Customized Solutions for Quality Control

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Quality and process control in micro and nanotechnology or semiconductor business is indispensable, because customer requirements are getting more specific. Very small structures have to be measured quickly with highest accuracy and resolution, because each failure in every individual process step has an impact on the quality of potentially all subsequent processes. This requires a lot of different measurement types like critical dimensions, alignment, step height- and thin film measurements.

Against the background of the above mentioned business and the demand on their process flow and their quality, several measurement methods for process control were established, e.g. interferometer or stylus profiler for topography measurements, image analysis systems adapted to a microscope for inspection und lateral dimension measurements of lithographic structures as well as white light interferometry or ellipsometry to measure photo resist thicknesses.

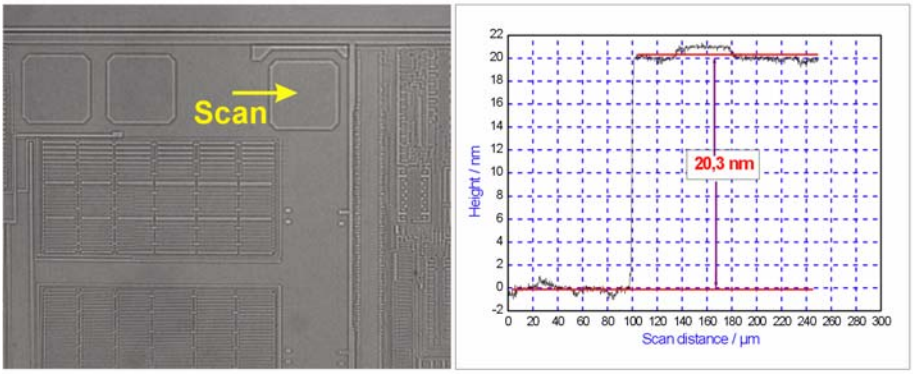
In contrast to methods like stylus profilers, optical measurement systems are preferred, because they allow contactless measurements, high throughput and the automation of the complete measurement cycle.

Standard metrology tools are typically designed for one specific measurement. In many cases they do not totally fulfill the customer requirements.

Figure 1: Integrated Solution for Data Storage Industry, MIPS-2 MT

The MIPS-2 MT (miniature interferometric phase sensor –2 metrology tool, see figure 1) as an example of a customized half automated solution integrates several non-destructive measurement methods, like differential laser interferometry, image analysis and white light spectrometry. This increases significantly the efficiency of production control. Besides the demand on the measurements a small footprint and maintenance convenience are features customers are asking for.

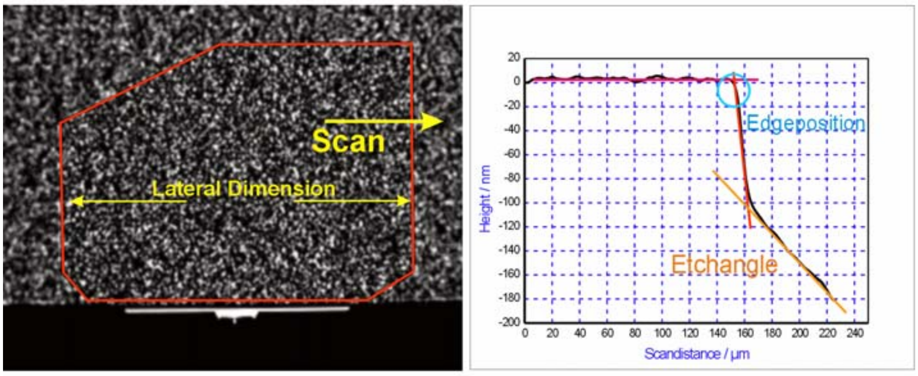
For interferometric measurements, two laser beams are focused on the sample surface. The height difference between the two beams will be analyzed by detecting the phase difference after reflection. The accuracy of this measurement is about 1 nm. The sample itself can be moved beneath the interferometer by a 3 axis piezo stage in order to detect the topography structure. The piezo stage has a lateral range of 800 µm to 800 µm and a range in z-direction of 200 µm. The lateral positioning accuracy is about 0.05 µm with a positioning repeatability of 0.01 µm. Figure 2 shows an example of a MIPS-2 MT profile measurement on a semiconductor wafer as well as the comparison to AFM step height measurements.



Step Height		
AFM nm	MIPS-2 nm	|Diff.| nm
7.2	7.7	0.5
13.4	14.4	1.0
20.2	20.3	0.1
34.4	34.3	0.1
42.7	43.3	0.6
98.6	100.0	1.4
122.3	120.3	2.0
176.6	176.0	0.6
180.3	179.7	0.6
Correlation: R^2 = 0.99		

Figure 2: Scan of a step on a semiconductor wafer. The right hand table shows the comparison between AFM measurements and the corresponding MIPS-2 MT step height measurements.

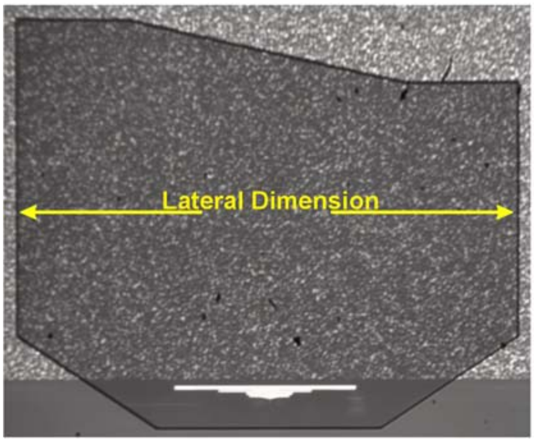
Topography structures with low contrast to the background material are often not directly accessible for image analysis measurements. Using the laser interferometer in combination with the lateral movement of the piezo stage allows to measure such low contrast structures. This situation arises i.g. by estimating the lateral dimensions of the read-write head flight structure in the data storage fabrication, see Figure 3.



Lateral Dimension		
PTB µm	MIPS-2 µm	|Diff.| µm
329.72	329.60	0.120
329.83	329.66	0.170
329.94	329.79	0.150
330.44	330.27	0.170
330.63	330.53	0.100
331.04	331.21	0.170
331.15	331.29	0.140
331.25	331.35	0.100
331.45	331.63	0.180
331.63	331.81	0.180
Correlation: R^2 = 0.99		

Figure 3: Scan on a milled structure. Because of the low contrast, the structure is highlighted by a red line. The right hand table shows the results of the MIPS-2 MT measurements. The results are compared to measurements of the lateral dimensions of the stepper mask that was used to create those structures. These values were characterized by the PTB (Physikalisch Technische Bundesanstalt, Braunschweig) and used as a lateral standard.

The MIPS-2 MT system is equipped with an image analysis unit (high-resolution CCD camera) that is used to align and focus the sample in an automated measurement routine. In combination with integrated image analysis algorithms lateral dimensions as well as alignment values can be measured with high precision. Figure 4 shows the accuracy of such an image analysis measurement.



Lateral Dimension

PTB µm	MIPS-2 µm	|Diff.| µm
329.83	329.99	0.16
330.07	330.12	0.05
330.25	330.29	0.04
330.44	330.44	0.00
330.63	330.56	0.07
330.83	330.78	0.05
331.04	331.02	0.02
331.25	331.26	0.01
331.45	331.43	0.02
Correlation: R^2 = 0.99		

Resist Thickness

Tencor µm	MIPS-2 µm	|Diff.| µm
6.075	6.060	0.015
6.020	6.020	0.000
6.014	6.000	0.014
5.987	5.980	0.007
6.237	6.220	0.017
6.212	6.200	0.012
6.274	6.280	0.006
6.144	6.180	0.036
6.040	6.060	0.020
Correlation: R^2 = 0.96		

Figure 4: The left hand picture shows a photo structure that is processed by image analysis. The table in the middle of the figure contains the comparison between the measured dimensions and the corresponding stepper mask dimensions introduced in Figure 3. Simultaneously it is possible to measure the thickness of such a photo structure. The results are compared to measurements performed with a stylus profiler (Tencor P-11 profiler).

In order to measure the thickness of a photo resist structure, a fraction of the back reflected illumination light is detected by a white light spectrometer. The results of this non-invasive measurement are compared with the measurement on a stylus profiler (Tencor P-11) and shown in the right hand table of Figure 4.

Conclusion

The contactless measurement of structures with high accuracy and high throughput is a big challenge. The interest in high precision and compact customized systems to optimize production control and to minimize costs is gaining of prime importance.
The MIPS-2 MT System is a good example for special tool design by considering customer requirements for the integration of techniques.