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 Employs 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
• Companies Like IBM Also Depend Heavily Upon In-Line Parametrics on Test Sites to 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