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COPY-EXACT PROCESS FOR MANUFACTURING

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Copy-Exact Process for Manufacturing

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Foreword

Transfer of process technology from development sites and lines to higher volume manufacturing sites, redundant sites or manufacturing lines by using Copy-Exact Processes has never been described in detail. The lack of rigorous definition has resulted in non-exact interpretation and confusion in the process and requirements for transfer, start-up/ramp and manufacturing.. The Copy Exact Process can apply to the transfer of any manufacturing operation / process, line and factory provided rigorous assessment and systems are in place.
This publication defines the requirements for Copy-Exact Process (CEP) matching, real-time process control, monitoring, and ongoing assessment of the CEP. The critical element requirements for inputs, process controls, procedures, process indicators, human factors, equipment/infrastructure and matching outputs are given. Manufacturers, suppliers and their customers may use these methods to define requirements for process transfer within the constraints of their business agreements.

Introduction

Copy-Exact Processes and methods that historically focused on exact matching of equipment inputs, and outputs have evolved to include real-time automated controls, inline monitors, human interfaces, and factory quality operating systems. Currently, (CEP) and methods require exact duplication of all aspects of equipment facilitation, connection, equipment model, process, procedure, control metrics, statistical process control (SPC), human factors and measured outputs. With the advancement of process technologies and demand for high-yield, high-volume factories at start up phases, evolution in CEP is key. Additionally, real-time feedback via process control systems (PCS) and complementary quality and reliability monitors, CEP also provide foundations for off-line quality management by correlations, trend analysis, corrective actions, inventory management and disposition.

CEP for high-yielding factory start-up/ramp and process maintenance utilizes online PCSs to complement real-time quality and reliability monitors. Offline process control quality management systems utilize real-time sensor monitoring, automated limit flags, human aided disposition, and records management. Real-time, on-line statistical process control (SPC) integrated with PCS data, automated analysis tools, and management of offline processes. SPC control limits, machine limits and disposition limits are continuously controlled and monitored. SPC signals are automatically dispositioned with predetermined response flows. Dispositions use online PCS data and in-line reliability monitors to identify, assess and screen units near the source of the SPC flag.

Introduction (cont'd)

Longer duration trending and process parameter correlation is performed daily with management oversight. PCS automation, flags, and automated decision processes are correlated with quality monitors and in-line reliability monitors at technology certification. Ongoing reliability monitors are replaced when CEP data are correlated to the reference factory certification quality and reliability data as production volumes increase.

CEP in semiconductor manufacturing integrates input controls, real-time process parameter controls, and in-line reliability monitors with human factors and infrastructure management to result in consistent high yield matching while achieving target product quality and reliability.

COPY-EXACT PROCESS FOR MANUFACTURING

(From JEDEC Board Ballot JCB-21-15, formulated under the cognizance of the JC-14.3 Committee on Silicon Devices Qualification and Monitoring.

1 Scope

This publication provides common definitions of critical elements to needed to evaluate, match, control, analyze and maintain a Copy-Exact manufacturing process when transferring between any qualified manufacturing lines, factories or sites. The process and elements may be used to qualify an exactly copied line using all the inline process control data, inline quality and reliability monitors and performance data from sort and assembly test in place of a full re-qualification internal to a company or if defined by a supplier and customer agreement.

2 Normative references

JESD557, *Statistical process control systems.*

JESD659, *Failure mechanism driven reliability monitoring.*

JESD50, *Special requirements for maverick product elimination.*

JESD94, *Application specific qualification using knowledge based test methodology*

JEP132, *Process characterization guidelines.*

JEP131, *Potential failure modes effects analysis (FMEA).*

JESD65, *Definition of skew specifications for standard logic devices.*

JEP143, *Solid state reliability assessment of qualification methodologies.*

JEP148, *Reliability qualification of semiconductor devices based on physics of failure.*

JESD86, *Electrical parameters assessment.*

JESD670, *Quality system assessment.*

3 Terms and definitions

For the purposes of this publication, the following terms and definitions apply.

3.1 automated process control (APC)

Several advanced control techniques such as feedforward, decoupling, inferential control, and model predictive control that are implemented within an industrial process.

3.2 certificate of compliance (CofC)

A certificate of compliance or conformance from suppliers that indicates the products received meet requirements set forth by a business agreement or regulation.

3.3 copy-exact process (CEP)

A process whereby exact copies of a manufacturing process are established and verified against a reference manufacturing line using all available process parameters, process control systems and statistical process control systems and quality operating systems.

- Examples of baseline process include manufacturing, physical/failure analysis, test, equipment, etc.
- Human factors related to training, documentation, people system and management practices are also required to be harmonized and exactly copied.

3.4 fault detection and classification (FDC)

A fault detection system with the capacity to detect equipment anomalies in-line, before output is affected and it is also a unified platform to facilitate integration of process data, metrology data and manufacturing data between APC components.

3.5 human factors

An interdisciplinary area that focuses on a range of different topics, including ergonomics, workplace safety, human error, human-machine interaction, product design, human capability, and human-computer interaction.

3.6 key process parameter (KPP)

A process parameter or group of parameters that correlate to process yield, quality, reliability or performance.

3.7 process control system (PCS)

An automated industrial process control system that continually operates using inputs from APC and real-time sensors to achieve process consistency, throughput and quality.

4 General

4.1 Objectives

The objective of this publication is to establish clear definitions for use of the Copy-Exact Processes and methods to copy a reference and transfer certified equipment, processes and factors. Use of the CEP method for production, qualification or risk-start, is subject to supplier – customer agreement. The method establishes the master reference matching checklist derived from specific matching categories. Individual elements and the entire linked process detail list is developed. The facsimile process is replicated exactly for facilities, equipment, process, procedure, sensing, automation, human factors. Are-check is performed with both in process and output parameter matching. Figure 1 shows the objective of CEP. The supplier and the customer may determine to replace the full qualification flow for qualified products where the data from inline quality & reliability monitors, inputs and performance data are matched. The continuous data may also be used to establish continuous certification validation. There are no degrees or levels of matching defined because exact matching is required. In practice, a certified process manufacturing technology transfer is transparent at the start up and operation at the target location after meeting the exact matching criteria.

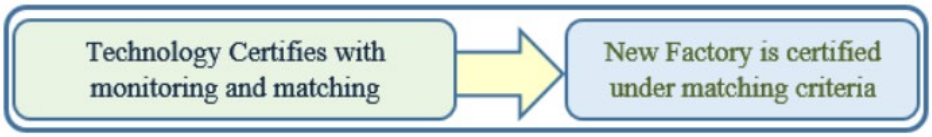


Figure 1 – The certification and qualification processes link reliability certification to monitoring and matching of outputs. This means that n+1 manufacturing lines or factories will match the key product performance metrics, human factors indicators, process quality and reliability performance metrics when the CEP review is successful.

5 Elements of Copy-Exact Process and Methods

5.1 Integration of elements

The CEP process utilizes inputs characterization and online controls that are established in development to produce matched high quality and reliable products. Table 1 provides detailed examples of some of the CEP details controlled. The exact copy of each detail without exception is required because unexpected and uncharacterized variation is not tolerable as it can lead to unknown responses. Furthermore, it may not be possible to know, understand and characterize all differences or interactions. [1, 2]

Table 1 – Examples of CEP in a manufacturing process

Element	CEP Purpose	Example
Facilities + connection	Exact copy	Pipe length & fittings, electrical line and junctions.
Equipment	Exact copy	Equipment model with same model of internal parts
Equipment sensors	Exact copy Online	Equipment sensor device part number, detectors with with exact firmware.
Fault detection	Quality assurance, test, reqliablity monitors + online at the process tool + big data outlier detection	Exact process process parameter, monitors and proceedures.
Quality system	SPC+PCS online & offline, management led	Exact SPC+PCS system (if not centralized)
Material disposition	Inventory catch point that uses quick stress monitor or test	Exact inventory catch points, quick stress monitors, tests and signal response algorithms as well as training
Quality & reliability	Inline PCS correlated to quality and reliablity certification and product qualification data and offline development monitors	Identical key parameters matched across sites and trending witthin allowed limits
Fab network	Online comparison Periodic offline trending	Identical on-line process comparisons and offline trending criteria & management expectations
Change Control Board (CCB)	Forum that ensures coordination, validation, verification, documentation and implementation of technical/process changes at master/prime references and multi-site	Exactly coppied recipe with necessary variation tetes and validated though the process. Tool matching parameter, output match parameter and tool:tool matching parameter.

The CEP methodology requires that the development or the reference process is documented in a detailed inventory checklist that includes categories for control additional to the normal processes and procedures. The master matching checklist includes (5M+E) categories for: Man, Machine/software, Metrology, Materials, Methods and the environment. Figure 2 shows a turtle diagram with examples of all the critical elements for inputs, development, requirements and output matching. The list is derived using FMEA (JESD131) which includes heuristic and historical information and development process learnings for adequate and necessary controls.

5.1 Integration of elements (cont'd)

Full process characterization following the requirements of JEP132 is necessary to establish the baseline process, statistical process control data, KPPs, yield and quality and reliability monitors. Monitor and metrology gauge studies, ongoing round-robin checks and process controls shall be established to the requirements of JESD557 and with outlier detection methods given by JESD50. Ongoing verification of visual inspection matching is a risk area to be managed at regular intervals and reviews. A quality system assessment, per JESD670 is required to perform CEP. Each element shall clearly and completely documented and a list of all the characteristics is created. The CEP checklist includes an identifier number for each characteristic that will be audited before, during and after the process development, during transfer and during manufacturing. Any changes to the checklist requires re-assessment under the direction of management in the change control board that governs all CEP matched factories. Any changes made after the CEP designation are propagated to all the CEP virtual factory network. Every part of the process that is copied must individually and as a linked process have attributes and parameters related to 5M+E itemized for exact replication. [3]

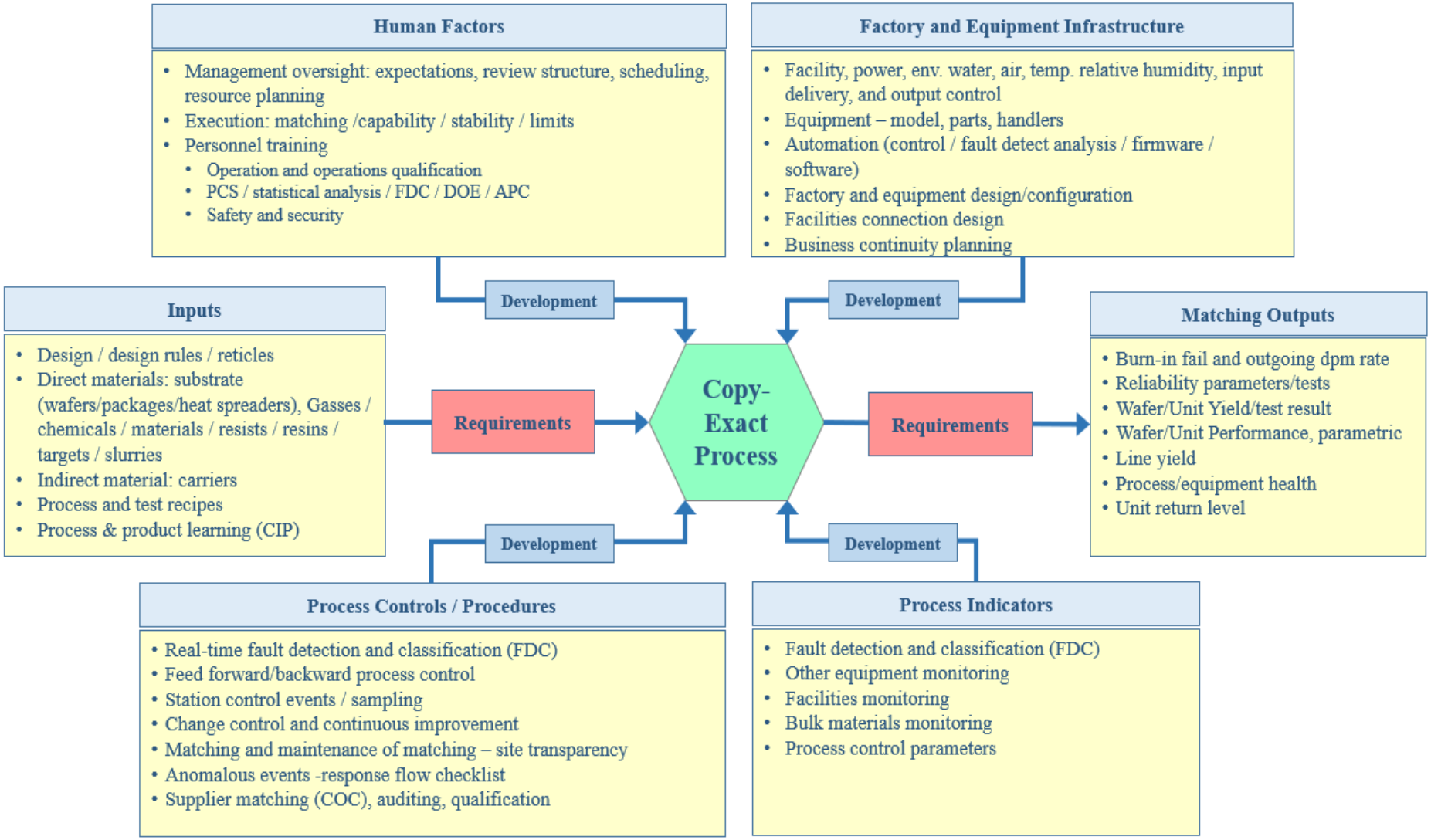


Figure 2 – Turtle diagram relating key elements of the CEP processes. Inputs and variations are eliminated or controlled and effects are characterized in the reference process and matched to any new line or factor.

5.2 Inputs

CEP inputs monitoring and controls are integral to automated decision systems. Inputs include: design items, direct/indirect materials, process recipes and process characterization information as established during development and initial production. Input variation (expected / unknown) is characterized, controlled, maintained, and monitored across the supply chain. Manufacturing process development accounts for input variations and integrated effects that result in manufacturing parameter set points or limits, monitors, yield, and outputs. In-line fab and assembly-test quality and reliability monitor baseline reference comparisons are part of the certification, matching and transfer processes.

5.2.1 Inputs requirements

It is required that a master copy-exact checklist include detailed and traceable information for all inputs and their variations Each input is required to be assigned an itemized matching identification number only after input criteria are established and an input verification process is in place. The detailed input list for all areas is required to be approved by the process management and factory management control board.

5.3 Factory and equipment infrastructure

Facilities and equipment infrastructure are exactly copied within the reference factory and across the virtual factory. The CEP status depends upon successful audit of a rigorous inventory, installation and facilitation list. Equipment capability is assessed during the research and development phase. Development establishes a rigorous master reference checklist that includes categories for man, machine/software, metrology, material, methods and environment (5M+E). Facilities and equipment are designed or modified to enable in-situ parameter data collection, quality monitoring, compatibility with the recipe control, and the data automation environment. Each equipment configuration is assigned a configuration control identification (ID) designation for copy and transfer. Subsequent purchases are exactly copied to reference equipment using the reference ID and audit process. Any equipment upgrades are evaluated and coordinated across the entire factory network, and even across technologies where applicable and managed by change control boards. Integrated validation of the CEP in high volume is achieved when the master reference process is certified, and product is qualified and maintained.

5.4 Process controls and procedures

Online, real-time process controls detect faults and classify them for assessment. Faults link to traceable and unique identifiers (units, wafers, lots or process step) from fab through assembly-test. Advanced process controls ensure unit-level recipe management and process control data are collected and work in conjunction with monitor sampling. Unique unit identification also ensures a known chain of custody and complete traceability when linked with incoming input data, station control process parameter records and test data. Unit-level data enables real-time identification of wafers, dice or finished units that may be flagged for disposition from signals in PCS, in-line reliability monitors, and test or burn-in data. Since c. 2005, fault detection and classification capabilities have been developed and integrated with online analysis algorithms. Systems extend beyond detection of single tool events to the entire process flow to identify integrated effects using data analysis automation from all factories in the network. Often tool or factory signals can indicate changes to specific inputs or tools before output matching data is available. Commercially available fault detection and classification systems can be used with APC systems to monitor the process, factory and virtual factory network in real time to assure ongoing matching. Regular offline review of integrated inputs, PCS, SPC and outputs assures continuous matching of the virtual factory network over longer times.

5.5 Human factors

Human factors and man-to-machine interfacing protocols are required to develop and maintain the CEP process for the duration of the product lifetime. Although data and decision automation are leveraged heavily to simultaneously maintain matched factories; human oversight and training are required. Personnel talent and assets are used to analyze the integrated online and offline data signals to enable identification of issues and opportunities for improvement if marginal to targets. New issue responses, learning and improvements are identified and tested using automation by highly trained and certified personnel. Management oversight ensures issues are addressed and any necessary changes are implemented across the network after approval of the appropriate change control board.

5.6 Process indicators

5.6.1 Input indicators

Input indicators and checks ensure that any materials or information entering the process is in conformance to predefined parameters. Direct and indirect materials are controlled inputs with pre-characterized or defined and allowed variance. Similarly, designs, reticles, and design rules conform to predefined parameters to limit incoming variation. Input process controls and test recipes are controlled for variance. At the process certification milestone it is expected that the final certification process has established and validated input limits along with the other higher level factors as an integrated validated set of information.

5.6.2 Control parameters and key process parameters

Real-time, inline process controls are data used to establish real-time monitoring and control of the process. The data may be used individually or together with other parameters to immediately indicate process health within predefine limits. Key process parameters are defined from individual correlated parameters that are used to flag significant anomalies or excursions. Standardized SPC methods are used to set the disposition and decision flags for PCS, inline data and performance data. Some products require tighter limits and flags than others where the limits are determined at product qualification. Flags are used to indicate issues and serve as input for decision responses. Examples of comparisons include machine deviation from set points, machine to machine matching of set points or critical parameters or machine within factory differences from the rest of the factory network. Near real-time flagging between machines, lines, and global factories ensures continuous automated control. Station control, automation systems and online process control systems use real-time data to continuously assess process health in order to detect issues at the source for automated or human assisted disposition.

5.6.3 Inline quality data

Inline quality data such as measurements and automated inspections are linked to the process control systems. Quality management system indicators that fall outside pre-characterized and predefined limits are flagged for disposition in the same way that process control parameters are flagged. Parameter response flows and correlations are used to disposition material at key inventory catch points close to the point of issue origination to prevent unexpected processing or interactions with other parts of the process.

5.6.4 Inline reliability data

Inline and fast reliability data that is correlated to the reference certification data is used in the CEP methodology with the PCS system to ensure continuous CEP matching. Inline reliability monitoring using fast accelerated stress testing is performed at the wafer or package-level at key points in the process. Figure 3 shows common inline fast reliability monitors that are correlated to the certification reference data to continuously verify CEP matching and reliability.

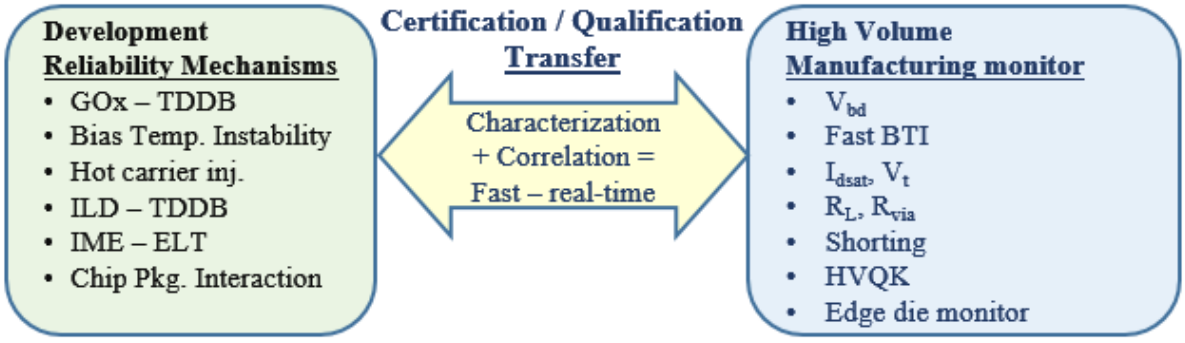


Figure 3 – Manufacturing quick stress and other electrical measurements are used in lieu of lab measurements once correlation is understood as well as event driven when re-evaluations are needed (e.g. process changes).

An example of a fast-accelerated stress is High Voltage Quick Kill (HVQK). HVQK is a short-duration, elevated voltage, dynamic stress applied at wafer test. The purpose of the test is to screen latent reliability defects resulting in lower infant mortality and for outlier detection of voltage accelerated defect modes. Differences in final assembly product yield versus sort and HVQK are also a final validation and indicator of process health. The matched HVQK data indicate similar performance, quality and reliability for output from all matched fabs and are used to continuously validate the correlation between fab certification data and product qualification data.

A second example of a fast stress test inline reliability monitor is the Voltage breakdown (VBD) test. VBD can be used to assess interconnect dielectric reliability, quantifying via to line miss-registration spacing as well as intrinsic dielectric integrity. Large area structures with representative worst-case layout as well as structures with calibrated differential spacings are employed in these in-line reliability monitors. The inline VBD is required to be matched across equipment, lines and sites with typical SPC and PCS controls in place to trigger review and disposition of discrepant materials to ensure continuous matching.

5.7 Product performance and yield output indicators

Product performance and yield output indicators are among the last checks for continuous CEP matching. In addition to final analysis of all the correlated matching outputs, the product performance and yield data must also match to provide product that are transparently integrated into customer systems.

5.7.1 Matching outputs

Matched outputs from the CEP system consist of matched PCS and SPC elements, in addition to matched quality, quick reliability and test yield monitors. Integrated unit output matching data is continuously assessed against the reference PCS data to achieve the targeted output levels of yield, performance, quality and reliability. In development, reliability mechanisms are matched to high volume manufacturing metrics for quality and reliability. Online control parameter data, monitors, test correlations and fast reliability monitors can be analyzed and continuously matched from fab and validated through assembly-test. For example, dielectric breakdown for dielectric and gate are assessed for quality. Online output matching data enable fast virtual factory ramp-up (fab or assembly), early identification of any issues and elimination of misprocessed or non-conforming units in real-time. The reference factory parameter data, process certification, test data and product qualification data correlations establish the link to maintain matching during the process lifetime.

5.7.2 Product performance data

Product performance and parametric data, specialized structures or testing may be used and in addition to other previous data to not only ensure process control matching but also functional performance matching. An example of good monitorable performance data is high frequency and low frequency minimum operating voltage matching of individual units. Like yield, product performance is the primary integrated metric of all the individual transistors.

5.7.3 Product yield

Product yield matching across lines and factories is another good indicator of process matching along with the other integrated indicators. Product yield may be track from the fab through assembly and burn-in to bolster CEP continuous matching.

5.7.4 Matching deviations

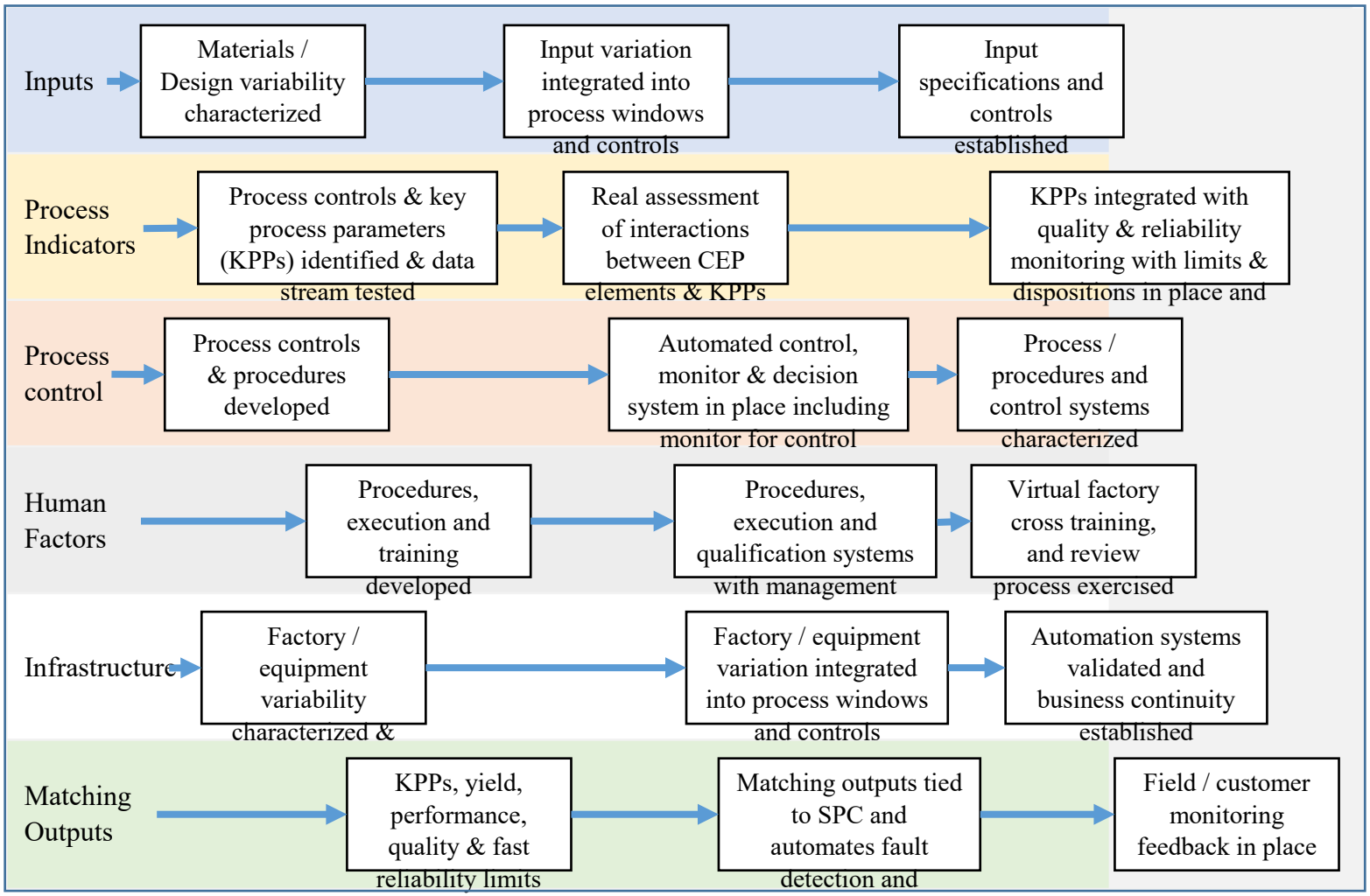
Matching deviations from the established data and controls baselines or verified customer detected issued are subject to material review board and customer notification per JESD46. Normal problem-solving processes and reporting shall be performed to JESD43.

6 Copy-Exact Process-Methods and Requirements

6.1 Decision / elements tree

The CEP process swimlane shows the relative timing of activities in each general element to achieve CEP status.

Figure 4 – Element and activity swim lane with relative timing for the CEP process.



6.2 CEP audit and decision

This publication provides a path to define requirements for the CEP methods to copy a reference line and transfer certified equipment, processes and factory systems; including personnel. The method establishes the master reference matching checklist derived from specific matching categories. Individual elements and the entire linked process detail list is developed, and the facsimile is replicated exactly for equipment, process, procedure, sensing, automation, human interfacing and final re-check with both in process and output parameter matching. Typical statistical confidence methods are used determine process matching. All measures are expected to be repeatable and capable as demonstrated by gauge evaluations to a level of statistical significance acceptable to the customer and supplier agreement. Upon completion of the Copy-Exact Process audit, a decision to designate exact matching status is made to either pass or fail the audit. Customer notification and reporting of the status is the accomplished in adherence to business agreements. The virtual factory management team is responsible to continue the matching of all the elements of the CEP checklist and the output of the monitors, quality data and fast reliability testing will ensure continuous certification and CEP maintenance. Changes to the reference CEP baseline require assessment and implementation across all factories and reassessment of all the integrated elements and modification of the checklists for a new audit.

6.3 Sustaining copy exact status during the manufacturing process lifetime

The same methods, tools and automation used to achieve the CEP process are used to maintain matching through the product manufacturing lifetime. The same audit checklists and data establish the master reference baseline that is used for formal change management and change propagation across the virtual factory. All elements of input controls, SPC, PCS, inline data and performance data feedback are maintained without change via automated systems with periodic management review. If a change is introduced, the change control board is required to assess a comparison against the reference baseline while establishing a new master reference baseline. As a new baseline is established the CEP checklist and master baseline (with data) is updated along with all the tool, procedure, quality or reliability monitors and outputs. All automation is updated when the outputs are certifiable. The change control board ensures that the CEP processes meet and continue to test and ensure continuous certification.

Annex A (normative) Example Copy-Exact Process checklist

Element	CEP checklist requirement	Example
Input	Reticle – revision - Source	Design number Source indicator
	Target – Part number (PN) PN certificate of compliance (CoC) established Lifetime characterized / tracking / replacement trigger	Identical part number from qualified supplier CoC verification Target use life limit established and in tracking and control system
	Process recipe revision	Recipe with allowed variance
	Material – Part Number (PN) PN certificate of compliance (CoC) established	Identical part number CoC verification
	Indirect material – carrier (PN) PN CoC established Lifetime / tracking / replacement trigger	Identical part number from qualified supplier Target use life limit established and in tracking and control system
Process Control / Procedures	Station control – hardware - Software - Calibration – characterization w/sensors - Limits for each sensed parameter - Alarms - Alarm response flow	Station control hardware / configuration Controller software revision w/security Calibrated input to controller Module/process limits for key parameter Alarm trigger identical Alarm disposition automation and/or personnel response flow.

Annex B Differences between (new document number) and (previous document number)

Initial release.

Annex C (informative) Bibliography

1. R. A. Gasser, "Achieving high microprocessor manufacturing output-the Copy Exactly! method," *IEEE International Electron Devices Meeting, Technical Digest*, vol. 98, pp. 317-20, Dec. 1998.

2. R. A. Gasser, "Yield learning and volume manufacturing of high-performance logic technologies on 200mm and 300mm wafers," *IEEE International Electron Devices Meeting, Technical Digest*, vol. 01, pp. 599-602, Dec. 2001.

3. C. J. McDonald, "Copy exactly! A paradigm shift in technology transfer method," *IEEE Advanced Semiconductor Manuf. Conference*, pp. 414-17, 1997.

4. A. E. Lucero, C. Connor, T. Utlaut, I. Hsu, "The Copy Exactly! Evolution story: High reliability fungible output base solely upon matching," *IEEE International Reliability Physics Symposium,* pp. 2B4.1-2B4.7, May 2017.

5. S. Natarajan, *et al.*, "A 14nm logic technology featuring 2nd-generation FinFET transistors, air-gapped interconnects, self-aligned double patterning and a 0.0588um2 SRAM cell size," *Proc. 2014 IEEE International Electron Devices Meeting*, pp. 3.7.1-3.7.3.

6. C.-H. Jan, *et al.*, "A 14nm SoC platform technology featuring 2nd generation tri-gate transistors, 70nm gate pitch, 52nm metal pitch, and 0.0499um2 SRAM cells, optimized for low-power, high performance, and high density SoC products," *Proc. 2015 Symposium on VLSI* Technology, pp. T12-T13. June 2015.

7. C. Prasad, *et al.*, "Transistor reliability characterization and comparisons for a 14 nm tri-gate technology optimized for System –on chip and foundry platforms," *IEEE International Reliability Physics Symposium,* , pp. 4B 51-8, April 2014.

8. Radhakisan Baheti and Helen Gill, "Cyber-physical systems," *IEEE, The Impact of Control Technology*, pp. 161-66, 2011.

9. T. Bauernhansl, M. ten Hompel, B. Vogel-Heuser (Hrsg.), " Industrie 4.0 in Produktion, Automatisierung und Logistik," Springer, 2014.

10. Mohd Fairuz Zakaria *et al*, “Reducing Burn-In Time Through High-Voltage Stress Test and Weibull Statistical Analysis”, IEEE Design & Test of Computers, March-April 2006.

11. A. Jauhri *et al*, ‘Outlier Detection for Large Scale Manufacturing Processes’, 2015 *IEEE Conference on Big Data*.

12. J. Moyne, J. Samantaraay, and M. Armacost, "Big data capabilities applied to semiconductor manufacturing advanced process control," *IEEE Advanced Semiconductor Manuf. Conference*, pp. 283-91, 2016.

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