Overview of Inline Metrology Challenges in IC manufacturing environment

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It is widely acknowledged that inline Metrology is a powerful enabler that speeds up the introduction of new technologies, secures the ramp-up of pilot lines, and improves yield in mature factories. Inline Metrology reduces the cost of manufacturing and development by providing valuable and extensive characterization of processes and products directly at the manufacturing line. Over the years, as technology requirements became more demanding, inline metrology had to constantly evolve and adapt to keep up with shrinking dimensions, atomic-scale layer thickness, and new 3D architectures. The increasing demand for ICs in the automotive market has led to a reinforcement of quality requirements associated with measurement system and product control plan management. Therefore, one of the major challenges in metrology is to maintain the level of performance for the key criteria, namely accuracy, sensitivity, stability, capability, and productivity, over the years.

From a technical perspective, classical inline metrologies, which were mostly based on optical techniques and scanning electron microscopes, have been reaching their limits since the development of More Moore technology nodes below 45nm. To measure thin and ultra-thin films, the industry had to rapidly adopt X-Ray based techniques such as XPS, HRXRD, and XRR, which were traditionally restricted to offline laboratories. To measure Optical CD, the complexity of 3D pattern structures has led to the introduction of Muller matrix and the combination of multiple optical modules for model fitting, while overlay techniques have moved from image-based to diffraction-based techniques. Overall, metrology techniques have continued to evolve towards more complex model-based techniques that support multiple physics and multi-scale parameters. On the other hand, for More than Moore applications, the introduction of a large number of new materials and the adoption of complex 3D stacking architectures have led to the emergence of new requirements, such as mechanical and thermal properties, adhesion strength, and piezoelectric characteristics (Fig.1). In general, industrial metrology solutions can be found by adapting existing laboratory techniques to fulfil industry standards and/or by creating prototypes through common development between IC makers and key suppliers from the sector. This collaborative approach is particularly important for inline metrology because all contributors share the same need for an anticipatory approach to ensure that adequate control methods are ready ahead of process qualification steps.

To push the limits further, other methodological approaches such as feed-forward strategies and Hybrid metrology (combining data from complementary techniques) have also been explored [1]. In the context of industry 4.0 evolution, metrology techniques themselves, and more specifically the way information is extracted from the given signal or image, are also evolving. With the introduction of Neutral Network and Deep Learning algorithms, the raw signal can now be exploited in a different way to extract the maximum level of information from a measurement step [2]. Metrology can now be applied to detect anomalies (for example, Good/Bad categories) rather than just extracting precise physical or chemical quantities [3]. In this context, the borders between metrology and defectivity activity domains are blurring, opening the door for the Metro-Spection concept (Fig.2). As a result, metrology, which still requires a background in SC fabrication, process, measurement technology, and physics, is now expanding its required skills to include data science for quick adoption. Some relevant application use cases related to MetroSpection will be presented and discussed in the oral presentation.

References

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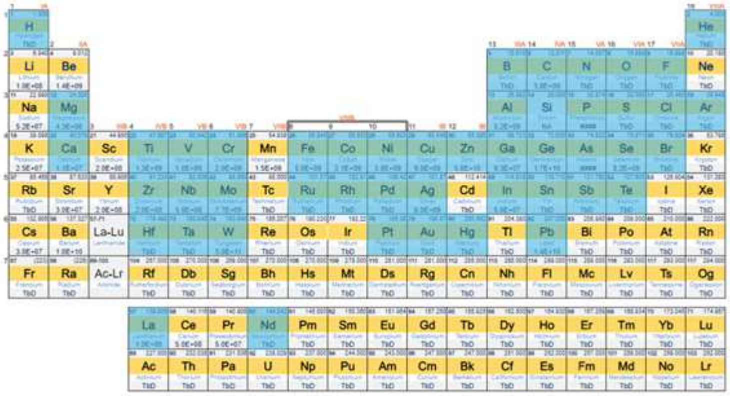

Figure 1: Example of chemical elements introduced in IC manufacturing (highlighted in blue).

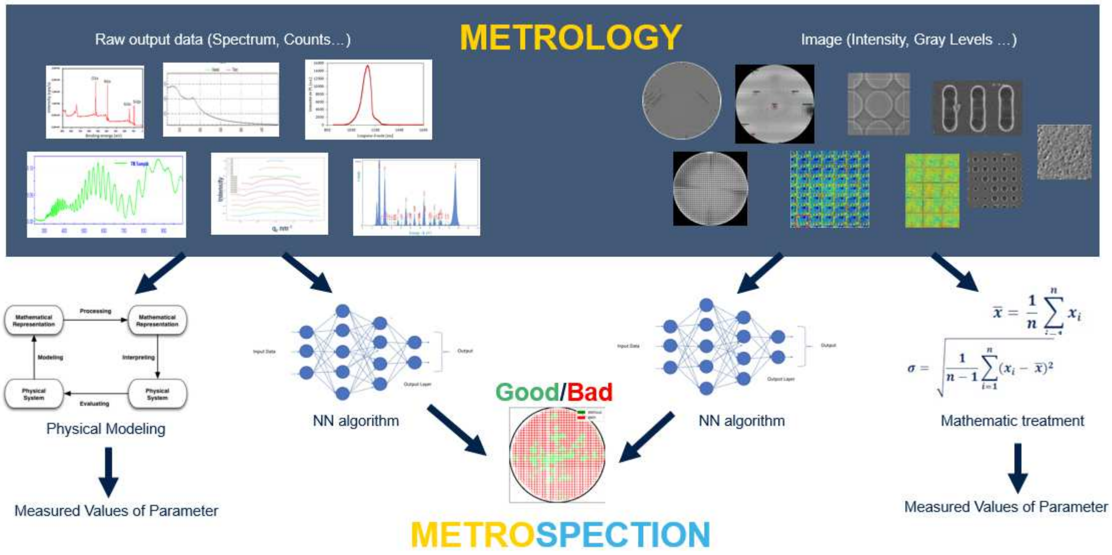

Figure 2: MetroSpection Concept. Metrology raw outputs being used for Good/Bad assessment.