Successful TUR Planning: The ADI Story

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Capaccio has been working in a partnership with Analog Devices, Inc. for over 18 years

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  ◦ Analog for over 20 years
  ◦ Field of Toxics Use Reduction for over 20 years.

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  ◦ Analog for over 6 years
  ◦ TUR planner for over 5 years.
Presentation Outline

- Process Overview
- Planning Tools Utilized
  - Brainwriting, Options Evaluation Techniques, Performance Indicators, EMS Integration
- Highlights
  - Previous Success
  - Ongoing
Semiconductor Manufacturing: Basic Steps

- Sand to silicon
- Ingot to wafers
- Photolithography
- Clean/Etch
- Implant/Deposition
- Test/Slice
- Assembly/Packaging
ADI Manufacturing Process

- Process begins with ultra-pure silicon
- Silicon is in the form of a wafer
- Wafers are approximately 30 mils thick and 6 inches in diameter
Photolithography

- Apply photoresist
- Expose to ultraviolet (UV) light
- Masks similar to stencil/film process
- Circuit patterns in multiple layers
- Several microprocessors on a single wafer
Etching and Cleaning

- Dissolve photoresist
- Clean
- Chemical etch
- Reveal mask pattern
Ion Implant

- Photoresist to protect areas not getting ions implanted
- Ion implantation/doping
- Remove photoresist
Layers

- Polishing
- Layering
- Complex circuitry
Sort Test and Slice

- Wafer sort test
- Wafer slicing
- Discard faulty dies
Packaging

- Individual die
- “Packaging”
- Processor
ADI Production Units

- DI water production (PU 002)
- Photolithography (PU 004)
- Etching (PU 005)
- Clean (PU 006)
- CVD/EPI (PU 007)

Former production units include HSD, WWT, silicon processing
ADI TUR Tools

- Materials accounting
  - Monthly tracking and trending
  - Process characterizations
  - Process flow diagrams – line diagrams outlining inputs and outputs
ADI TUR Tools

- TUR options identification
  - Review previous ideas implemented or not
  - Bring in vendors/employees - Different perspective
  - No suggestion is too small
  - Never lose ideas, especially from year to year
  - Solicit ideas throughout the year
  - Process flow diagram/sticky note method

- Brainstorming/Brainwriting*
Brainwriting Exercise

- The only way to have a good TUR option is to have many options.
- Avoid the search for the single right answer.
- Generating TUR options involves creativity.
Brainwriting

- Works with teams that may be less familiar with one another (e.g. suppliers)
- Easier to facilitate than brainstorming
- Generates many TUR options (20+)
- Allows for constructive criticism and building upon options
- Facilitates discussion of TUR Options
- Creativity enhanced by provocation ‘outrageous’ TUR options
Provocation for ‘Outrageous’ TUR Options

- A fundamental thinking process that is useful in generating new TUR options
- If you do not expect the unexpected, you will not find it for it is not to be reached by search or trial
Brainwriting Sheet

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ADI Production Units

- DI water production (PU 002)
  - Process is very water intensive
  - Used in Etching (PU 005) and Clean (PU 006)
  - As part of process need to regenerate resin columns using TUR chemicals (HCl and NaOH)
ADI TUR Tools

- TUR options evaluation*
  - Preliminary screen
  - Comprehensive/documentated review
  - Resulting in option(s) selection
- Bubble sorting exercise
- Rating scale review
Bubble Sorting TUR Options

- Bubble-up/bubble-down is designed to select a TUR Option for **feasibility** analysis
- It is a **forced-pair** comparison
- It allows for extensive team interaction
- No alternatives are eliminated
- **Additional information may be required in an interactive prioritizing process**
Which TUR Option is Best?

- Which is more efficient in reducing waste and conserving resources
- Which is easier to implement
- Which costs less
- In any organization, ability to implement and cost are more important in the short term than effectiveness!
Prioritized TUR Options

- **Quick wins** may be found at the top – often implemented without TUR evaluation
- **TUR options** found below for TUR evaluation
- Less probable alternatives at the bottom – future TUR options when you know more
- Outrageous TUR options spur thinking **outside the box**
- Discussion aids in preparing TUR options evaluation
ADI TUR Tools

- TUR options evaluation*
  - Comprehensive documented review
  - Evaluate formally taking into consideration the following:
    - Technical feasibility
    - Economic feasibility
    - Process concerns
    - Health & safety concerns
    - Environmental concerns
ADI TUR Tools

- TUR plan implementation
  - Schedule
  - Tracking
    - Process/Performance metrics vs. target metrics
  - Integrated right into EMS – Management Review
  - Set realistic goals/stretch goals
  - Periodic review by TUR team
Performance Indicator

- Performance indicator tracks progress towards target

- Example
  - **Objective**: Reduce energy use
  - **Target**: Achieve 10% reduction relative to prior year for energy use from manufacturing operations
  - **Indicator**: Quantity of fuels & electricity used per unit of production
Considerations: Performance Metrics

- Will metric clearly show whether target was achieved
- Is data readily available to track progress
- Does indicator need to be normalized to account for misleading data
Performance Standard

- After achieving target can set performance standard

- Examples
  - Use of ozone-depleting substances is prohibited in manufacturing operations
  - All new electrically-powered equipment must meet a minimum energy efficiency rating of (specify)
  - All new sink installations must have electronic detection devices to control rinsing
Components of ISO 14001 EMS

Policy

- Legal & Other Requirements
- Environmental Aspects/Impacts
  - Objectives & Targets
  - Programs

Planning

- Implementation & Operation
- Checking & Corrective Action

Management Review

Continual Improvement
Management Review

- Involve top management
- Review progress toward targets (via metrics)
- Assess to ensure continuing suitability, adequacy, & effectiveness of the program as well as address the need for changes
TUR-Related Achievements: Selected Highlights

- Sulfuric acid aerosol reduction
- Reduced chemical/gas use & inventory
- Resource conservation
  - Water use reduction (and associated chemical use reductions in DI water production)
  - ODSs and GWGs
  - Energy and solid waste
Sulfuric Acid Aerosol Reduction

- Utilization of ozone in the process to clean as an alternative to sulfuric acid
- Some parts need to be cleaned with sulfuric acid however, it’s use has been reduced by ~20% in this process
- At first only one tool was installed and evaluated - a second has since been installed and a third has been ordered
- The tools spray both ozone and SA
Reduce Chemical/ Gas Use and Inventory

- Constantly reviewing the usage of new photoresists/developers in the process
  - Elimination of ethylene glycol
  - Elimination of perfluorooctylsulfonates (PFOS)
  - Elimination of phenol (A30)
  - Reduced xylene below reporting threshold
Reduce Chemical/ Gas Use and Inventory

- Moved from 4-6” wafers
- Bulk delivery systems
  - No pouring/less handling
  - Automatically feeds a metered amount reducing usage
  - Less solid waste generated
Water Conservation Achievements

- Potable Water  5%
  Used in bathrooms, kitchens drinking fountains

- Industrial Water  35%
  Used to run facilities equipment

- Ultra Pure Water  60%
  (City water filtered onsite)
  Used by production

- No wonder why process water savings arrived at the top
- Ongoing
Water Conservation Achievements

- Activities:
  - Tool Upgrades, Ongoing Audit Program, Flow Meters/Regulators, SOPs, reclaim

- Reclaim system has reduced city water used by facilities by 75%.

- Decrease in DI water reduces regenerations.

- To date, efforts have saved 50,000 gallons per day of DI water use and 250,000 gallons per day of city water.
Reduction of ODSs and GWGs

- Although not TUR chemicals, ODSs and GWGs were eliminated/reduced using the same process and tools described above.
- Site continues to reduce use of ODSs and GWGs
- Ongoing review – GWG abatement for now
Energy and Solid Waste

- Again the same TUR approach is taken when reviewing options for resource conservation
  - Electrical use
  - Natural gas use
  - Solid waste
Lessons Learned

- Integrated into EMS – Management Review
- TEAM WORK
- Low hanging fruit – keeps growing
- Bunt versus grand slam
- Documentation
- Organization
- Learn more every planning cycle
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