Design for Safety / Design for the Environment in the Semiconductor Industry

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DfS/DfE in the Semiconductor Industry

- What is the concept?
- How is it applied?
  - Semiconductor Manufacturing Equipment Industry
  - Device Manufacturing
- The benefits
DfS/DfE Concept

- A management decision-making process to minimize the life-cycle costs of ESH impacts on business operations, by considering those impacts systematically during the design process.
- Comprehensive incorporation of ESH into the overall process.
The “Old” Model

SUPPLIER
- Design Product
- Present to Potential Customer
- Product redesign

CUSTOMER
- Identify Product concerns and requirements
- Purchase Product
- Address additional ESH concerns
- Address additional Requirements for Installation
- Product Installed and ON-LINE
The “Ideal” DfS/DfE Model

SUPPLIER

Identify Product Concerns and requirements

Design Product, Present to Customer

CUSTOMER

- Engineering
- ESH
- Facilities

Purchase Product

Product Installed and ON-LINE
Semi Equipment Manufacturers and Device Maker Interactions

- Needs to be viewed as an integrated process
- Clearly defined responsibilities
  - Suppliers
  - Procurement
  - Process Engineering/Production
  - Facilities
  - ESH
- Clear lines of communication
Industry and Regulatory Drivers

- **Industry Standards**
  - **SEMI Safety Guidelines:**
    - SEMI S2 Product Safety Guideline
    - SEMI S8 Ergonomics/Human Factors
    - Other guidelines

- **Regulatory Requirements**
  - OS&H Regulations
  - Building Codes and Fire Codes (ex: UFC Articles 51 and 80, NFPA 318)
  - European Union / CE (MD, LVD, EMC)
Process Design

- Train process and equipment design engineers in the concepts
  - Integrate into the very earliest stages of design
    - Process Chemistry
    - Resource Conservation

- Cost Benefits of early integration
Return on Investment

Timing for integration of EHS requirements into product development determines Return on Investment (ROI)

- Implementing a solution in Design stage
- Implementing a solution in the manufacturing stage
- Retrofitting
ESH Benefits

- **FINANCE**
  - ROI; Cost-Benefit; impact on growth potential; bank lending; insurance coverage

- **SALES/MARKETING**
  - Cost of Ownership (COO) for customers, marketing advantage, customer satisfaction, positive PR

- **SERVICE**
  - Customer Satisfaction, serviceability of products, products designed to facilitate easier and safer accessibility

- **LEGAL**
  - Liability; compliance

- **HUMAN RESOURCES**
  - Employee safety, productivity & morale

- **ENGINEERING**
  - Time to develop new product
Equipment Design & Manufacture

- Incorporate DfS/DfE Principles in Equipment
  - Materials of Construction
  - Safety Interlocks

- Testing & Certification
  - Internal Programs
  - Use of Third Parties

- Delivery of Equipment and certifications
  - Documentation
Equipment Installation

- Take well-designed equipment and install it in a well-designed and well-operated factory
  - Ensure that all equipment maker safety controls are operational and used during production and maintenance
  - Ensure complete documentation for quality and safety
**Facility & Equipment Process**

1. **Base-Build Design**
2. **Review Design**
3. **Verify During Construction**
4. **“Walkdown” of Facility Systems**
5. **Equipment Identified**

**Equipment Sign-Offs**

- **Create Safety Punchlist**
  - **SEMI S2 Acceptable?**
    - Yes: **Authorize for Production**
    - No: **Reject and Request Update**

**Installation Acceptable?**

- Yes: **Authorize for Production**
- No: **Correct Problems**

*Sign-off process:*
1. Level 1: Electrical/Physical Hazards Controlled
2. Level 2: Hazardous Materials Controlled
3. Level 3: All items complete, baseline Industrial Hygiene complete documentation complete
The Benefit of Success

The Success of SEMI S2 & Installation Process
“Potential hazards are to be identified early in the design stage, while it is still easy and cost-effective to correct or eliminate problems.”

Before

Installation
Safety
Qualify

After

Safety + Installation
Qualify

Weeks

0
2
4
6
8
10

Value of 2 weeks of production: $4M - $40M!!!

Consequences of Failure

- **Cost of New Facilities**
  - 200 mm ~US$1.5 Billion
  - 300 mm ~US$2-3.0 Billion

- **Cost of Equipment**

- **Cost of Business Interruption**

- **Risk to Personnel**
  - Short-term
  - Long-term
DfE After Production

- Product Stewardship Issues
  - Material Use Restrictions
  - Product Disposal Regulations
  - Product Take-back Requirements
  - Packaging and Eco-labeling
DfS/DfE Design Tools

- ESH risk assessment -- comparisons of process tool alternatives
- ESH impact costs at process step
- Full life-cycle ESH impacts/costs
- ESH impact at process step
- Energy optimization
- Water conservation
- Emission control
- Water Energy Chemicals
- Emissions

- Design Review
- Checklists
- Material & Energy Balance
- CARRI
- ESH Cost Modeling
- ALCA
- Facility/process ESH impacts
Increasing Global Restrictions

- **Emerging Markets**
  - Developing Countries
  - Increasing Regulations
  - Differing Requirements

- **Customer Drivers**
  - End-user ISO 14001 programs driving suppliers
Resource Conservation: Water

- The average 200 mm fab in 1996 generated 16 million in$^2$ (~2.5 acres!) of silicon wafers
- Used the same amount of water as a city of ~26,000 people
- 300 mm Fab (29M in$^2$ silicon) is expected to nearly double that usage
- Water costs are expected to be ~$540M per year for all US fabs by 2002
Resource Conservation: Energy

- A typical 200 mm fab uses the same amount of energy as a city of 50,000 people (15-30 Megawatts)
- Energy use has upstream environmental impacts - air pollution, waste production, global warming
- Energy usage is expected to cost US fabs ~$430M per year by 2002 (Source: SEMATECH 1/97 & 10/97)
  - HVAC recirculating fans (including tool exhaust) account for ~50% of fab energy consumption
  - Tools consume ~40% (including UPW, PCW, N2, and vacuum, but not including exhaust)
The cost of running the equipment can be very expensive.

$2.5M piece of equipment can cost $500K to install and $300K/yr to run.
International Technology Roadmap for Semiconductors

- Chemicals, Materials, and Equipment Management
- Climate Change Mitigation
- Workplace Protection
- Resource Conservation
- ESH Design and Measurement Methods

http://public.itrs.net/
ITRS: Chemicals, Materials, and Equipment Management

- **Chemical Data Collection**
  - Document and make available environment, safety, & health characteristics of chemicals

- **New Chemical Assessment**
  - Quality rapid assessment methods to ensure that new chemicals can be used in manufacturing, while protecting human health, safety, and the environment w/o delaying process implementation

- **Environment Management**
  - Develop effective management systems to address issues related to disposal of equipment, and hazardous and non-hazardous residue from the manufacturing process

- **After 2005:**
  - Rapid introduction of chemicals and materials into new process requires the understanding of process fundamentals in order to reduce ESH impacts.
ITRS: Climate Change Mitigation

- Reduce Energy Use Of Process Equipment
  - Design energy efficient larger wafer size processing equipment

- Reduce Energy Use Of The Manufacturing Facility
  - Need to design energy efficient facilities to offset the increasing energy requirements of higher class clean rooms

- Reduce High Global Warming Potential (GWP) Chemicals Emission
  - Need ongoing improvement in methods that will result in emissions reduction from GWP chemicals

- After 2005:
  - Reduce Energy Use: The importance of reducing energy use for climate change will grow.
  - Reduce High GWP Chemicals Emissions: No known alternatives and international regulatory pressure to reduce emissions of GWP chemicals.
ITRS: Workplace Protection

- **Equipment Safety**
  - Need to design ergonomically correct and safe equipment.

- **Chemical Exposure Protection**
  - Increase knowledge base on health and safety characteristics of chemicals and materials used in the manufacturing and maintenance processes, and of the process byproducts; and implement safeguards to protect the users of the equipment and facility.

- **After 2005:**
  - Equipment Safety: Need ergonomic principles integrated into the processing and wafer moving equipment for both operation and maintenance aspects, and into the overall manufacturing facility.
ITRS: Resource Conservation

- **Reduce Water, Chemicals And Materials Use**
  - Requirements for large amounts of water, chemicals, and materials limit sustainable growth.

- **Waste Recycle**
  - Increase in resource use as the result of increasing process complexity will require that efficient waste recycling methods be developed.

- **After 2005:**
  - Reduce Water, Energy, Chemicals And Materials Use: Need resource efficient processing and facility support equipment and improved water reclaim and recycling methods. Emphasis on resource sustainability will grow.
Evaluate and Quantify ESH Impact

- Need integrated way to evaluate and quantify ESH impact of process, chemicals, and process equipment, and to make ESH a design parameter in development procedures for new equipment and processes.

After 2005:

- Evaluate and Quantify ESH Impact: Need integrated ESH design in development of new equipment and processes.
Conclusion

- Purely “compliance model” will only bring companies up to a minimum level that will NOT provide economic advantage.
- DFS/DfE model provides companies with competitive advantages.
Driving Force

Increase market share

Maintain market access

Minimize time to market

Decrease cost of ownership

Customer satisfaction

“Competition in the world marketplace is relentless. Those who can get the highest quality, price-competitive product to market in the least time are going to be winners.”