INNOVATIONS IN INTEGRATED METROLOGY

Asaf Baran[1], Ovadia Ilgayev [2]

[1]Nova Ltd asaf-b@novami.com

[2]Nova Ltd ovadia-i@novami.com

5 David Fikes St., Rehovot 7632805, Israel

Integrated metrology (IM) serves as the workhorse metrology in manufacturing and is a key enabler for process control. Integrated tools typically reside on the same platform as the process tool and allow easy, dedicated feedforward and feedback for automatic and much tighter process control. This technique has been proven to improve process variability (Cpk), is commonly used in fabs, and is an enabler for efficient re-work.

In-die-based W2W (Wafer-to-Wafer) and WIW (Within Wafer) control is essential to yield performance, in advanced technology nodes. Increased complexity of design rules and more process steps add new requirements for integrated metrology. Strong demand to measure directly on the device for better process control, new requirements for measurement of thin residues directly on structure, more parameters to be extracted from each measurement, e-test results prediction and tightening of process windows all require continuous innovations in integrated metrology solutions. All these requirements need to meet sampling and cost of ownership targets for High Volume Manufacturing (HVM) control. Recent developments in Machine Learning (ML) can be implemented with IM solutions to comply with such requirements.

ML has exhibited an increased demand in semiconductor fabs, and its presence is rapidly growing. There are multiple reasons to adopt ML solutions in HVM fabs, such as fast time-to-solution, measurement error reduction, and high productivity. ML solutions, leveraging high-accuracy reference metrology data and/or electrical test data, have been proven to optimize measurement sensitivity to actual process excursions that correlate to the electrical data.

As a market leader, Nova continues to drive both ML and HW innovations into the IM world. Such innovations include new process control capabilities enabled by advanced Machine Learning algorithms as well as Multi-Channel Integrated Metrology (MC IM). In this paper we will discuss and demonstrate these and other new directions to enhance IM.

Design complexity in advanced technology nodes derives a requirement to measure directly on a device on the Memory cell or on complex structures such as SRAM and Ring-Oscillator in order to better predict device performance. Implementing advanced ML algorithms with IM measurements can eliminate scribe-line and in-die error, and enable accurate and fast measurements on such structures. We will show that the overall metrology performance could be improved by using ML with IM measurements, including matching-to-reference, repeatability, and T2T.

A vital application use case that we will examine is ultra-thin residue detection on a structure. Post CMP residues are critical for process control and yield enhancement. In-die detection of remaining dielectric or metal layers, post-CMP process, pose challenges for control for various reasons, such as low sensitivity, complex modeling, and longer time-to-solution. Using Multi-Channel IM, we can utilize high sensitivity with an Oblique channel for thin layers and obtain excellent performance for such layers measured on complex 3D structures. In order to further enance the measurement, we utilize the known and already FAB-proven technique of in-line XPS. XPS is a direct quantitative high-accuracy reference that enables the extension of IM capability for challenging residue detections. Combining reference information from an XPS tool, ML algorithms, and IM measurements makes it possible to achieve $<20A$ sensitivity for residues on the IM platform, allowing every wafer, and within wafer, residue detection (see Figure 1).

Can we extend CMP process control beyond standard OCD measurement? An excellent case is Metal CMP resistivity control. Current measurement techniques, such as in-line electrical tests, introduce many challenges, including low throughput and productivity, Q-time violation, and defects due to contact-based measurement. The end-of-line (EOL) electrical test is an impressive technique, however, it does not allow early excursion control. On the other hand, due to continuous scaling of BEol Metal lines, trench measurement does not adequately predict e-test results. IM measurement with ML, labeled by the electrical test measured directly on e-tests, shows excellent correlation to EOL e-test. Such a methodology demonstrates high TPT performance, allows high sampling for WIW and W2W control, and completely eliminates any Q-time concern (see Figure 2).

An additional IM use case is the ability to monitor in-die dishing and erosion. We have demonstrated that combining an IM signal with an ML model labeled by AFM allows in-die dishing/erosion monitoring, excursion prevention, and CMP quality control for every wafer (see Figure 3).

In conclusion, we have demonstrated recent innovations in metrology solutions, such as the Multi-Channel IM tool, which enhances measurement sensitivity with additional measurement channels and ML-driven solutions that add unique metrology capabilities beyond standard OCD measurements.

Corresponding Author:
Asaf Baran
Tel: +972-54-4488176
E-mail: asaf-b@novami.com
5 David Fikes St., Rehovot 7632805, Israel

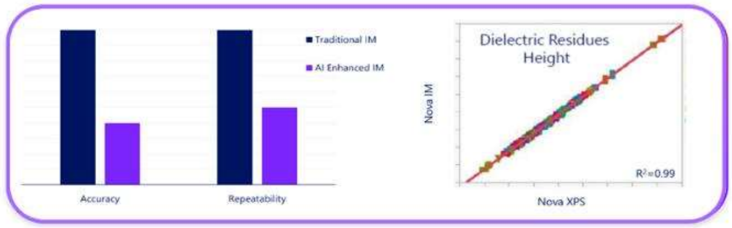

Fig.1 In-die ultra-thin residue metrology

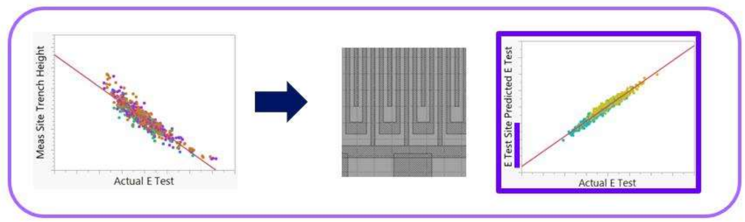

Fig.2 Resistivity control with IM measurements with ML

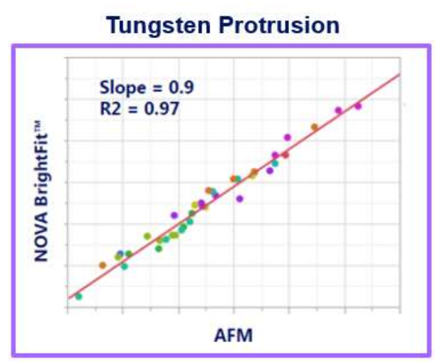

Fig.3 IM measurement of W Protrusion using AFM labeling

Preference: ☐ <u>**Oral**</u> ☐ Poster

Topic Area: <u>**Semiconductor**</u>