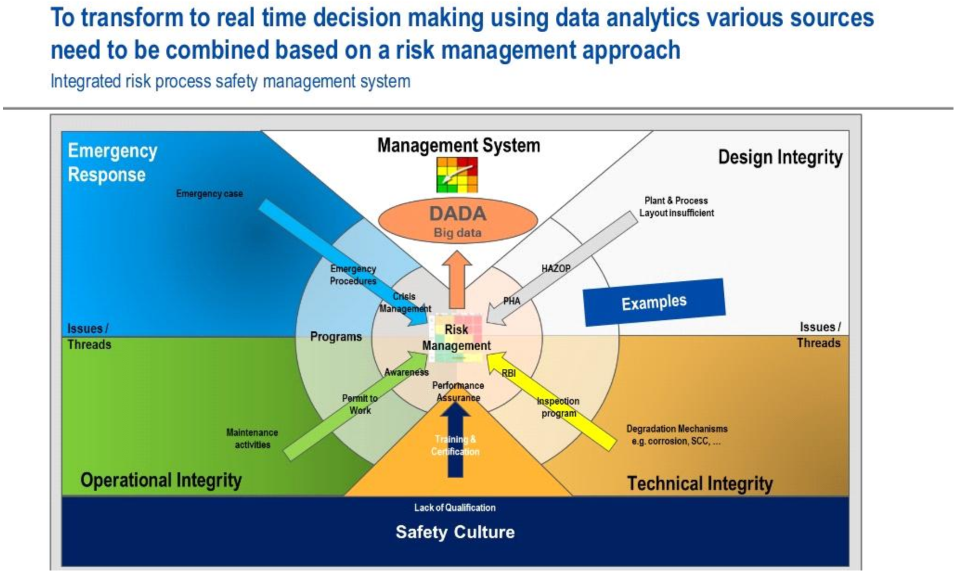
Big Data Analytics 활용을 통한 (반도체)공정 모니터링 및 안전 향상

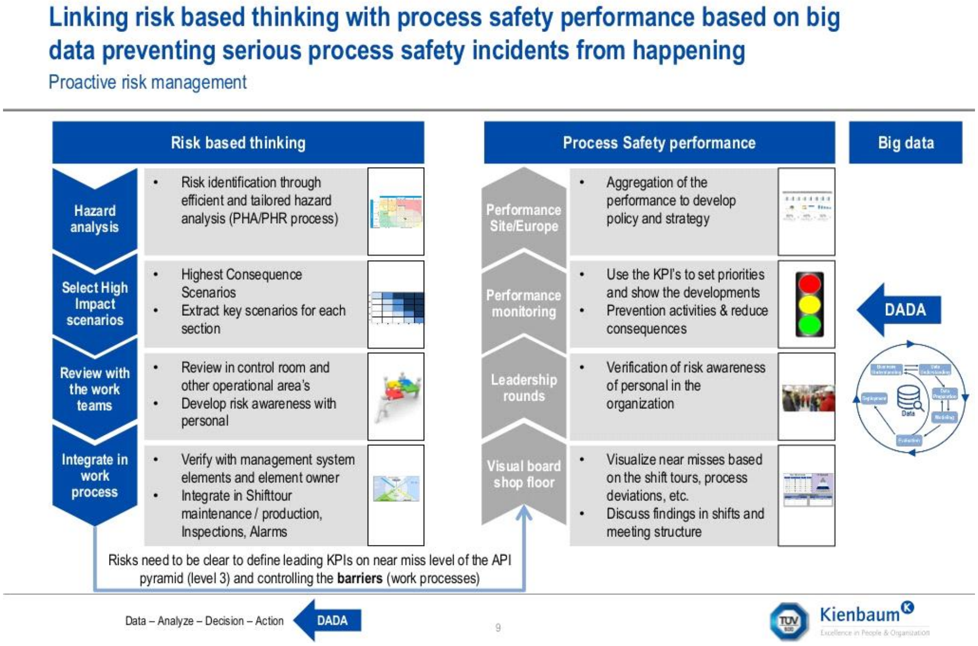
산업체의 다양한 안전 주제들이 논의되는 미국화학공학회(AIChE) 춘계 학술대회 (San Antonio, 2017년 3월) 및 Global Process Safety Congress 발표들중 인상적으로 혁신이 기대되는 부분은 4차 산업혁명, big data 기술의 모니터링 적용 및 이를 활용한 안전 향상이었다. 향후 상세분석 보고서를 별도 작성해 올리기로 하고, 본 보고서에선 주요 근거 자료만을 첨부해 공유한다.

1. Big data 활용 통한 안전성 향상 및 risk based thinking framework (van Driel and Kauer)



To transform to real time decision making using data analytics various sources need to be combined based on a risk management approach

Integrated risk process safety management system



Linking risk based thinking with process safety performance based on big data preventing serious process safety incidents from happening

Proactive risk management

Risk based thinking		Process Safety performance	
Hazard analysis	Risk identification through efficient and tailored hazard analysis (PHA/PHR process)	Performance Site/Europe	Aggregation of the performance to develop policy and strategy
Select High Impact scenarios	Highest Consequence Scenarios Extract key scenarios for each section	Performance monitoring	Use the KPI's to set priorities and show the developments Prevention activities & reduce consequences
Review with the work teams	Review in control room and other operational area's Develop risk awareness with personal	Leadership rounds	Verification of risk awareness of personal in the organization
Integrate in work process	Verify with management system elements and element owner Integrate in Shifttour maintenance / production, Inspections, Alarms	Visual board shop floor	Visualize near misses based on the shift tours, process deviations, etc. Discuss findings in shifts and meeting structure

Big data

DADA

Risks need to be clear to define leading KPIs on near miss level of the API pyramid (level 3) and controlling the **barriers** (work processes)

Data – Analyze – Decision – Action DADA

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Kienbaum

Excellence in People & Organization

2. Big Data Analytics Applied to Semiconductor Manufacturing

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Introduction

As "big data" requirements and capabilities in data volumes, velocity (rates), veracity (quality), variety (merging) and value (analytics) increase rapidly, semiconductor manufacturers are faced with a need for new approaches to data management and use across the fab [1]. During semiconductor manufacturing a silicon wafer is transformed into a grid of silicon chips in a fabrication facility or "fab". Each chip or "die" has layers of complex circuitry that must be controlled to the nanometer or even molecular level. The semiconductor manufacturing process usually has hundreds of these precision control steps. The dynamic control of these steps in this industry is facilitated with a set of capabilities collectively termed "Advanced Process Control" or APC [2]. Over the past two decades the APC family of capabilities has included dynamic model-based process control, termed "run-to-run" or R2R control [2,3], and Fault Detection and Classification or "FDC" (also referred to as excursion detection and failure mode determination) [2,4]. More recently the APC family of capabilities has been expanded to include predictive capabilities such as Predictive Maintenance (PdM), Virtual Metrology (VM) and even end-of-line yield prediction and yield excursion root cause analysis. The expanded set of APC capabilities represents the primary area where big data solutions are generating significant benefits in semiconductor manufacturing.

Big Data and Semiconductor Manufacturing Advance Process Control

Big data advancements have facilitated improvement in all of the APC capability types. The following are two examples where significant return on investment (ROI) is being achieved.

- *Predictive Maintenance*: Predictive Maintenance, PdM, also referred to Predictive Preventative Maintenance, PPM, or a component of Prognostics and Health Management (PHM) is receiving considerable attention in semiconductor manufacturing because it is focused on reducing unscheduled downtime, which is a major source of quality loss and cost in manufacturing [5]. PdM is the technology of utilizing process and equipment state information to predict when a tool or a particular component in a tool might need maintenance, and then utilizing this prediction as information to improve maintenance procedures [2]. This could mean predicting and avoiding unplanned downtimes and/or relaxing un-planned downtime schedules by replacing schedules with predictions. In semiconductor manufacturing some PdM solutions are relatively straight-forward extensions of FDC, however most involve extensive data mining and analysis capabilities to develop models that not only predict the future occurrence of an equipment or component failure, but, as illustrated in Figure1, also indicate the time horizon for remaining useful as well as a confidence and range of the prediction. These PdM prediction events are linked into maintenance, inventory, scheduling and manufacturing execution systems to optimize uptime, cost, productivity and quality [5].

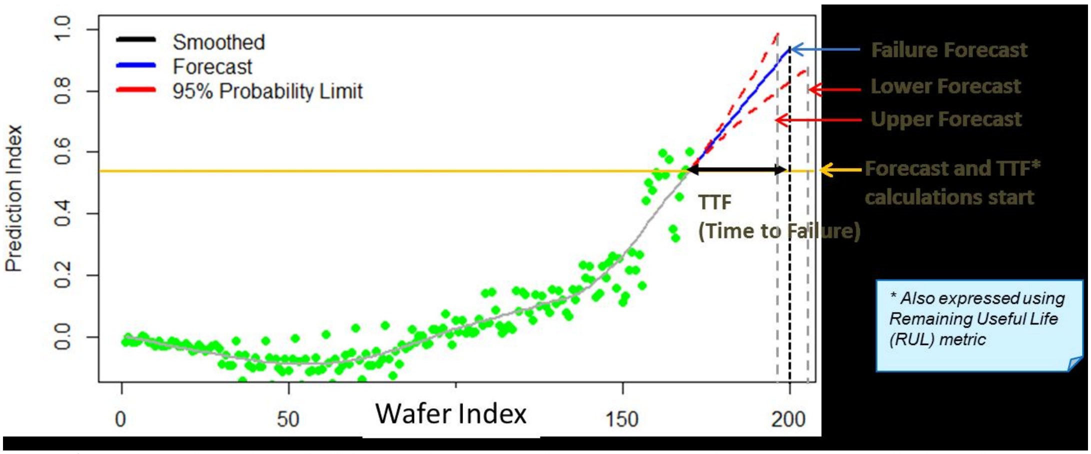

Figure 1: Illustration that PdM solutions require not only the actual prediction, but also a prediction horizon (Time to Failure-TTF) and an indication of prediction quality (provide here as a 95% probability range).

⏱ *Next Generation FDC*: Fault Detection (FD) utilizes real-time trace data collection of key equipment and process variables, along with process output quality information and advanced analytics to determine when an excursion has occurred. Fault Classification (FC) then tries to relate the excursion to a cause or classification. FDC is particularly challenging in semiconductor manufacturing because the processes complex and dynamic to the point that purely empirical solutions generally are ineffective. In other words equipment and process subject matter expertise (SME) must be incorporated into the development and maintenance of these models. As a result the FD model development process is usually highly manual and univariate leading to tens of thousands of models and millions of limits to monitor and manage across the fab. With the advent of big data capabilities the model and limits building and management can be semi-automated and optimized leveraging big data analytics advancements while retaining the ability to incorporate SME in solutions. New FD enhancements that are proving effective include semi-automated trace partitioning, feature selection, and merging in of process quality data to support feature ranking and limits optimization through receive-operating-characteristic (ROM) analysis. Interestingly many of the same algorithms leveraged for PdM can be applied here especially for ranking and optimization. The primary benefits over traditional FD are significantly reduced time for model setup and maintenance, and reduced false and missed alarms [6].

Industry Requirements for Big Data Analytics

The choice of analytics being leveraged to provide enhanced APC capabilities in semiconductor manufacturing reflects the complexity of semiconductor manufacturing processes in terms of the need for precision on 3 analytics response, the dynamics of the processes, and the need for incorporation of (human) SME into the analysis. As an example, typical multivariate supervised techniques such as Partial Least Squares (PLS), and Support Vector Regression (SVR) are often leveraged for predictive capabilities, however clustering techniques are also needed to help separate out the prediction event types, model adaptation techniques are needed to track the process dynamics, phenomenological model elements are often needed to improve empirically-tuned model accuracy, and the entire model building and maintenance process must be structured to support SME involvement. Additionally predictions must include an indication of prediction accuracy so that decision making can be optimized based on an understanding of the potential for false or missed alarms and the associated financial impact. All of these techniques benefit from the increased data volume and improved data quality for model building, however volume and quality of data to support robust models is still the primary impediment to the widespread success of prediction capabilities in the industry. Thus while many other manufacturing environments might turn to more general big data techniques, such as deep learning, for generalized analysis solutions, the semiconductor industry is currently focused on more guided techniques that leverage an understanding of the process, equipment and data management domain knowledge.

Summary

As the semiconductor industry advances into the era of smart manufacturing, specific requirements must be met to address the challenges of increasing manufacturing complexity. As shown in Figure 2, the big data infrastructure will enable a number of capabilities from manufacturing operations optimization, through supply chain network integration, and the leveraging of the simulation space and the concept of a "digital twin" for continuous fab optimization [7]. APC capabilities continue to be improved in order to optimize individual processing with respect to maximized quality and throughput and minimized cost. These capabilities include control, diagnostics, and more recently, predictive solutions. They leverage big data opportunities in analytics that allow for the incorporation of process, equipment and data expertise across the entire solution development and maintenance life cycle. It is expected that this approach will continue as the industry evolves from reactive to predictive to prescriptive computational analysis.

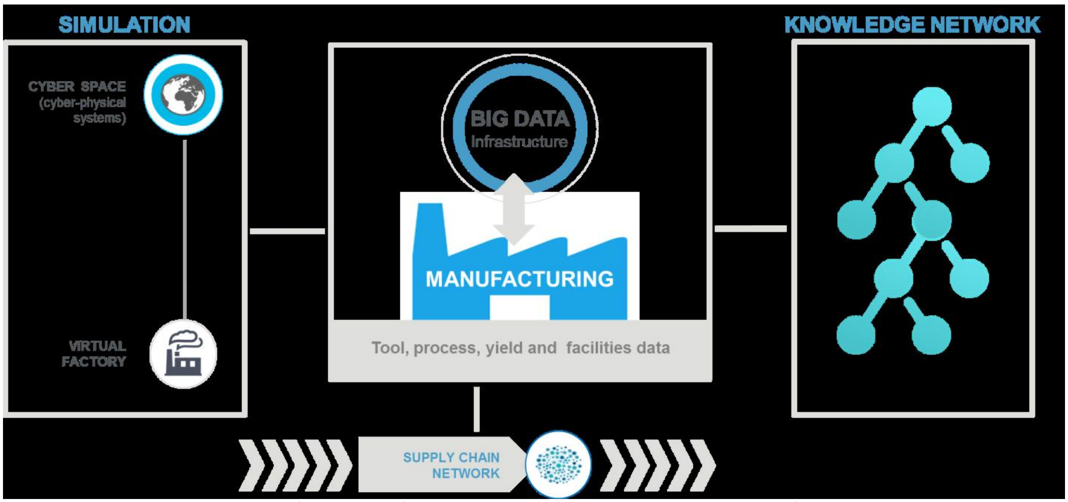

Figure 2: The Fab of the future requires integration of equipment, expertise, manufacturing capability and computational data analysis

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