CMP Consumables: Meeting Technology Challenges with Quality Incident Free Performance

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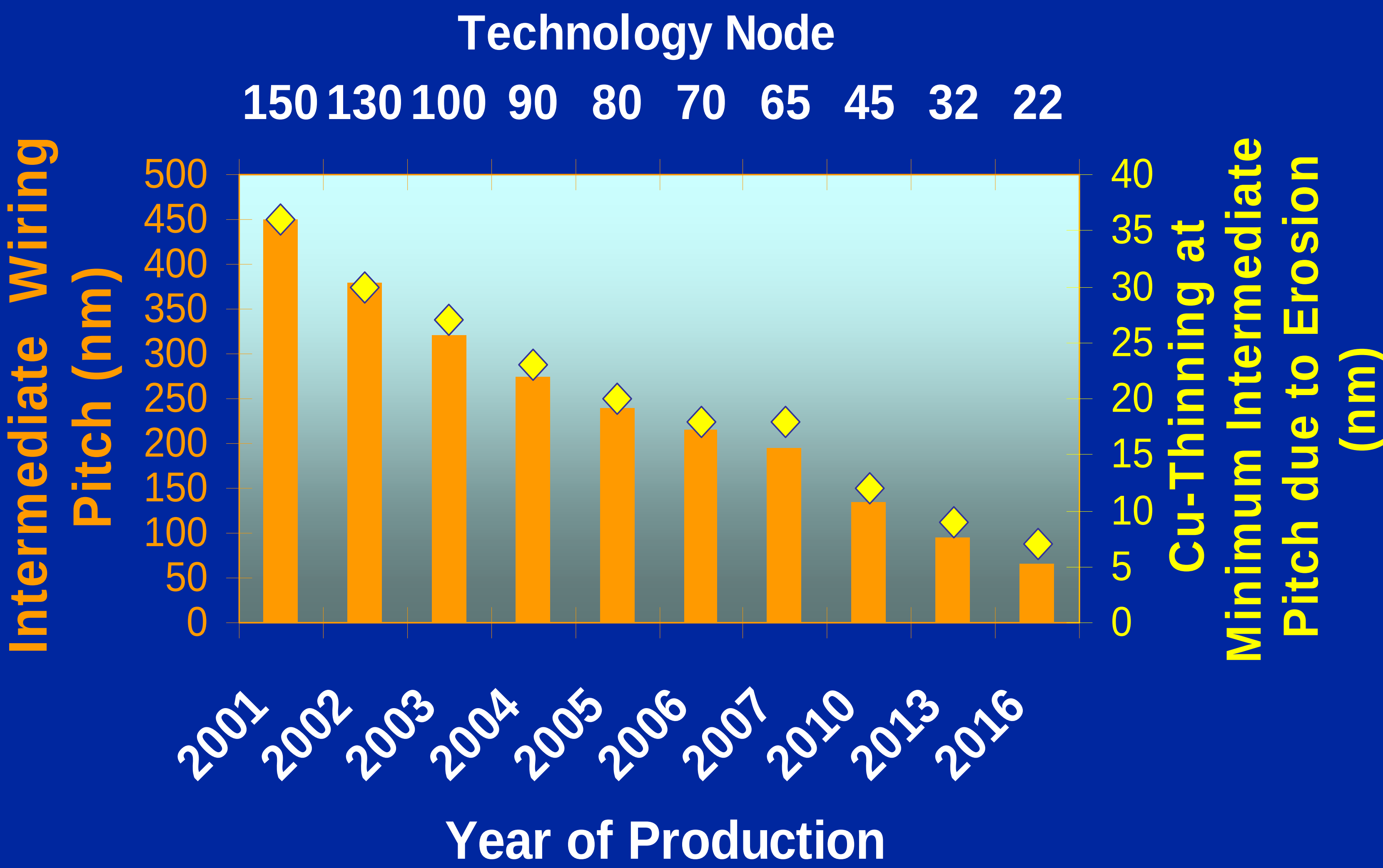
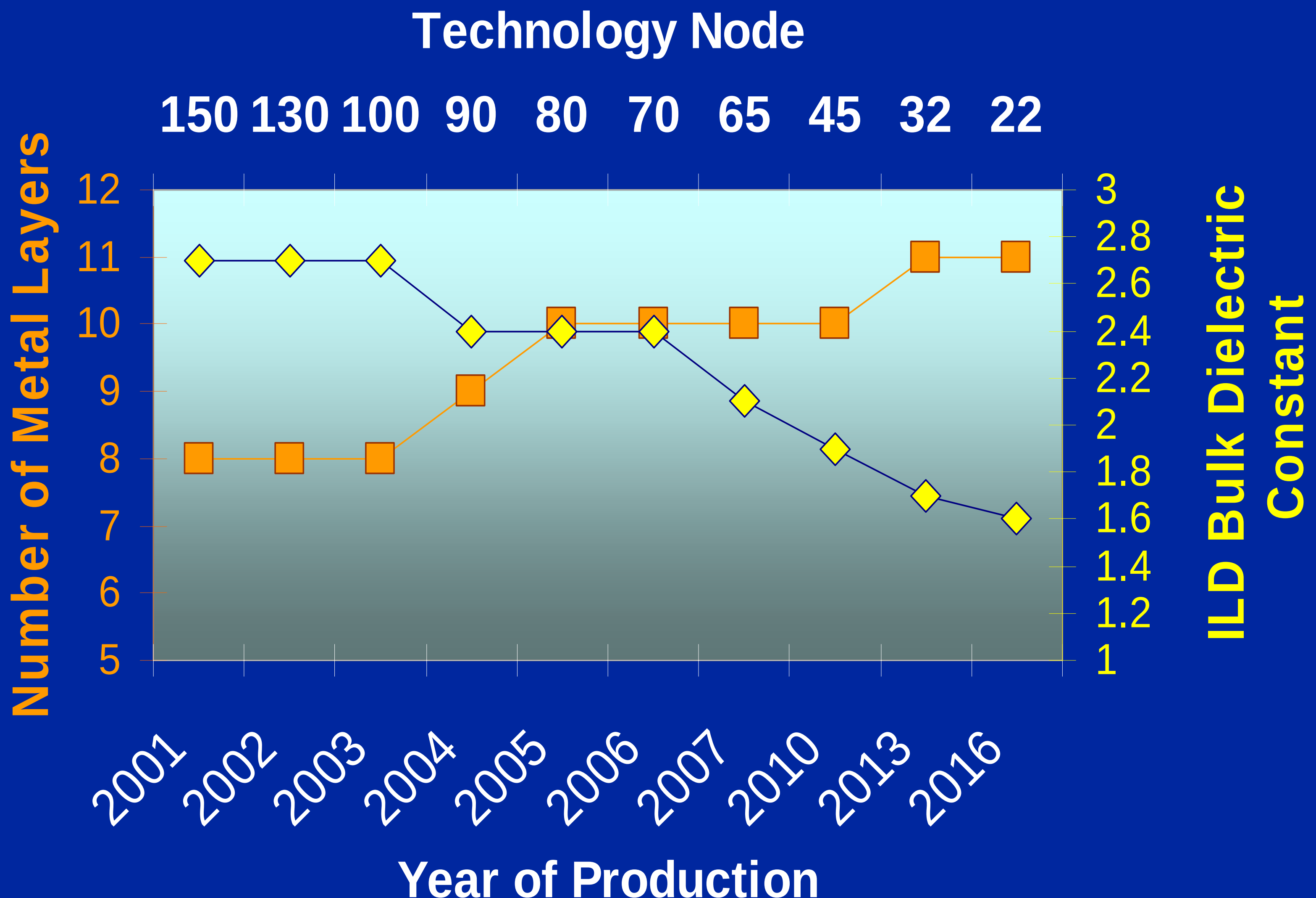
ITRS 2001/2002 Projections



ITRS 2001/2002 Projections

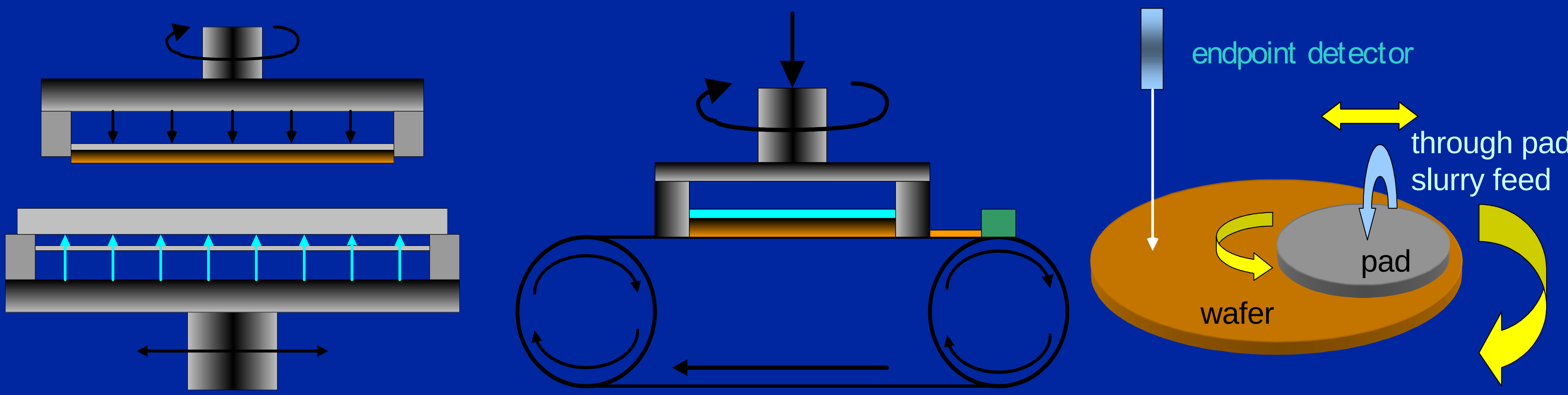


Evolution of CMP

Logic Technology	Application	Equipment	Post-CMP Cleaning Processes
First Generation (0.8-0.5 um)	• Oxide (ILD)	Single platen, Single head, One step polishing	Wet station cleaning, DI wafer scrub
Second Generation (< 0.5 um)	• Oxide +ILD0 • W CMP + STI	Multiple platens & heads, Two-step polishing, End-point, On-board metrology	DI wafer scrub, NH_4OH clean
Third Generation (< 0.25 um)	• Oxide +ILD0 • W CMP + STI • Cu, doped ILD	Multiple platens & heads, Multi-step, End-point, On-board metrology, Integrated dry-in/dry-out, non-rotary (orbital, linear CMP)	DI wafer scrub, NH_4OH clean, HF-clean, Integrated dry-in/dry-out, new chemistries
Fourth Generation (< 0.18 um)	• Oxide +ILD0 • W CMP + STI • Cu, doped ILD • Low-k, ULK	Multiple platens & heads, Multi-step, End-point, On-board metrology, Integrated dry-in/dry-out, non-rotary (orbital, linear CMP)	DI wafer scrub, NH_4OH clean, HF-clean, Integrated dry-in/dry-out, new chemistries

M. Moinpour, A. Tregub, A, Oehler, and K. Cadien, “*Advances in CMP Consumables*”, MRS Bulletin, October (2000)

CMP: Key Challenges Going Forward



Rotary | **Linear** | **Rotary Inverted**

- Miniaturization-Driven Planarity Requirements
- New Materials and Processes
- Low- κ & Ultra Low- κ (ULK) Incorporation
- Post-CMP Cleaning Process
- Development of New Planarization Techniques

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Specific Challenges of Low-k Materials

- Mechanical Property Limitations
- Interconnect Structural Stability Concerns
- New Integration Processes Required
- New CMP Approach Required
- Post-CMP Cleans, Corrosion and Defectivity Issues
- Alternative Planarization Techniques

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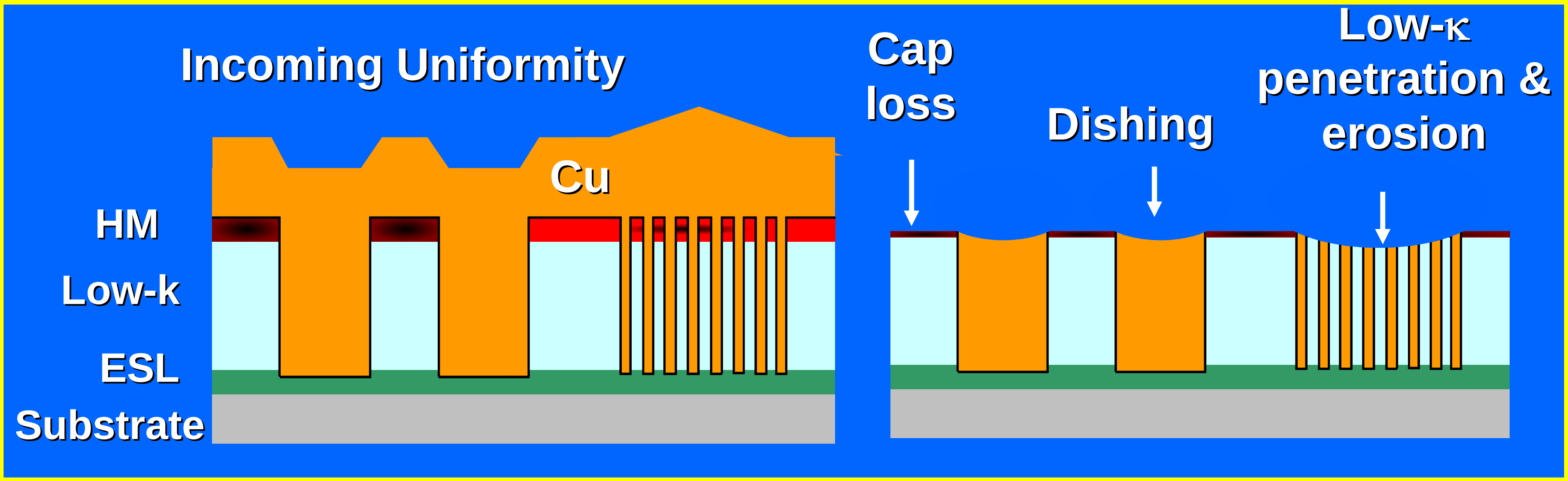
Pattern Dependent Concerns



- Independent of Cu/low-k, Conventional CMP Metrics
- New Challenges
  - Mechanical Integrity Issues
  - Corrosion & Defectivity Concerns

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Integration-Related Challenges for CMP

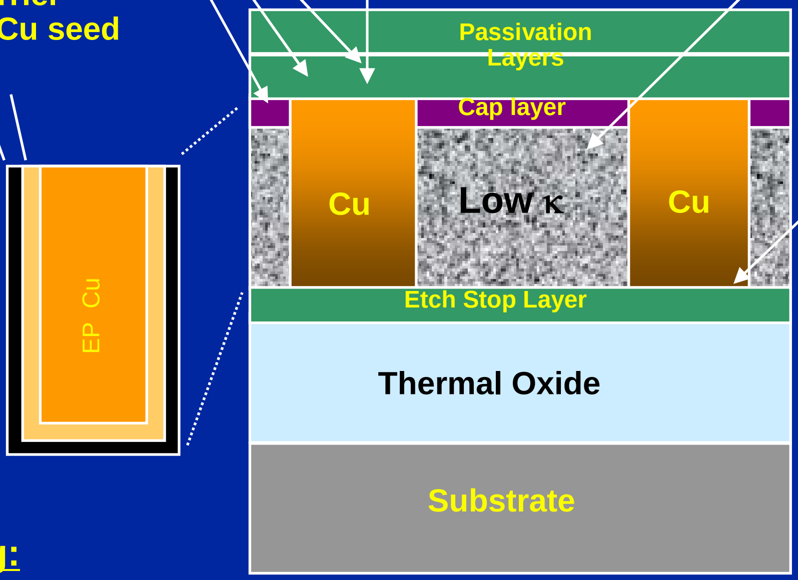
Mechanical integrity for CMP:
• Adhesion of low-k to cap & barrier adhesion for CMP

Film "damage" by CVD plasma capping layer

Low-κ Defects:
• Film striations due to spin-process,
• solvent formulation

PVD barrier
PVD Cu seed

Barrier/seed quality:
• Void-free Cu fill
• Out-gassing during barrier deposition
• Barrier morphology on porous sidewall



(Not to Scale)

Etch Processes:
• selectivity to capping films and substrate;
• film "damage" during photo resist removal
• Sidewall damage, preferential failure site.

Electroplating and Annealing:
• Topography variations
• Electroplating bumps near electrode positions
• Preferential deposition in trenches
• Copper grain size and distribution
• Anneal
• Impurities, copper sulfates

CMP Process Variables

Input Variables

Particle Characteristics
Size, Size distribution, Shape, Mechanical Properties, Chemistry, Dispersion, Concentration, Agglomeration, Oversized Particles

Slurry Chemistry
Oxidizers, pH stabalizers, Complexing Agents, Dispersants, Concentration, pH and pH drift

Down Pressure & Linear Velocity

Pad Characteristics
Mechanical Properties, Topography, Conditioning

Substrate Characteristics
Feature size, Feature density

Micro-scale Parameters

Pad
Contact area, Pressure on pad

Particles on pad
Pressure, Coverage

Chemical Conc. & Distribution

Contact mode
Direct, Mixed, Hydroplaning

Nano-scale Interactions

Chemo-mechanical
Surface-layer formation; Thickness, Uniformity, Rate of formation, Layer removal mechanism, Abrasion frequency

Chemical & Mechanical
Etching, Mechanical removal

Output Parameters

- **Removal rate**
- **Planarization**
- **Surface finish**
- **Selectivity**

Source: R. Singh, and R. Bajaj "*Advances in Chemical-Mechanical Planarization*", MRS Bulletin, October (2000)

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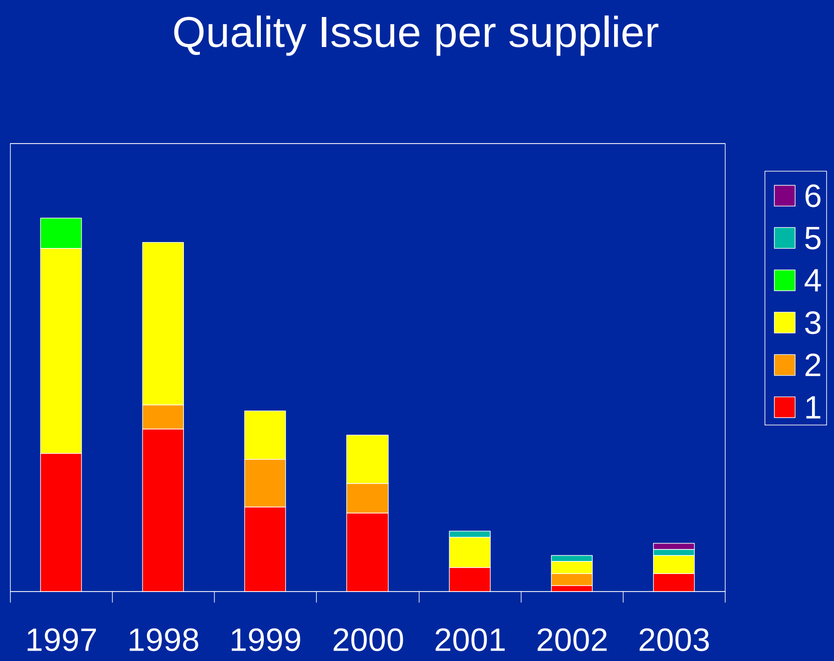
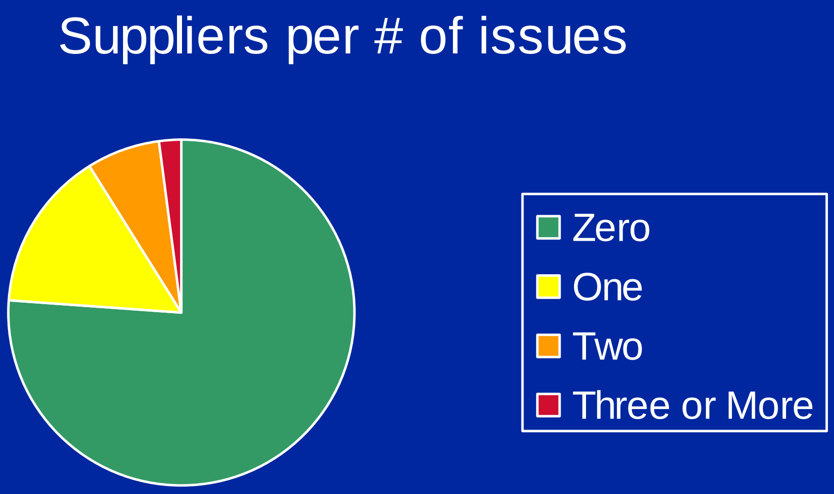
Fab Materials Quality Issue

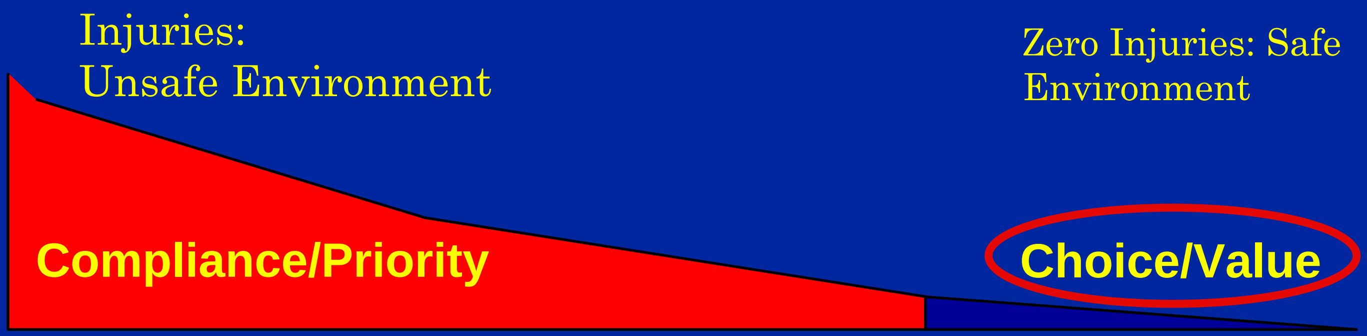




- Quality Issue reduction stalled in 2001-2003
- Most suppliers have no issues
- How do we get to ZERO!

Quality Incident Free

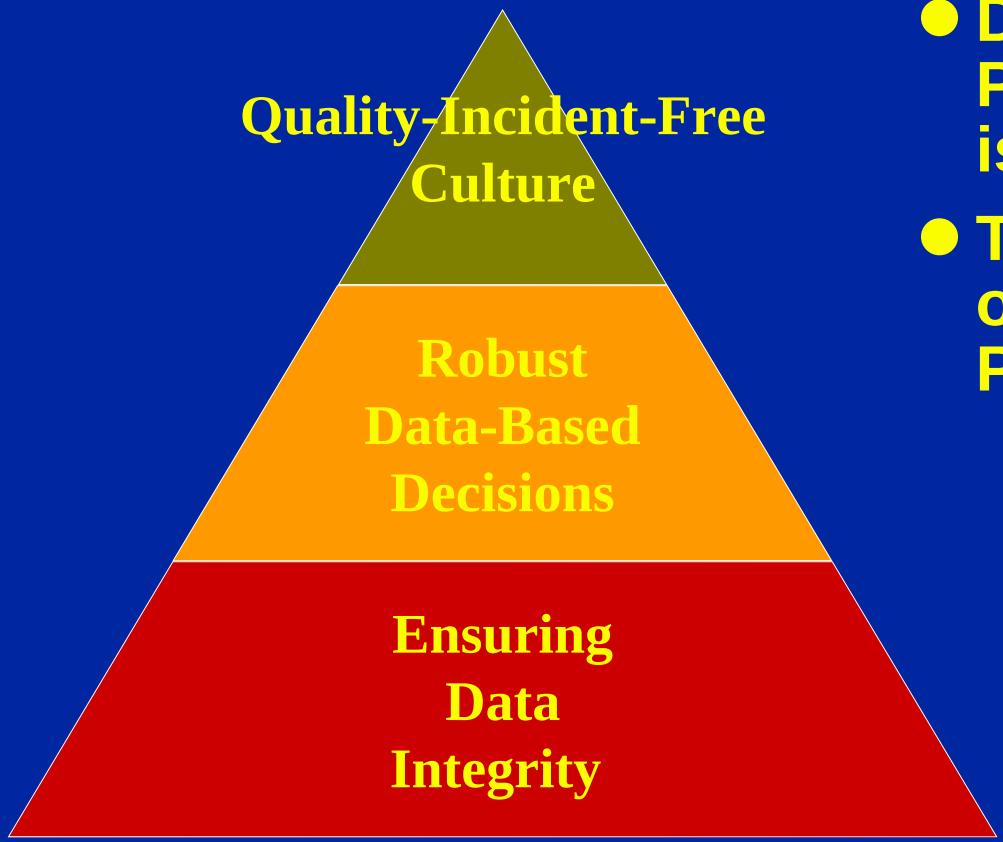
Safety Analogy



It has been found that only 80% of a safe environment can be created with rules and regulations. The other 20% must come from **all project personnel choosing** safe behaviors.

QIF Behavior	Instead of
Quality is a Value	Quality is a Priority
Quality by Choice	Compliance to specs
Excursions are preventable	Excursions are inevitable
Look for problems	React to problems

Process Control System Development

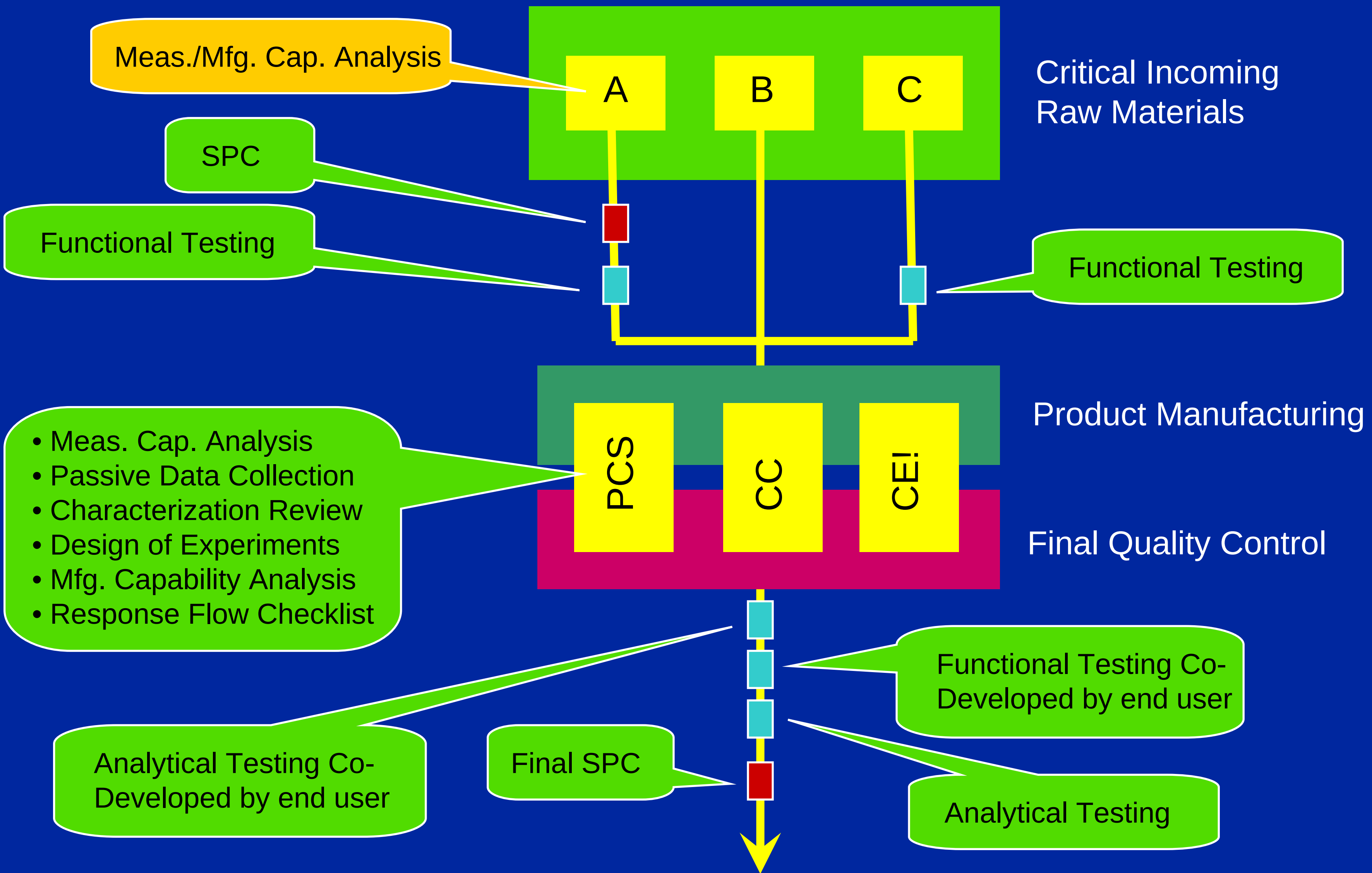


- Developing a Robust Process Control system is based on Data Integrity
- Timely Characterization of Key and Control Parameters is required

Example of Characterization

- Previous work
  - Targeted large variations in key components to verify process modulators
- Spec validation
  - Narrowed key component concentrations
    - To stabilize process performance
    - Verify component synthesis, aqueous blending and manufacturing delivery system control parameters
- DOE Variants
  - Component A, B, Abrasive, H_2O_2

Total Quality Control Model



Variable measured

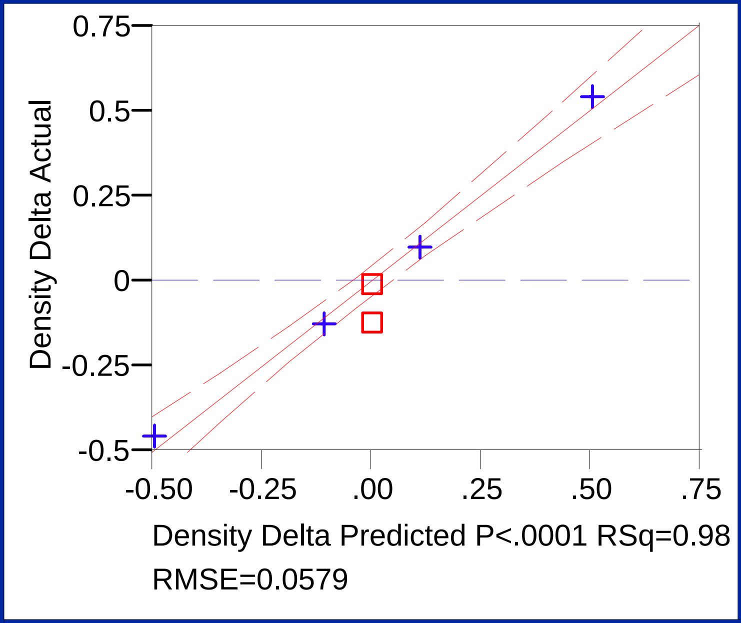
- **Supplier Variables**
  - Assay
    - Component A
    - Component B
  - Physical
    - pH
    - Specific gravity
  - Functional
    - Removal Rate
    - Uniformity

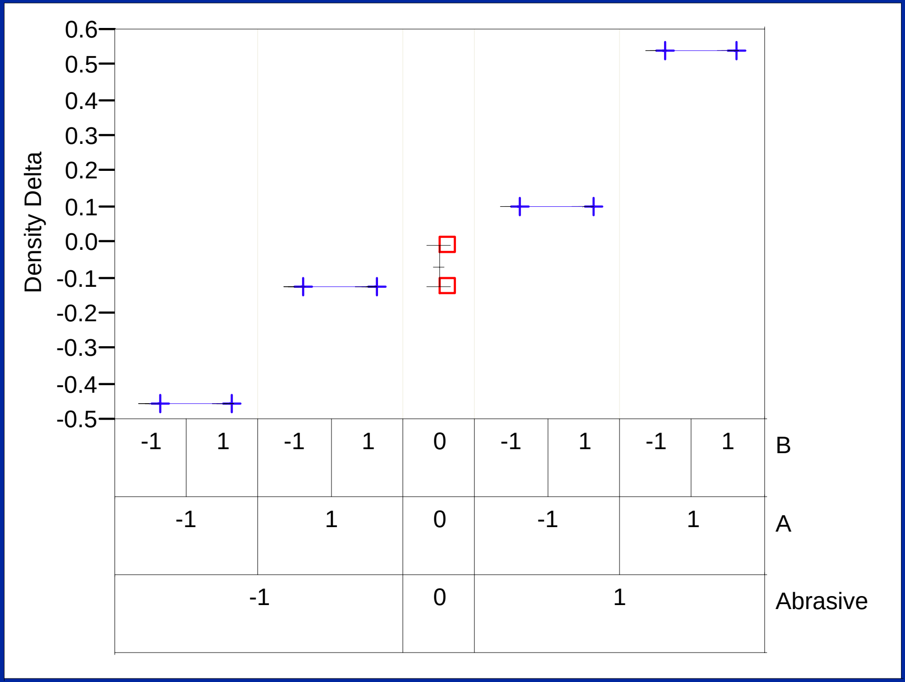
- **IC manufacturing Variables**
  - Test Pattern
    - Removal Rate
    - Uniformity
    - Topography
    - Reviewed Defects
  - Chemical Delivery
    - pH
    - Specific gravity
    - Peroxide assay

Focus for discussion Today

Specific Gravity

- Specific Gravity is dominated by highest weight percent item
  - Abrasive
  - Component A
  - It is not an independent measure of Abrasive content
- Control Scheme
  - Specific gravity is okay
  - Component A needs to be data considered in PCS decisions for specific gravity

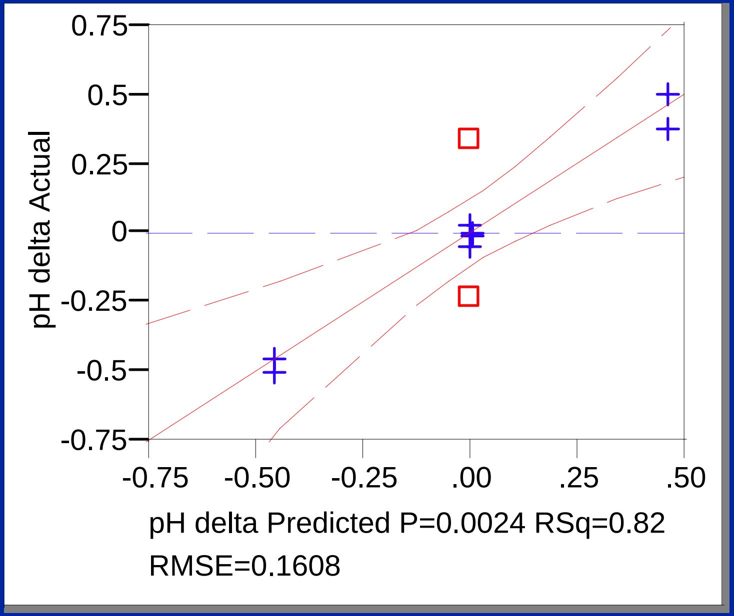


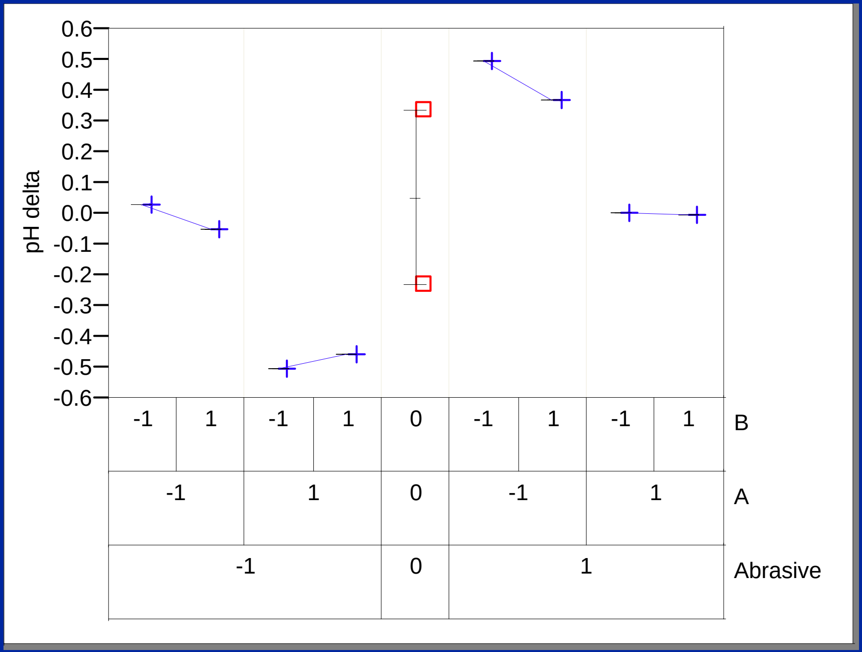


- Density Delta is a normalize specific gravity difference

pH

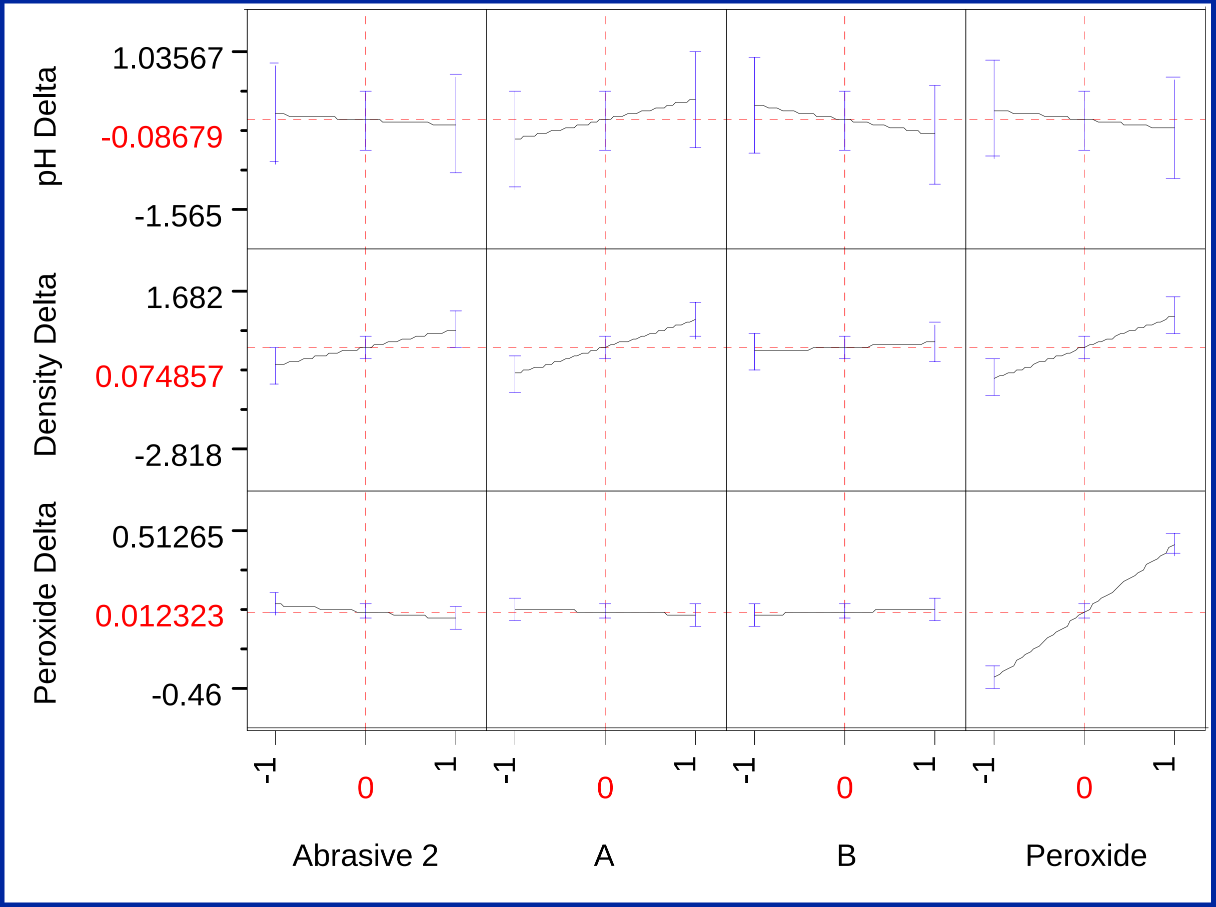
- Buffer effects
  - Abrasive, with silica, acts a weak buffer solutions
  - Component A, also acts as a weak buffer
- No interactions
- No manufacturing control in blending operation
- Control Scheme:
  - pH in Abrasive and Component A synthesis
  - Abrasive weight percent
  - Component A assay





- pH delta is a normalized pH difference

Peroxide Addition Effects



- pH
  - No main effects or interactions
- Specific Gravity
  - H2O2, Abrasive and component A all influence
- H2O2 assay
  - Only influenced by H2O2 addition
- Control scheme
  - Specific gravity okay
  - H2O2 assay needs to be data considered in PCS decisions for specific gravity

parameter delta is a normalized parameter difference

What Do We Mean by Characterization?

- **Characterization & Technology Engagement**
  - Materials characterization as part of design & synthesis
  - Characterization during material selection and process integration (IP barrier)
  - Characterization post material selection (IP barrier)
    - High volume and scalability effects
    - Stability and predictability
    - SPC and Quality Control
    - Material delivery and waste treatment; recycling
- **Materials Characterization in CMP**
  - Polymer Characterization
  - Thermomechanical characterization of pads
  - Rheological studies of slurries, particle agglomeration

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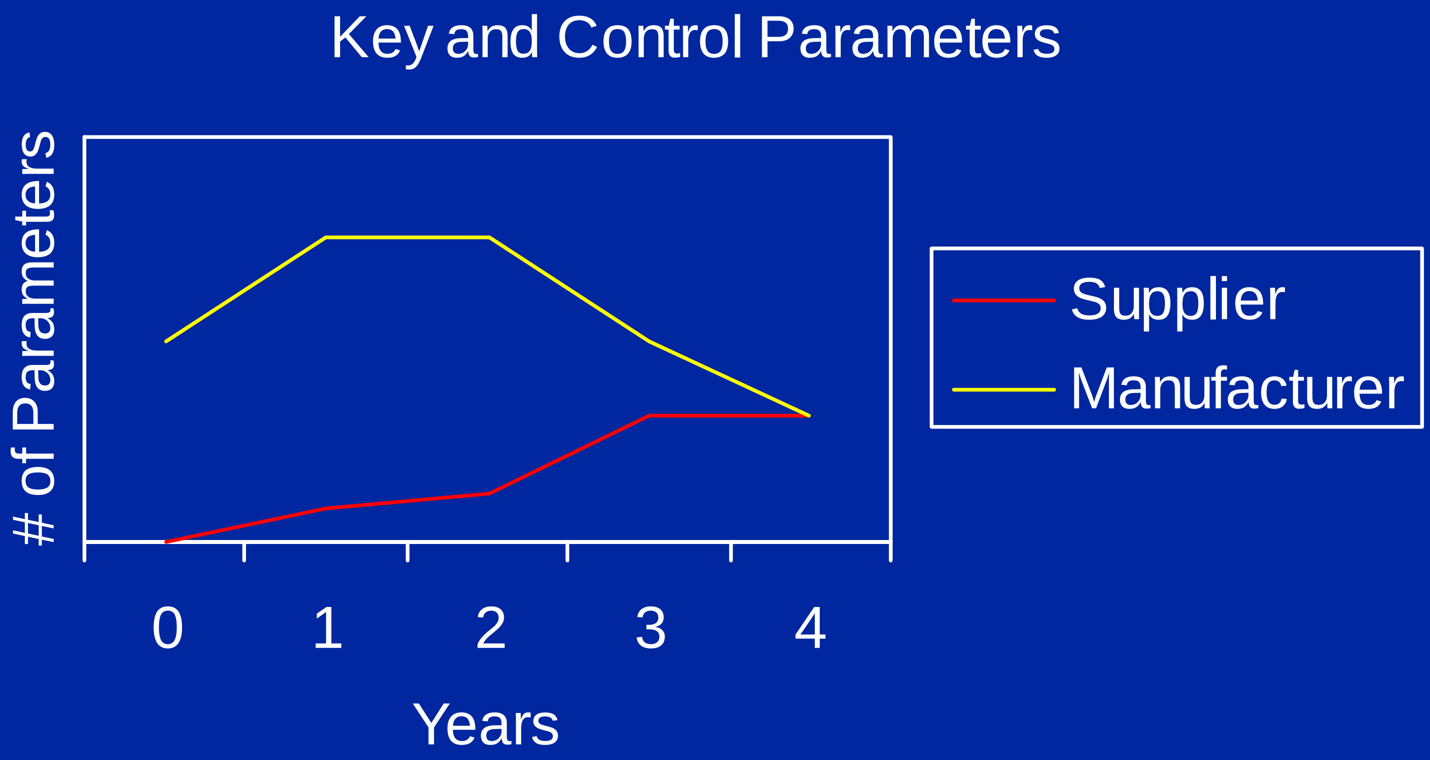
Limiting to Key Parameters



- **Supplier is lagging IC manufacturer in identifying and limiting key and control parameters**
- **Pro Active Characterization is Needed during Development!**

Acknowledgments

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  - Anne Miller
  - Herng Liu
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