ONYX: A New In-Line & Non-Destructive Hybrid Technology for Semiconductor Metrology

By Benny Donner, Roni Peretz and Brad Lawrence, XwinSys, Israel

Abstract: XwinSys has recently launched the 'ONYX' - a novel in-line and non-destructive hybrid metrology system, uniquely integrating advanced XRF, 2D and 3D optical technologies, designed to meet the current and future metrological challenges of the semiconductor industry.

Introduction

The increasing complexity of materials and geometries in modern semiconductor manufacturing is driving the need for advanced metrology techniques and methodologies. The industry is experiencing a movement of sophisticated off-line analytical metrology tools into the fab line providing automatic in-site process control. Multi-sensor technology combined with holistic software appears to be the path of choice for metrology in the fab.

Metrology suppliers have been compelled to combine enhanced resolution, advanced imaging and smarter applications to meet the increasingly complex requirements of chipmakers, on their transition to advanced nodes and 3D devices. Optical CD and X-ray metrologies are at the leading edge of these increasingly demanding requirements.

Yield loss at assembly is extremely expensive, since the wafer has a high value at this step. Resolving defects can manifest as a yield problem, but usually result as a reliability problem making it harder to detect and control. Missing layer detection and the ability to measure ultra-thin metal stacks with complicated interface characteristics are another crucial challenge that requires creative solutions.

The ONYX system addresses these challenges by leveraging the integration of three complementary technologies to achieve state-of-the-art synergic performance.

ONYX – Innovative Hybrid Technological Integration

A comprehensive process control strategy for the complex flow of chip making, requires a multi-discipline inspection and metrology capability; the strategy of combining automated optical inspection techniques with X-ray fluorescence technology and software to analyze defects and metrology data, is considered to be an efficient and cost effective approach for inspecting features and managing visible and non-visible defects in advanced assembly flows.

FIGURE 1: The ONYX System

Innovation

The ONYX integrates enhanced ED-XRF micro-spot analysis, 3D scanning and 2D microscope technologies (Figure 3), and unique integrative software to operate in one fully automated system, serving in-line and non-destructive applications. The result of this unique integration is a synergic effect that enables dealing with complex applications in the following way: Geometrical parameters can be monitored easily with high throughput and precision with the optical components and include feature width, length, height, shape and surface. By measuring with the enhanced ED-XRF component, material and volumetric parameters can be obtained such as film thickness and composition.

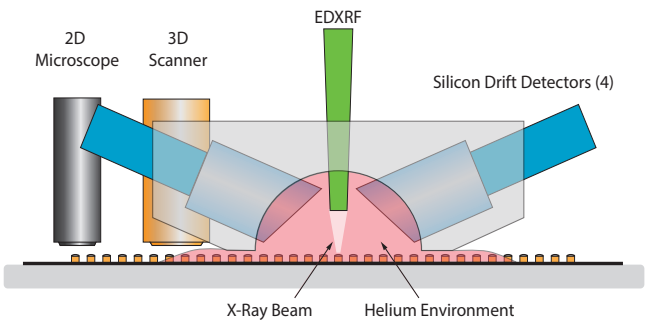

FIGURE 2: Hybrid Module

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The integrated system of individual sensors creates a synergistic approach to problem solving and product monitoring. By integrating the component outputs, full scaled inspection parameters can be obtained: voids or missing layers can be detected and analyzed by comparing the geometrical volume to the atomic volume; multi stack layer's thickness and composition can be monitored by both optical and XRF components. This unique hybrid configuration of the ONYX enables a solution to challenging applications through various analytical approaches.

Reliability

The capability to integrate three measuring technologies and offer holistic application solutions, makes the ONYX a value add metrology tool rendering analytical techniques appropriate to the process requirements.

By offering solutions for monitoring physical parameters, the ONYX becomes a key tool enabling consistent processing:

- Perform thickness measurements of metal film stacks with XRF and 3D Scanning
- Measuring feature dimensions with the 3D Scanner and 2D Microscope
- Stable and accurate Z-axis control (focus) by the 3D Scanner and 2D Microscope
- Verify XRF thickness standards with 3D Scanner
- Detecting specific mis-processing out of a multi-variable metrology application
- Algorithm compensation for one parameter variation of a film stack

As part of the metrology adaptation to the process constraints, the ONYX system can monitor a film stack in one shot on a production wafer. Multi stack monitoring is available for any requirement: first layer thickness, third layer thickness, total feature height, composition, process defect, and more.

Flow-Ability

The ONYX is equipped with a wide range of advanced options, allowing quick decision making in a plurality of requirements. Yet its operation and maintenance are easy and simple, unimposing to the process flow.

Process monitoring using the ONYX enables several physical parameters to be measured across the wafer, wafer to wafer, and lot to lot - ensuring the process is in control.

SPC in the fab of all the process tools is a requirement for high quality production. The ONYX can measure several of these parameters with its hybrid techniques which were only possible with off-line analytical tools in the past. This includes the ability to measure and report excursions, which, if gone undetected, could cause a significant yield reduction.

ONYX's unique capability to quickly select or alter an in-line inspection recipe, with a single click adds in-depth metrology feedback, without interrupting the process flow, bringing a significant value for process control requirements.

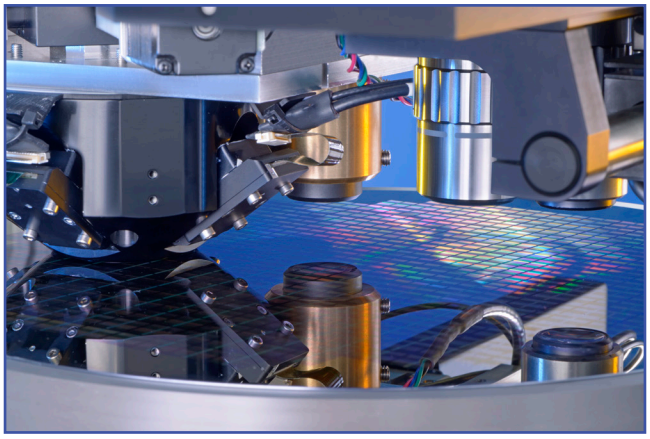

FIGURE 3: Hybrid Configuration

As a multiple integrated technology system, the ONYX efficiently handles multi-variable problems by using intelligent state-of-the-art analytical software algorithms which are capable of isolating the problem and contributing data to calculate the best solutions.

The ONYX challenges the existing metrology market by uniquely allowing multiple options and methods to monitor the process, and fit the metrology to the specific process needs, all in real time and in a non-destructive manner.

Summary

The ONYX system incorporates enhanced ED-XRF with 3D Scanning and 2D Microscope technologies, and offers a unique integration of capabilities to determine metal film stack composition and thickness together with 3D geometric structural analysis.

This unique triple-mode technology is designed to serve multiple in-line and non-destructive metrology and inspection needs in the semiconductor and related micro-electronics industries.

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Case Study:

The feature illustration below (Figure 4), represents a typical industry requirement for several critical parameters to be measured and quantified: Critical Dimensions (CD), total feature height, upper metals concentrations and individual layer thickness (Metals 1-3).

To resolve this kind of challenge, geometrical and atomic data are needed, hence requiring X-ray and optical technologies combined - a solution which was absent in the industry until now.

Another typical challenge for the XRF tool in providing layers' thickness is the difficulty to distinguish between Metal 1 and M1 readings (usually being the same metals). To date this problem could not be addressed in-line and in one integrative system.

A unique (patent protected) solution for these challenges is offered by the ONYX:

- XRF measures thicknesses of Metal 2 & 3;
- 3D Scanner measurs the feature total height and surface roughness;
- 2D Microscope measurs the CD values.

A simple deduction of Metal 2 & 3 thickness (XRF) from the total height (3D Scan) provides Metal 1 thickness, in a quick and non-destructive method; Table 1 below demonstrates the full data display of 20 repeating runs over 8 sites - obtained by one recipe run in a single click.

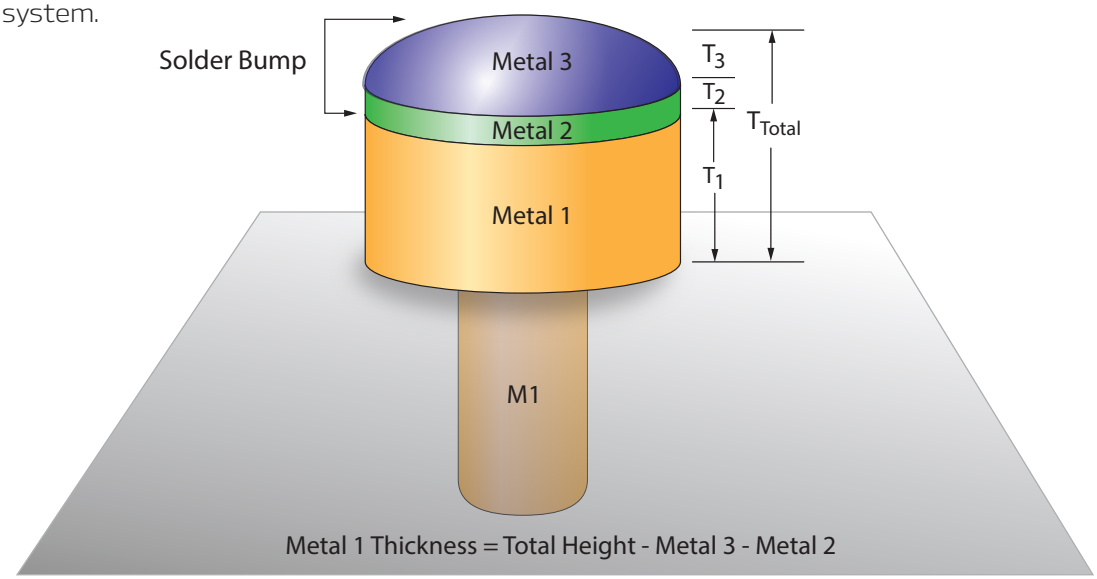

FIGURE 4: Multi-Stack Application

TABLE 1:

Site	XRF Results (µm)			2D Mic (µm)	3D Scan (µm)	Calculation (µm)
	Average %Ag [Wt]	Solder Layer	Ni Layer	CD	Total Height	Cu Thickness
1	1.72	12.70	2.56	40.12	39.40	**24.14**
2	1.67	13.77	2.31	39.59	41.15	**25.07**
3	1.82	12.59	2.03	39.76	37.90	**23.28**
4	1.90	12.52	2.39	39.65	37.23	**22.33**
5	1.67	12.40	2.31	39.95	39.98	**25.27**
6	1.73	13.51	2.10	39.82	39.49	**23.88**
7	1.70	15.12	2.01	39.58	42.16	**25.04**
8	1.79	13.73	2.34	39.68	40.36	**24.29**

This unique and reliable solution can also address other similar application in a non-destructive manner, i.e. UBM, RDL and other bump or feature oriented layers monitoring.