

*Process Development and Process
Integration of Semiconductor Devices*

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Process Development Activities

- **Worked in Process Development for Fifteen Years Both at IBM and Texas Instruments**
- **Activities Ranged Across a Wide Variety of Different Areas**
 - **Failure Analysis**
 - **Reliability**
 - **Process Engineering**
 - **Equipment Engineering**
 - **Yield Enhancement**
- **Main Focus of Activities Centered on Reliability and Yield Enhancement**

Product Cycle

- **Objective of Wafer Fab is to Produce Product**
- **Next Generation Product Requires Several Years to Develop**
- **Development Cycle Must Encompass Following Stages**
 - **Research**
 - **Early Development**
 - **Productization Development**
 - **Manufacturing**
- **Product Evolves from Basic Concepts and Processes to an Integrated Product and Finally Full Scale Manufacturing**

Product Cycle Example

- **IBM Employed a Product Cycle Encompassing Several Increasingly Demanding Checkpoints**
- **Checkpoints Include T0, T1, T2, S0, S1, and S2**
 - **T0 and T1 Includes Basic Development with Increasing Levels of Product Qualification**
 - **T2 Includes Extensive Functional and Reliability Qualification by an Independent Assurance Group**
 - **S0 and Beyond Involves Release to Manufacturing and Transition to Quality Control**

Wafer Fab Culture

- **Wafer Fabs are Manufacturing Facilities Running Around the Clock Seven Days a Week**
- **Most Development Runs in this Type of Environment**
- **Wafer Fabs are Large Multi-Billion Dollar Facilities Involving the Contribution of a Variety of Different Groups**
- **Process Engineering is One of the Most Key Groups in a Fab**
- **PE is a Very Interdisciplinary Area Involving Engineers from**
 - **Materials Science**
 - **Physics**
 - **Chemistry**
 - **Chemical Engineering**
 - **Electrical Engineering**

Wafer Fab Organization

- **However, Numerous Organizations Contribute to the Development and Production of Semiconductor Products**
- **These Organizations Include**
 - **Process Engineering**
 - **Process Integration**
 - **Equipment Engineering**
 - **Equipment Vendors**
 - **Yield Enhancement**
 - **Quality Assurance**
 - **Reliability**
 - **Product Assurance**
 - **Product Engineering**
 - **Failure Analysis**
 - **Design**
 - **Final Test**
 - **Manufacturing**

Process Engineering

- **Responsible for All Process Related Issues Throughout Wafer Fab**
- **Can Broadly Categorize PE Into Three General Functions**
 - **Thin Films**
 - **Photolithography**
 - **Etch**
- **Process Engineers Have Very Specific Functions**
 - **Ion Implant**
 - **Poly Dep**
 - **Oxide Deposition**
 - **Metal Deposition**
 - **CVD Barrier Metal**
 - **Silicon Etch**
 - **Oxide Etch**
 - **Metal Etch**
 - **CMP**
 - **Clean**
- **PE is a Very Large and Important Engineering Area**

Process Integration

- **Responsible for Coordinating and Integrating Semiconductor Processes in Order to Develop a Functional, Reliable, and Yieldable Product**
- **Key Wafer Fab Organization**
- **Much Smaller Than Process Engineering Function**

Equipment Engineering

- **Sustains and Supports Manufacturing Equipment In-Line**
- **PE and EE Often Work Together on Resolving Tool Issues**
- **Responsible for Coordinating Tool Installs**
- **EE Oftentimes Works with PE on Evaluating and Accepting Next Generation Tools**

Equipment Vendors

- **Develops Equipment for Semiconductor Manufacturing**
 - **Develops Tool Platform and Process for Manufacturing**
 - **PE May Alter or Adjust Process to Meet Manufacturing Needs**
- **Often Supports and Maintains Their Equipment In-Line in Place of EE Under Equipment Service Contract**

Yield Enhancement

- **Drives Product Yield In-Line In Order to Expedite Yield Learning**
 - **Shorten Product Cycle During Product Development**
 - **Or Maximize Product Yield During Manufacturing**
- **Typically Uses Expensive Defect Detection Tools In-Line to Identify Yield Limiting Problems**
- **May Also Utilize In-Line Parametrics on Test Sites to Help Drive Yield In-Line**
- **Problems May Range from Regular Daily Particle Excursions to Large Catastrophic Yield Problems**

Quality Assurance

- **Sets Up Control Charts and Limits for Various Process Parameters**
- **May Actively Monitor and Enforce Quality Standards**

Reliability

- **Assures and Monitors Product Reliability**
 - **Serious Reliability Issues Can Be Disastrous for a Company**
 - **Can Be Costly for a Company and Seriously Hurt Its Reputation**
 - **Responding to a Reliability Problem in the Field Can Take Months**
- **Main Responsibilities Include**
 - **Stressing Product During Product Qualification**
 - **Implementing In-Line Monitors and Controls**
 - **Monitoring Field Returns for Problems and Issues**

Product Assurance

- **Performs Qualification of Product Prior to Product Release**
 - **Extensive Reliability Test**
 - **Extensive Functionality Test**
 - **Assures Manufacturability of Product**
- **Performed by Independent Product Organization to Assure Unbiased Assessment**

Product Engineering

- **Drives Yield from End of Line By**
 - **Evaluating End of Line Final Test Data and Parametrics**
 - **Performing Failure Analysis of Defective Product**
- **Provides a Powerful Combination of Electrical Data Analysis with Physical Failure Analysis**
- **However, Issues Include**
 - **Long Turnaround Time Before Product Reaches Final Test**
 - **Extensive Time Required for Physical Failure Analysis**

Failure Analysis

- **Provides Physical Failure Analysis and Construction Analysis for Various Engineering Functions Including**
 - **Process Engineering**
 - **Process Integration**
 - **Yield Enhancement**
 - **Reliability**
 - **Product Assurance**
 - **Product Engineering**
- **Provides**
 - **Basic Metallographic Services Such as Polishing and SEM**
 - **More Sophisticated Services Such as STEM, SIMS, Auger, and ESCA**

Design

- **Design May Get Involved with Process Development Issues**
 - **Most Issues Are Typically Resolved Through a Process Action**
 - **However, Occasional Issues Must Be Resolved with a Design Change**

Final Test

- **Develops Final Test for Semiconductor Product**
- **Provides Electrical Parametric Data Which Drives Manufacturing Line**
- **Also, Provides Key Final Test Data Commonly Required to Fix Product Yield**

Manufacturing

- **Actually Runs the Product Through the Manufacturing Line**
- **Large and Powerful Group Within a Wafer Fab**
- **Typically Engineering Teams Must Work Around Manufacturing Even in Development in Order to**
 - **Minimize Turnaround Times and Maximize Yield Learning in Development or**
 - **Minimize Turnaround Times and Improve Tool Utilization in Manufacturing**

Conclusions

- **Process Development Very Long and Involved Engineering Process**
- **Requires Numerous Groups to Develop and Yield a Semiconductor Product**