ID PC-O-034

Frame for Virtual Metrology Implementation Technology Investigation from QC Operation Aspect -

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1. Introduction

The frequency and the number of points of metrology have ever been increasing for process outcome confirmation due to the narrower process windows and the stronger demand for the metrology of process control purposes as well. Virtual Metrology (hereafter VM) has been drawing more attention as one of the solutions to this problem.

This report will discuss the intrinsic VM needs and how it is expected to be implemented from manufacturing operation perspective and a discussion frame for VM implementation technology based on the article investigation on VM conducted by Selete.

2. VM technology positioning based on VM article investigation

Summary of VM technology investigation on the articles (presentations) that appeared in APC/APC symposium after 2005 is shown in Table 1. The technology positioning is graphically represented in Figure 2. VM technology positioning requires basically 2 aspects; solution provision for production challenges and technologies that enable VM implementation.

2-1. Positioning from solution provision for production challenges

The driver of the strong VM expectation turns out be the reduction of time lag from the metrology step to confirm the process outcome to the timing of feedback to the process or equipment. It is thought important that the metrology data is to be made available within a time period given for the process quality control standpoint.

This needs can be understood as essentially equivalent needs as the enhancement of metrology affiliated in the process quality management layer of the process quality control operation perspective (Fig., 3).

2-2. Positioning from enabling technology standpoint

VM has to fulfill the technology requirements that endorse the realization of operational desire of 2.1. VM is expected to fulfill the general requirements as metrology technology.

VM implementation needs to be planned so as to deliver metrology data and some kind of needed decisions within a shorter time period, consequently, VM is to rely on the source data that can be acquired much earlier than from ordinarily metrology data. The source data, in many cases, is not affiliated with the same process quality data layer. The algorithm for those metrologies should measurement estimation across the quality control layers. VM can be, thus as mission wise, defined as “measurement value estimation using the source data from the different process quality operation layer than the estimation so as to provide expected outcome at earlier timings or more points that are usually provided by the real metrology means

3. VM Implementation and Challenges

VM functions are divided into 2 categories as shown in Fig. 2; data collection, model development and metrology operation. The corresponding functionalities are summarized in Table 2 with an aspect of the relation between the expected functional items and the corresponding technologies. Data collection, data preprocessing, estimation model development, and estimation model renewal have strong relation with the expected measurement functional items.

Development procedure of the metrology value estimation is based on statistical data analysis according to the article investigation as shown in Table 1. There are some articles that argue necessity of physico-chemical modeling in the process.

Table 3 shows the relation between metrology value estimation model development procedure and the expected functional items. Accuracy, repeatability, reproducibility are important as metrology technology. It is understood that the chemical/physical model or equivalent model inclusion is important from this table.

4. Discussion frame that facilitates VM technology discussion

If it is assumed that this symposium is to start a VM dedicated session in order to encourage more technical discussions, it is necessary to include 6 items of Table 4 into discussion. This will facilitate more effective and efficient information exchange of VM technology.

Many articles dealt with items #2 and #3 and 2 papers dealt with #4 within the coverage of the investigation.

For #1 it is expected that applied workflow, targeted characteristics (process outcome or equipment process performance adjustment), and to-be requirements are to be dealt with so to describe what are the boundary conditions are for the technology of interest as much as possible.

For #5 it is expected that model’s coverage such as effective term and applicable processes or the boundary conditions as well as tuning cycles are to be discussed. The discontinuity of the model application over the maintenance work on the equipment should be dealt.

For #6 it is expected that not only the IT system configuration is discussed but the generic requirements such as data format alienation and data characteristics extraction as preprocessing with hierarchical process quality assurance is to be dealt with consistent clarity of hierarchical affiliation of source and metrology data.

In the future VM will be enabled to provide effective metrology data for those not estimated today such as 3D measurement with the aid of this same discussion frame, and eventually it will contribute more elaborated semiconductor production technology development.

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Table.1. the article investigation Result on VM

Objectives	Time lag elimination (metrology data delivery time reduction) Electrical characteristics estimation as process quality results Reduce metrology cost (tool purchase and running cost reduction) Improve tool utiliztion (Reduce false fail?) Reduce test wafer # Improve yield (more accurate process control and reduce tool downs)
Target process	Plasma etch, deposition, CMP, electro-plating CVD, Oxidation, Lithodgraphy, RTP
Source data	・MES ・FDC ・RealMetrology ・Process parametric trace data (RF power, Pressure, Temperature, Gas flow, etc.)
Preprocessing of source data	・Abnormal data filtering, ・Unstable data filtering and reduction. ・Averaging, standard diviation, frequency component analysis, data mining ・Data compression, Data summarization
VM modeling approaches	Statistical modeling: 8 papers Principal components: 1 paper Neural Network aproach: 2 papers PLS method: 5 papaers Linear regression: 1 paper Needs of physico-chemical models: 2 papers
Utiloization of VM output	SPC of VM results as well as the real metrology results VM-APC FDC, remote disgnostics, chamber matching, equipment diagnostics
Effect	・ Tool OEE (overall equipment efficiency) 5-10% improvement Reduction of tool monitoring freqency C/W reduction of 20-40% Reduction of monitoring wafer and related material reduction Human productivity improvement as much as 5% Day-to-day monitoring operation reduction
Others	Data utilization ssytem establishment for VM

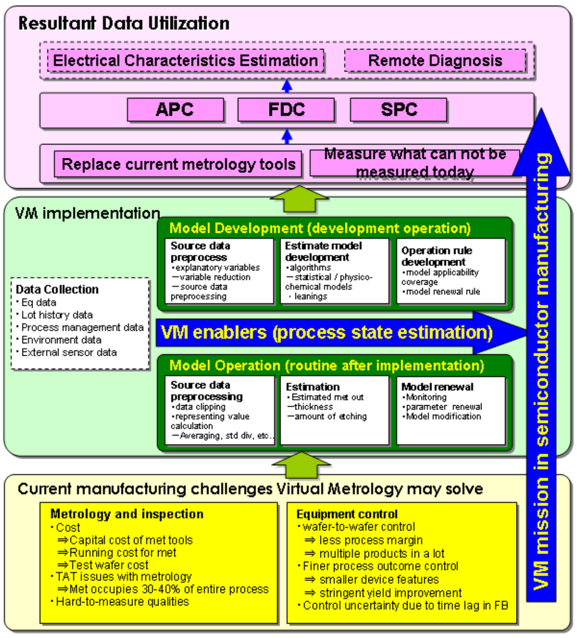
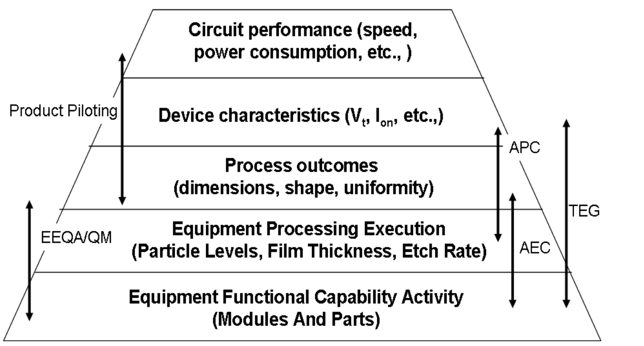


Fig.1. The VM technology positioning



F1g.2. Process Quality Model Chaining Hierarchical Quality Layers

Table.2 Relation between the expected functional items and the corresponding technologies

Requirement items	Data Collection	Model Development: Source data PreProcessing	Model Development: Estimation Model	Model Development: Operational Rule
Metrology data delivery tim	X	X	X	
Trueness	X		X	
Precision	X	X		
Conformality	X	X	X	
Repeatability			X	X
Reproducibility			X	
Correction				X
Bias			X	
Error	X	X		

Table.3. Relation between VM Model development and Expected functional items.

	Model development approaches	
	Statistical model	Physico- chemical model
Metrology value estimation based on source data from other than process quality control layer	"Modeling" is highly flexible but lacks reasoninig "No model is correct, but some are useful." (Comment: above is the aphorism for statistical analysis.)	Model that provides the reasoning
Accuracy	Depends on the variability of the source data	Valid so long as the reactions for the process remain same
Repeatability	Valid so long as the paprent population remains unchanged upon process setting change	Valid so long as the reactions for the process remain same
Reproducibility	Valid so long as the paprent population remains unchanged upon process setting change	Valid so long as the reactions for the process remain same

Table.4 Discussion frame that facilitates VM technology discussion

#	Expectation	Contents
1	Mission	Positioning of the VM technology in the paper (why is it have to be VM rather than real metrology? What operation of manufacturing is VM result intended to be applied? (AEC/APC/or equipment performance adjusting?)
2	Positioning	Positioning of the VM technology in the paper to show which layer of process quality assurance is extimated using data come from which layer
3	Validation of estimation	Conformance validation of VM resltant data as metrology
4	Model validation	Physico-Chemisto model validation or reation modeling validation
5	Effective time period of models Reproducibility Deployability	Model applicability coverage (equipment, equipment types, time period, maintenance event dependancies) Examples ・Lateral deployment to the other tools ・Model coefficients' effective time of period ・Model applicability across such events as equipment maintenance
6	implementation common requirement (data flow)	Source data requirements, reporting data format (items and structure), preprocessing methods