Ω/□	Max:	0.95 Ω/□
Min:	62.13 Ω/□	Min:	61.7 Ω/□	Min:	-0.08 Ω/□
Std.Dev:	1.4 %	Std.Dev:	1.47 %	Std.Dev:	48.22 %
Range:	4.78 Ω/□	Range:	4.93 Ω/□	Range:	1.03 Ω/□
Interval:	1.0%	Interval:	1.0%	Interval:	30%

Figs. 7-9