

# Successful TUR Planning: The ADI Story

November 2010



# Analog and Capaccio

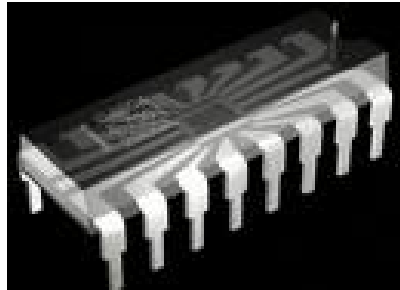
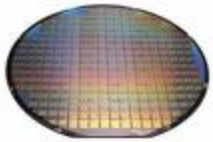
- ▶ Capaccio has been working in a partnership with Analog Devices, Inc. for over 18 years
- ▶ Lisa F. Wilk, P.E., President –
  - Analog for over 20 years
  - Field of Toxics Use Reduction for over 20 years.
- ▶ Dan Forsythe, TURP, CHMM –
  - Analog for over 6 years
  - TUR planner for over 5 years.

# Presentation Outline

- ▶ Process Overview
- ▶ Planning Tools Utilized
  - Brainwriting, Options Evaluation Techniques, Performance Indicators, EMS Integration
- ▶ Highlights
  - Previous Success
  - Ongoing



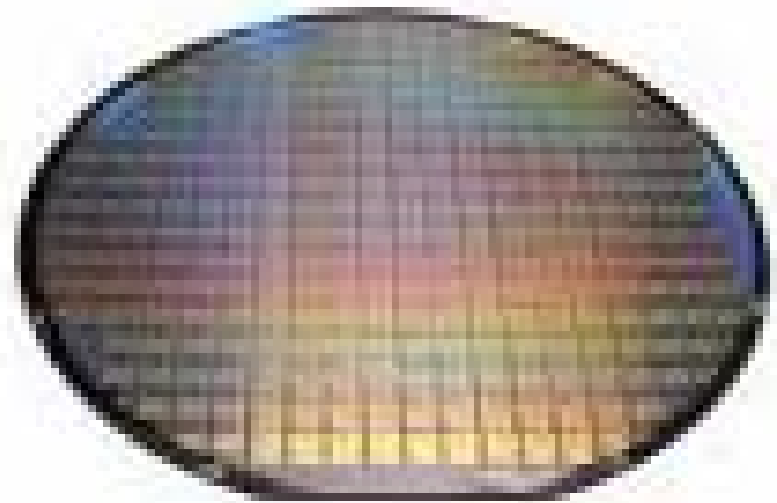
# Semiconductor Manufacturing: Basic Steps



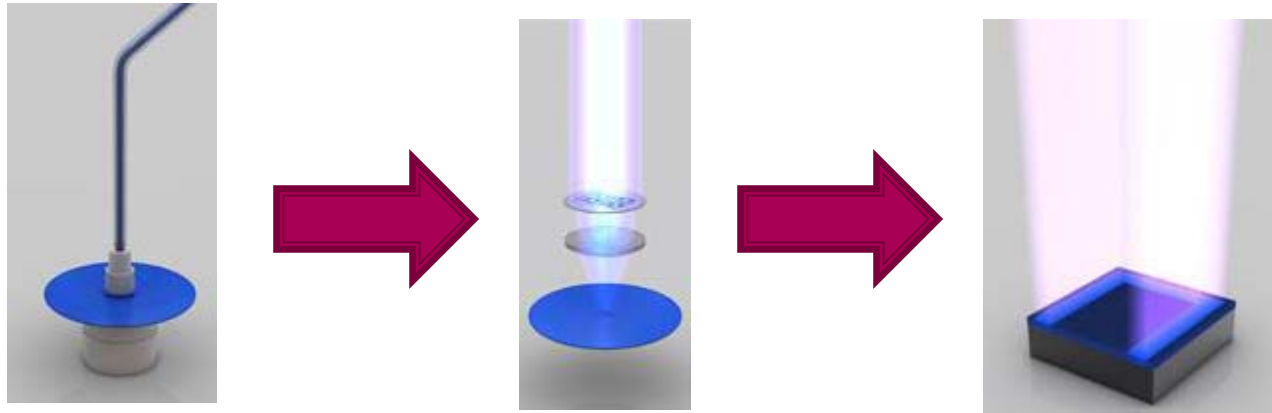
- ▶ Sand to silicon
- ▶ Ingot to wafers
- ▶ Photolithography
- ▶ Clean/Etch
- ▶ Implant/Deposition
- ▶ Test/Slice
- ▶ Assembly/Packaging

# 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

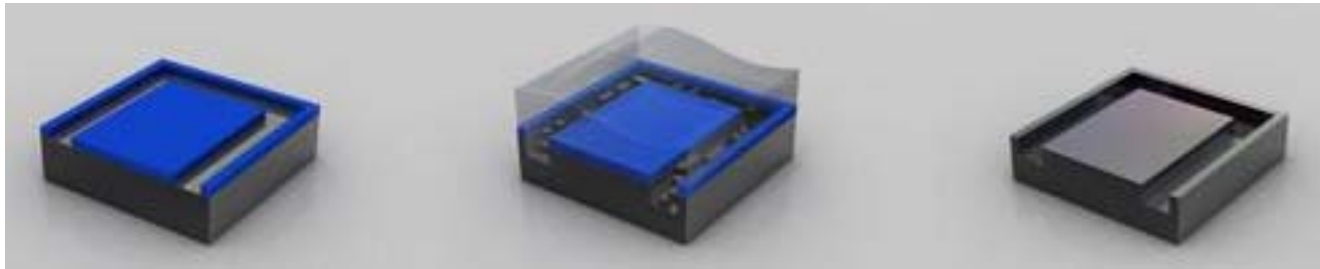


# Photolithography



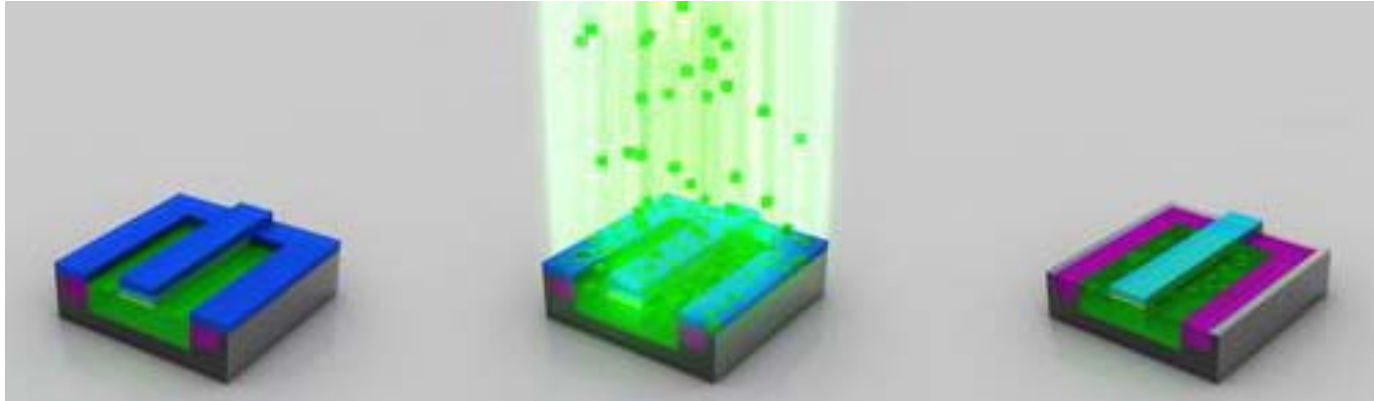
- ▶ Apply photoresist
- ▶ Expose to ultraviolet (UV) light
- ▶ Masks similar to stencil/film process
- ▶ Circuit patterns in multiple layers
- ▶ Several microprocessors on a single wafer

# Etching and Cleaning



- ▶ Dissolve photoresist
- ▶ Clean
- ▶ Chemical etch
- ▶ Reveal mask pattern

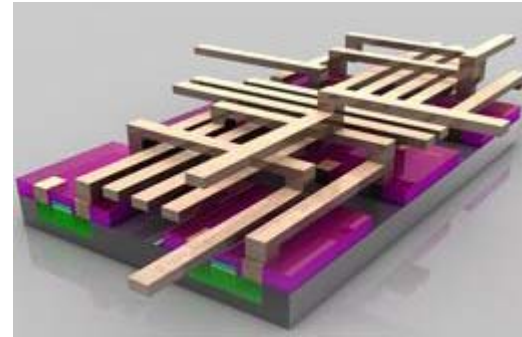
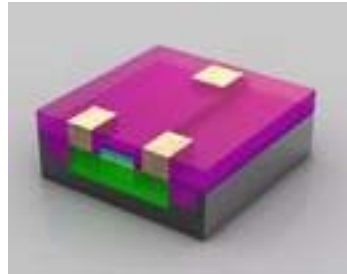
# Ion Implant



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

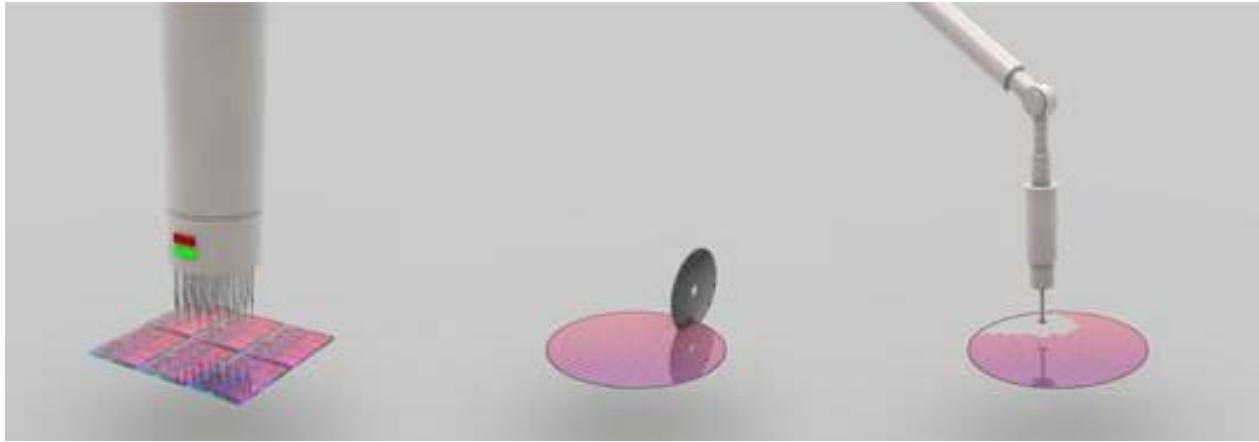


# Layers



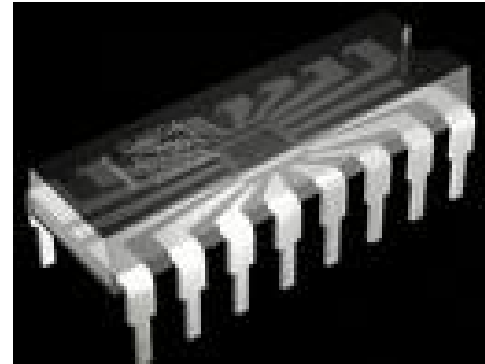
- ▶ Polishing
- ▶ Layering
- ▶ Complex circuitry

# Sort Test and Slice



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

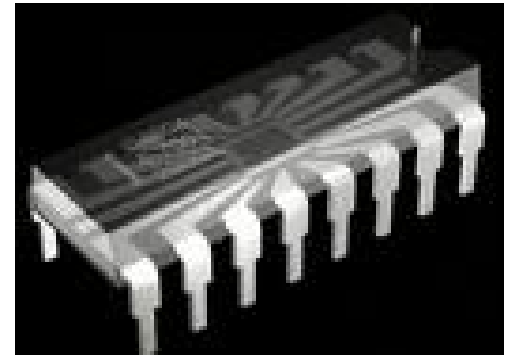
# Packaging



- ▶ 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 through out 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

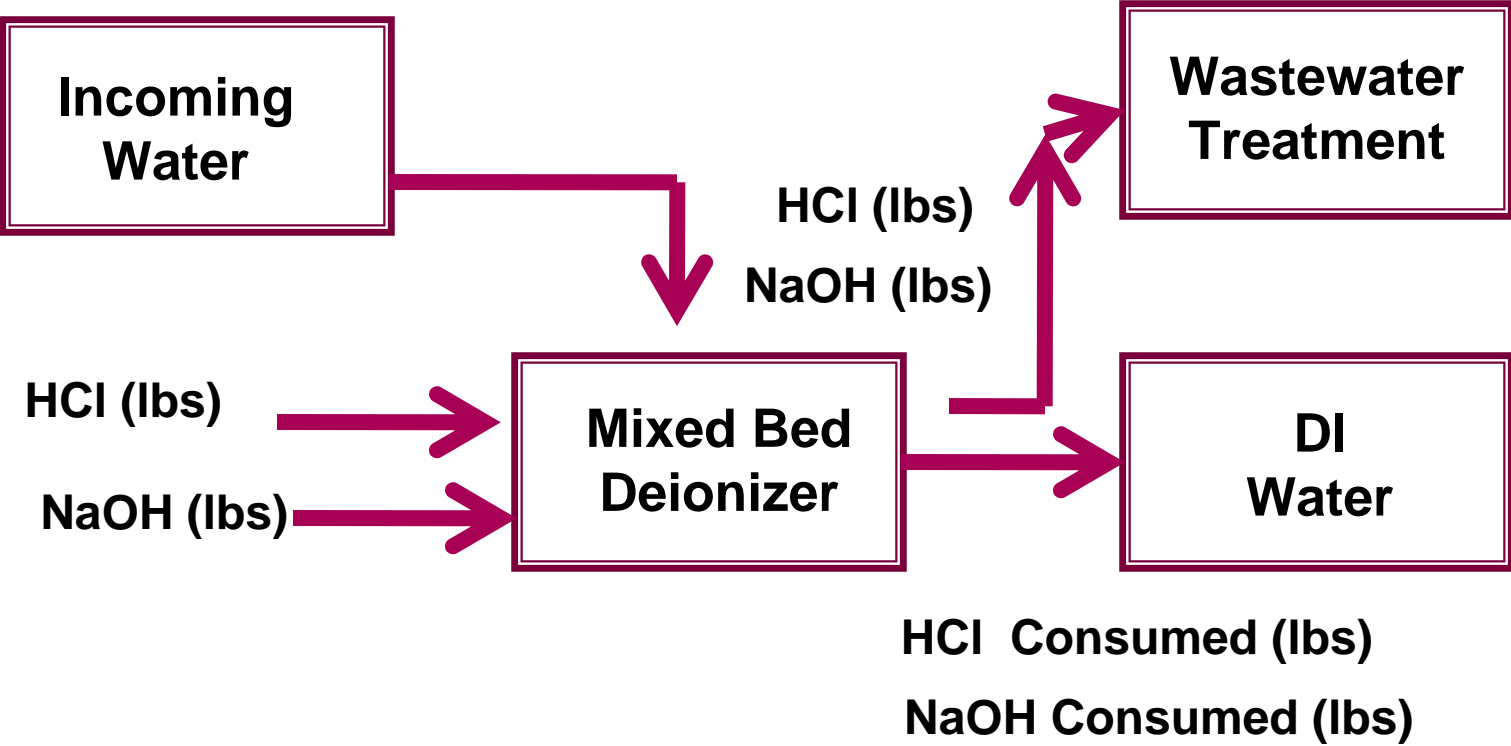
1	2
3	4
5	6
7	8
9	10

# 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)



# DI Water Production Unit




# 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!
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# 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

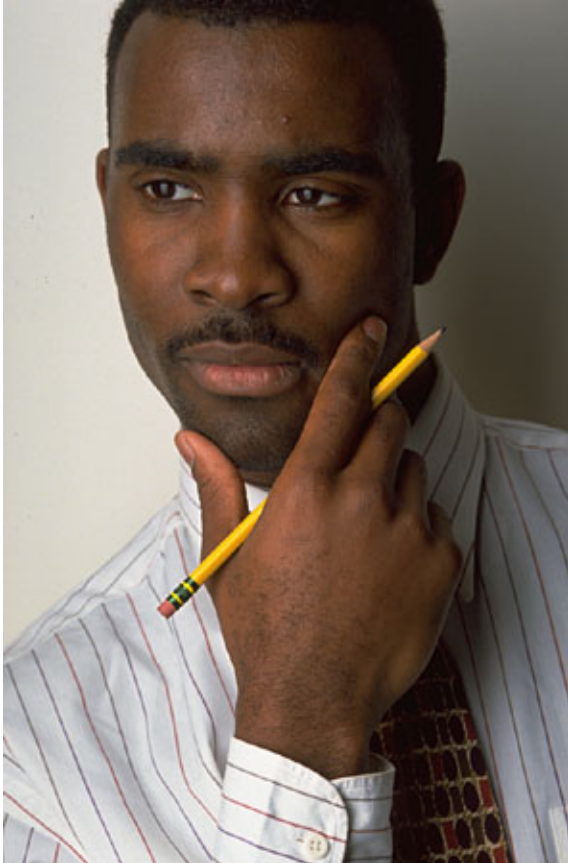
- ▶ TUR plan implementation
  - Schedule
  - Tracking
    - Process/ Performance metrics vs. target metrics
  - Integrated right into EMS – Management Review
  - Set realistic goals/stretch goals
  - Periodic review by TUR team

# 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

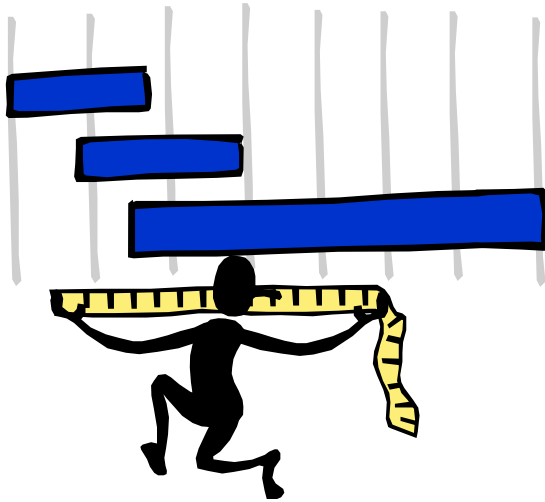


# Considerations: Performance Metrics



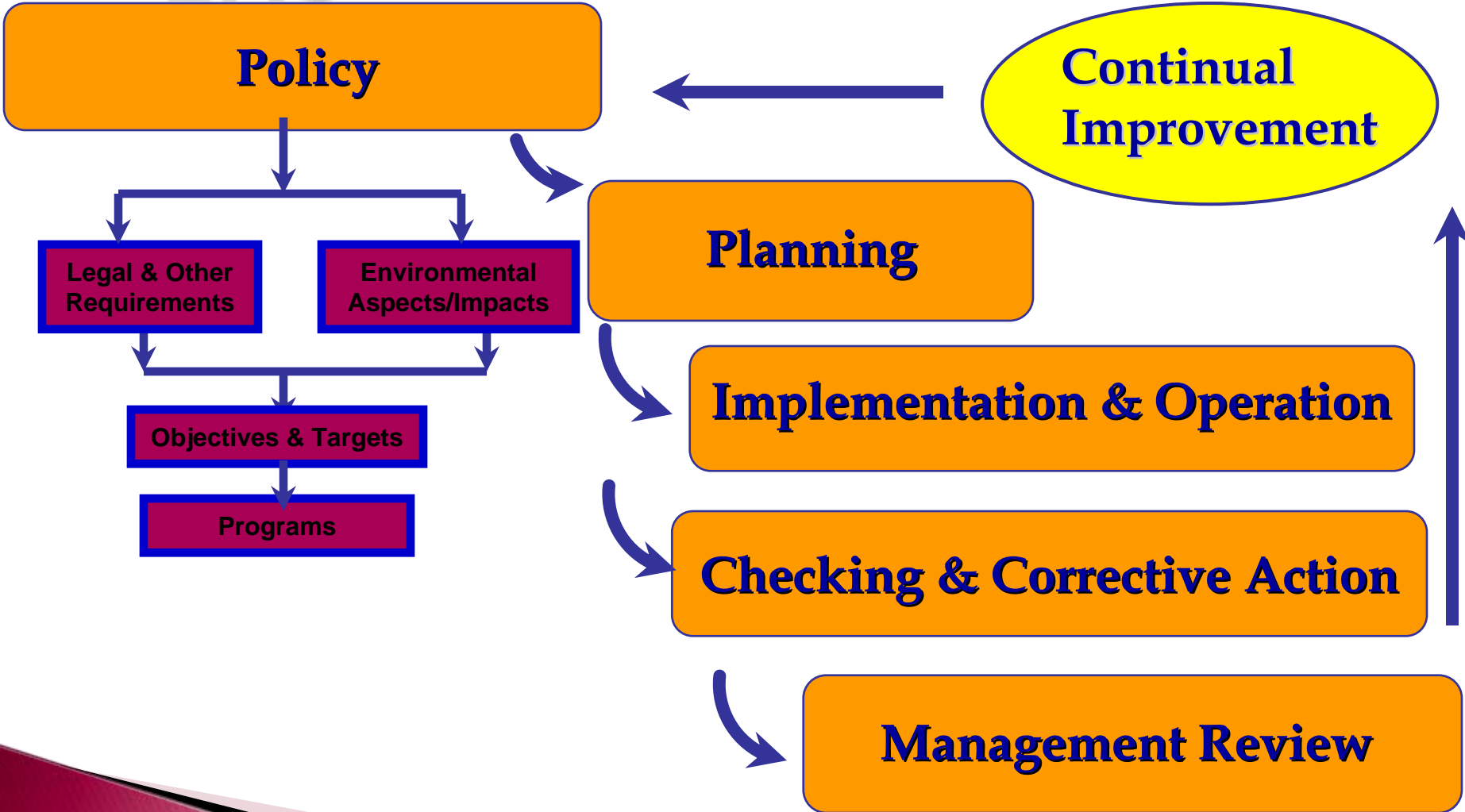
- ▶ Will metric clearly show whether target was achieved
- ▶ Is data readily available to track progress
- ▶ Does indicator need to be normalized to account for misleading data

# 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



# 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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