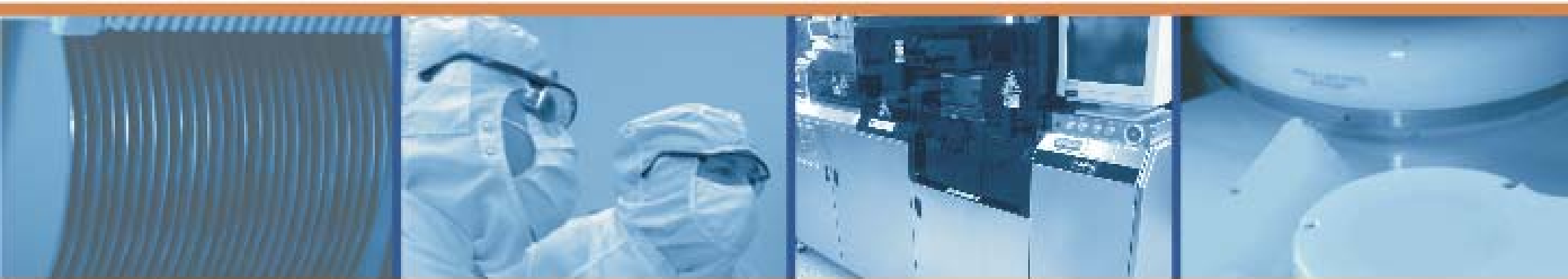


# Outsourced CMP for Accelerated Process Development

by

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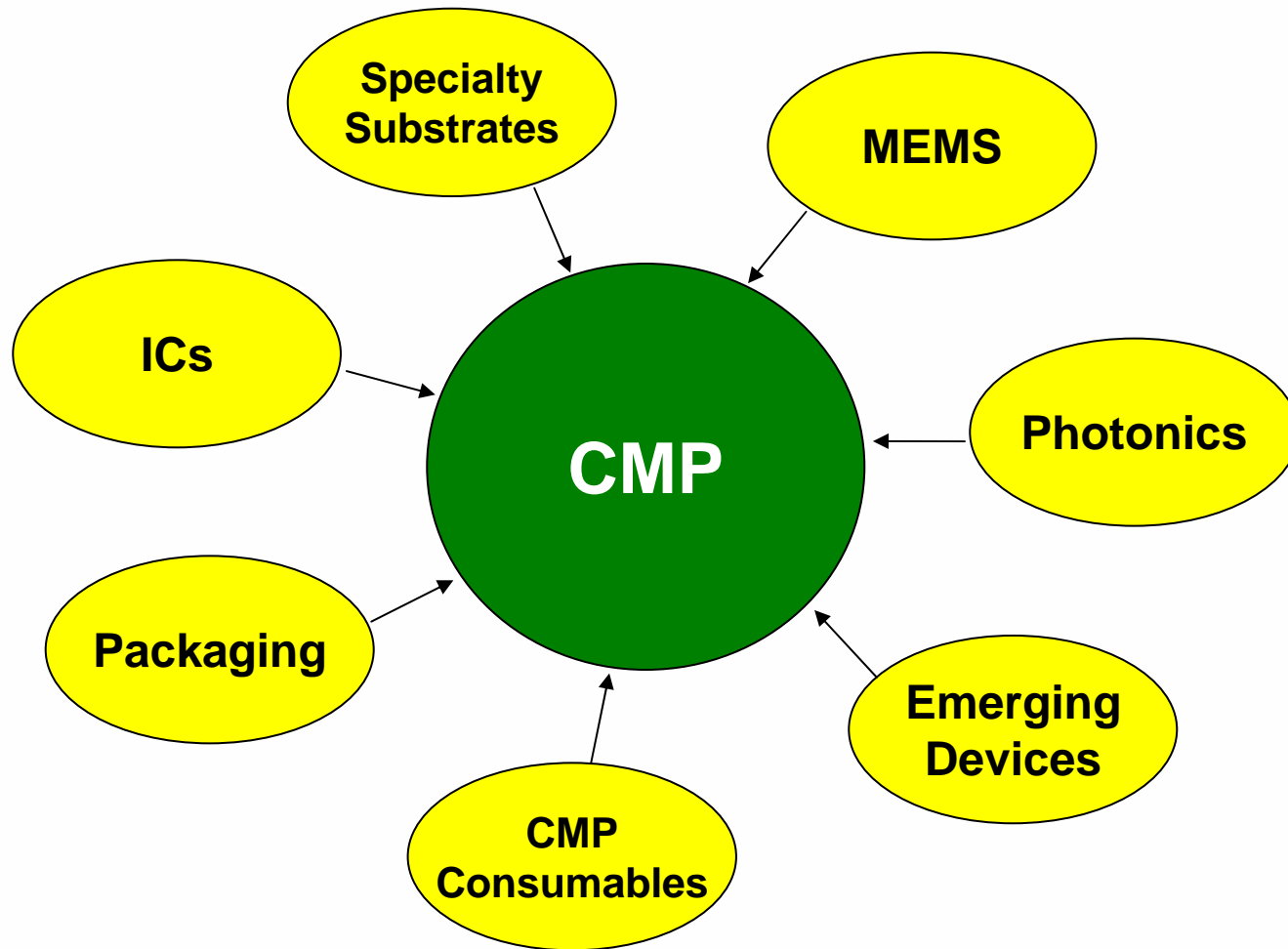
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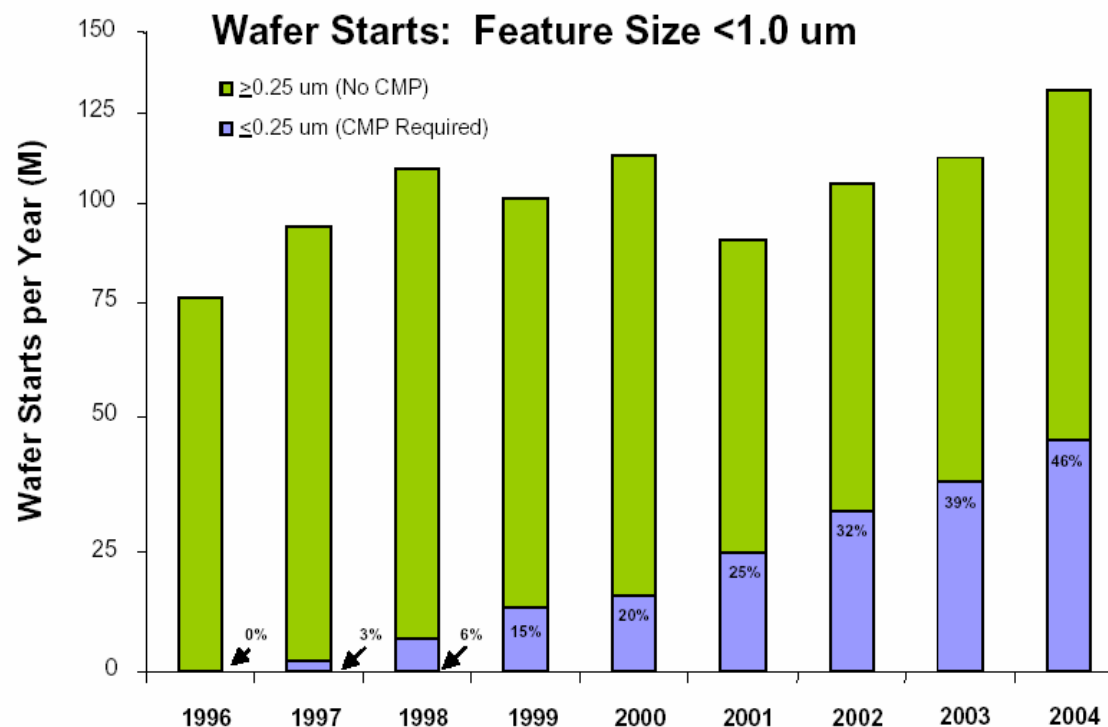
- **Why Outsource CMP?**
  - **Background**
  - **Expanding applications**
  - **Economic drivers**
  
- **CMP Process Development**
  - **Internal vs outsourced development**
  - **Technology issues and financial impact**
  - **Examples**
  
- **Comments and conclusions**

- **CMP is now recognized a necessary process for most advanced IC process flows.**
  - Initially guarded as trade secret, now a mainstream process
  - Still high cost and long implementation time
  - Requires extensive process and integration expertise
  - Mainstream on oxide, W, STI, Cu ... others in development
  - Critical to achieving acceptable yield on many device flows
- **Many other applications are also in development to leverage CMP for applications beyond traditional CMOS integrated circuits.**



Drive to increase output per wafer → device & geometry shrinks → more CMP

- Higher device output per wafer result from feature size shrinks utilizing CMP
- CMP also significantly increases electrical device yields per wafer
- Competition compels manufacturers to reduce unit costs by utilizing CMP on an increasing percentage of wafer starts



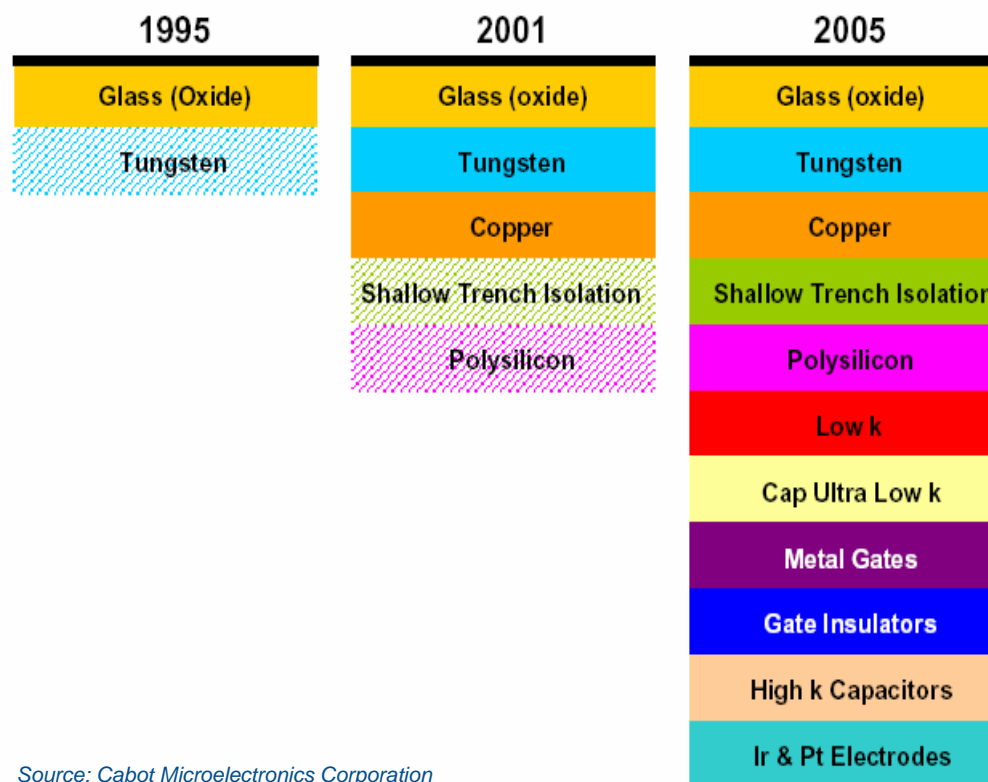
Source: VLSI Research, June 2002

**NOTE:** Chart is conservative in estimations as many use CMP at or below 0.5  $\mu\text{m}$  due to dramatic yield improvement

# New Materials Drive Expansion of CMP

New materials → new manufacturing requirements → new polish steps → more CMP

- Chip designers are continually exploring the use of new materials to increase performance, lower power consumption, etc.
- Manufacturing chips with these materials requires new complex CMP processing step.



Source: Cabot Microelectronics Corporation

## Few companies can afford the luxury of in-house expertise required to address the increasing complexity of CMP processes

- **Wafer Parameters**
  - Size / Shape / Flatness
  - Film Stack Composition
    - » Metals (Al, Cu, W, Pt, etc.)
    - » Oxide (TEOS, PSG, BPSG, etc.)
    - » Other (polysilicon, low-k polymers, etc.)
  - Film Quality Issues
    - » Stress (compressive or tensile)
    - » Inclusions and other defects
    - » Doping or contaminant levels
  - Final Surface Requirements
    - » Ultralow surface roughness
    - » Extreme planarization, esp. Copper
    - » Low defectivity at <0.12 um defect size
- **Pad Issues**
  - Appropriate materials selection (polyurethane, felt, foam, etc.)
  - Conditioning method often not optimal
  - Lot-to-lot inconsistency from suppliers
- **Slurry Issues**
  - Chemistry optimization often required
  - Mixing and associated inconsistency
  - Shelf life and pot life sometimes very short
  - Slurry distribution system (design, cost, upkeep)
    - » Agglomeration and gel formation
    - » Filtration is often required
  - Cleaning method specific to slurry and film
  - Waste disposal and local regulations
- **Process Issues**
  - Long list of significant input variables
    - » Downforce (polish and conditioning)
    - » Platen speed
    - » Carrier speed
    - » Slurry flow
    - » Conditioning method
      - Disk used (material, diamond size, spacing, etc)
      - Force
      - Speed
      - Sweep profile
  - Highly sensitive to local pattern variation
  - Must maintain consistency at high throughput
  - Must optimize for variation of incoming films
- **Integration Issues**
  - Materials Compatibility
    - » Electrochemical interactions with two or more metals
    - » Film integrity and delamination, esp. low-k
    - » Film stack compressibility
  - Interactions with adjacent process modules
    - » Photolithography
    - » Metal deposition and metal etch
    - » Dielectric deposition and etch
  - Electrical design interactions
    - » Feature size constraints
    - » Interactions with local pattern density
    - » Line resistance variation, esp. damascene copper
    - » Dielectric thickness variation
    - » Contact resistance variation

## Expertise:

- Highly trained and experienced technical staff
- Understanding of materials science, chemistry, tribology, and more
- Support staff for infrastructure, maintenance, etc.

## Equipment:

- Major capital investment
- Process tools: Polisher & Cleaner
- Metrology: film thickness, defect inspection, surface topography, etc.
- Ongoing expense to maintain

## Cleanroom:

- Minimum of Class 100, preferably Class 10 or Class 1
- Required support systems include: DI water, compressed air, waste water treatment, nitrogen, etc.
- Substantial overhead cost even when idle or unused

## Consumables and Test Wafers:

- New materials require new slurries
- Pad optimization can be difficult
- Requires in-depth expertise
- Access to large supply base is extremely helpful in early testing



- **Faster Execution**
  - Tap into existing facility, equipment, and process technology
  - Reduce implementation time by 12 months or more
- **Lower Risk**
  - Leverage technical expertise and known baseline processes
- **Lower Cost**
  - Zero capital required
  - Low unit costs even for low to moderate volume production

# Typical Internal CMP Development Project

## Internal Development:

- **Project Team:**
  - Project manager, several members of technical staff from Process, Equipment and Facilities Engineering,
  - Most companies then supplement with outside construction contractors
  - Ongoing staff required for daily operation, maintenance, etc.
- **Capital investment:**
  - **Equipment:**
    - » CMP, post-CMP Clean, and Metrology
  - **Facilities:**
    - » Site prep, Isolation, Slurry Distribution, DI water, Waste Treatment, Compressed Air, Process Vacuum, and possibly Emissions Control.
- **Timing:**
  - Minimum project timing of 12 to 18 months after decision to commit and funding available
  - May encounter construction or startup delays if issues with local permits

# Typical Outsourced Development Project

## Outsourced Development:

- **Project Team:**
  - Typically one technologist (may include more if desired)
  - Outsource staff provide technical consulting throughout the project
  - Outsource staff maintain the facility and the equipment
  - Leverages access to advanced processes and expertise
- **Capital investment:**
  - **Zero:** Eliminates capital investment for equipment and facilities
- **Timing:**
  - Available immediately

# CMP Development Project Comparison

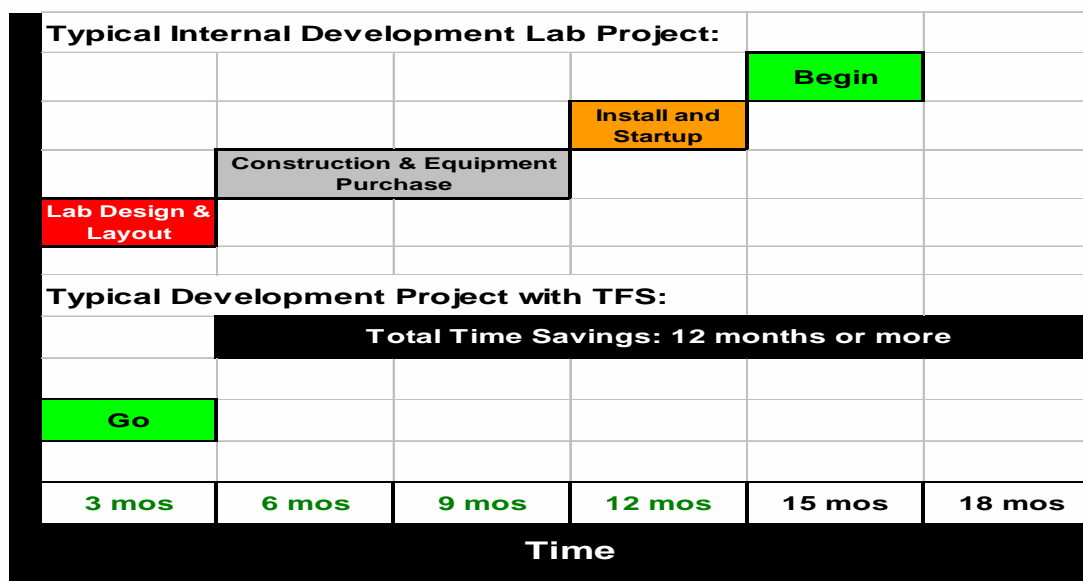
## Internal Development:

- Capital Invest: \$ 1.5 M
- Several Engrs + Staff: \$ 1.0 M/Yr
- Time to Develop: 18-24 mo.
- Multiple learning cycles

## Outsourced Development:

- Capital Invest: \$ 0
- One Sr. Engineer: \$150K/Yr
- Time to Develop: 6-9 mo.
- Leverage existing processes, staff, experience, and consulting

## Time to Implement:



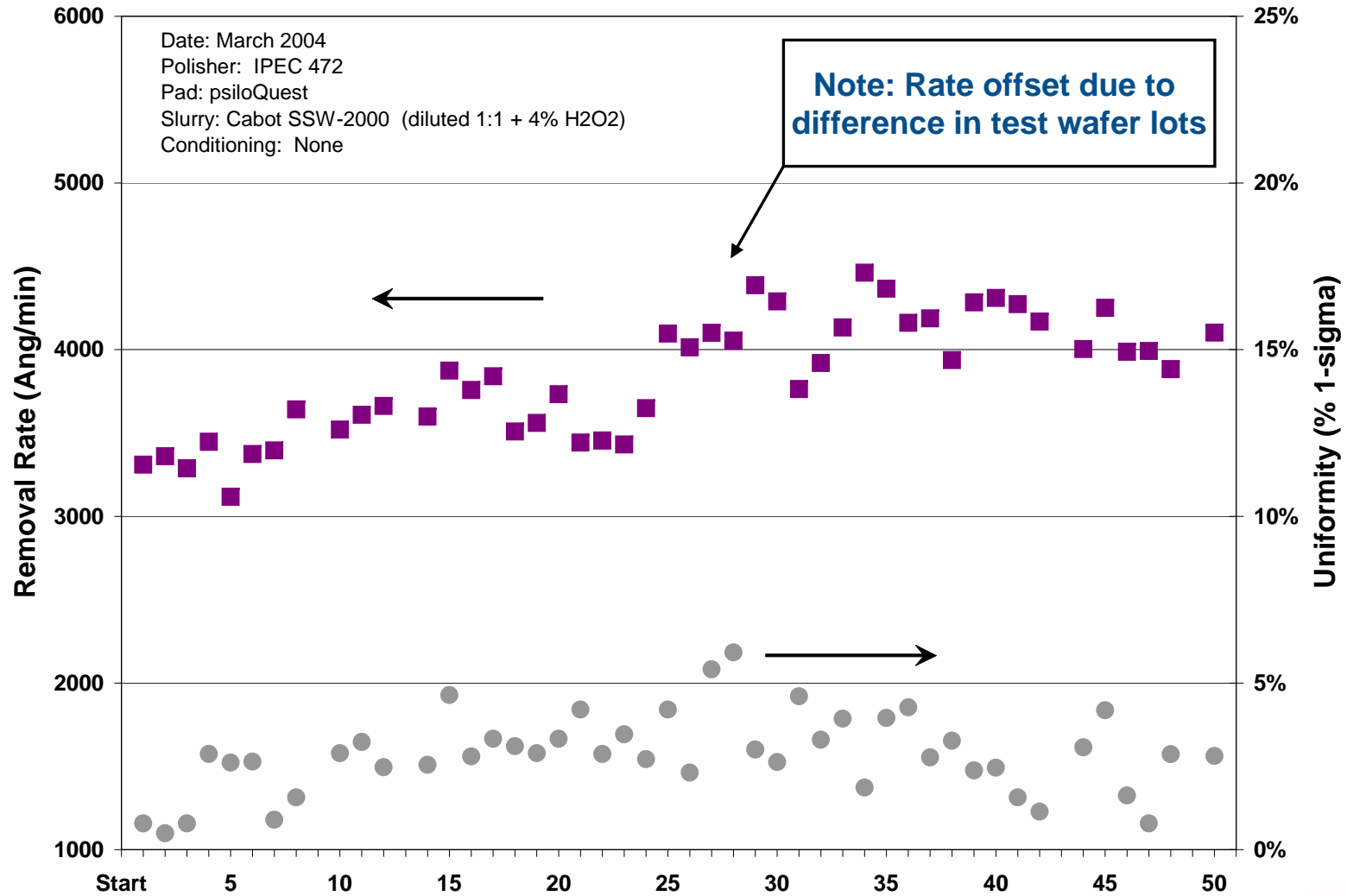
**As shown in the previous comparisons, outsourced CMP development accomplishes the following:**

- 1. Simplifies the internal project team (saves headcount) and leverages the expertise of the provider.**
- 2. Substantially shortens the timeline for project execution, especially for those who are new to CMP or for fabs that are looking at adding polishers.**
- 3. Zero capital outlay which allows the customer to buy only tool time necessary to execute each project (avoids adding excess capacity).**

- **Consumables Development**
  - Technology issues and financial impact
  - Example customer: psiloQuest, Inc.\* (CMP pad supplier)
- **Integration and Device Qualification**
  - Technology issues and financial impact
  - Example customer: Medtronics, Inc.\* (Medical device supplier)

\* Company names used with permission.  
All other names of Entrepix customers are withheld.

- **psiloQuest, Inc.**
  - **CMP pad supplier trying to penetrate mainstream market**
  - **Previously invested in their own internal apps lab**
  - **Needed additional capability, esp. for cleans and defectivity**
- **Results**
  - **Improved product characterization (verified by customers)**
  - **Through joint efforts, pad was qualified for use with 3rd party mainstream production wafers**
  - **Recent decision to shut down internal lab and outsource all applications work through Entrepix**





- **Typical needs for CMP integration and qual:**
  - **Technical inputs into composition and thickness of layers**
  - **Feedback to design team on CMP module sensitivities**
  - **Guidance on consumables choices**
  - **Starting point CMP processes**
  - **Short process runs for prototype devices**
  - **Honest technical feedback from an independent perspective**
  - **Optimized CMP processes with ability to ramp when needed**



**All of these can be obtained from a properly equipped CMP outsource provider**

# CMP Integration and Qual of New Users

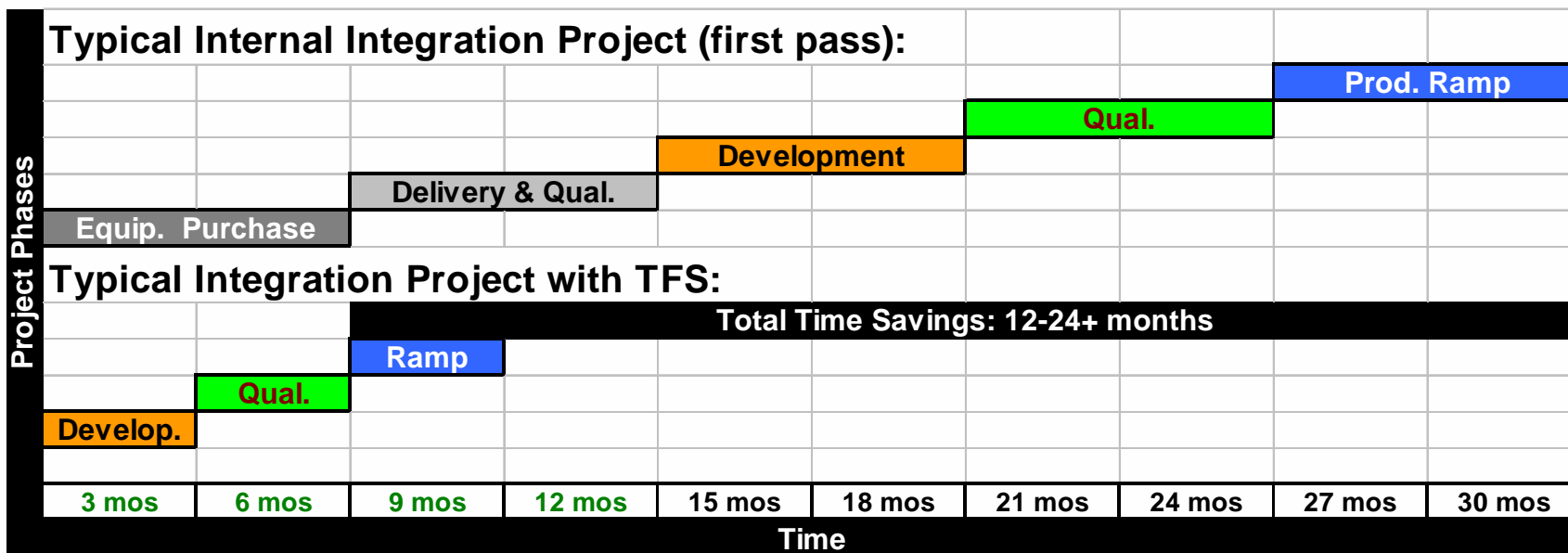
## Internal:

- Capital Investment: \$2.2-3.3M
- Multiple Engrs + Staff: \$ 1.0 M/Yr
- Time to Develop: 18-24 mo.
- Multiple learning cycles

## Outsourced:

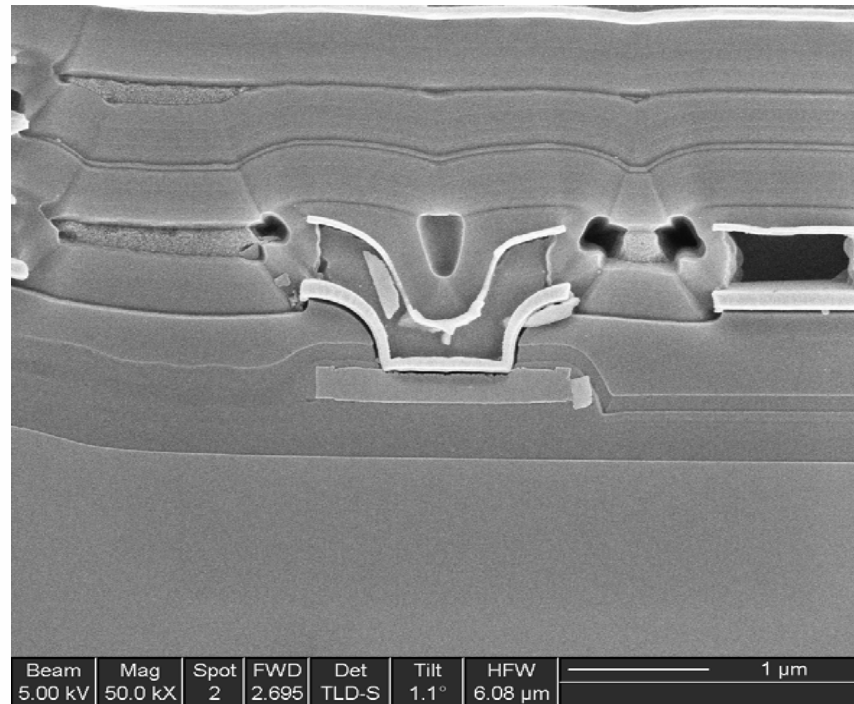
- Capital Investment: \$ 0
- One Sr. Engineer: \$150K/Yr
- Time to Develop: 6-9 mo.
- Leverage existing processes, staff, experience, and consulting to reduce risk and learning cycles.

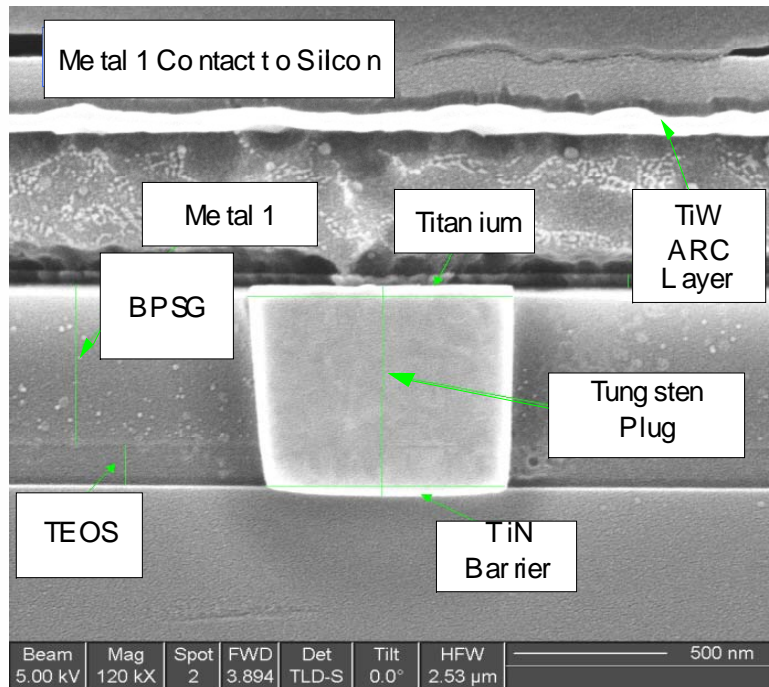
## Time to Implement:



- **Medtronics, Inc.**
  - Small production fab for medical devices
  - Unique device integration, including thin CrSi resistor layer
  - Running 0.6-0.8 um and desires to shrink to 0.35 um
  - Extreme focus on reliability
- **Results**
  - Straight to 3-level CMP integration with both ILD and W CMP
  - Debugged on existing mask set using < 50 product wafers
  - Less than 8 months total from concept to first silicon out
  - First lot to reach probe floor yielded working devices
  - Design team now working on new masks and qual plans

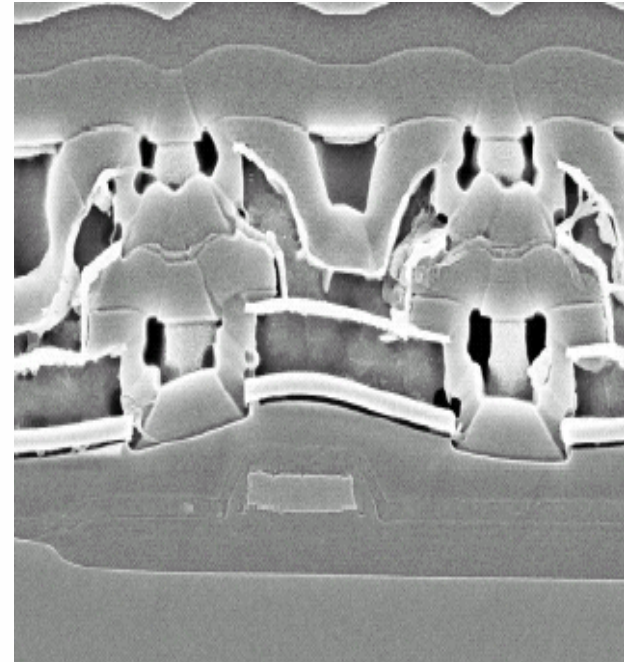
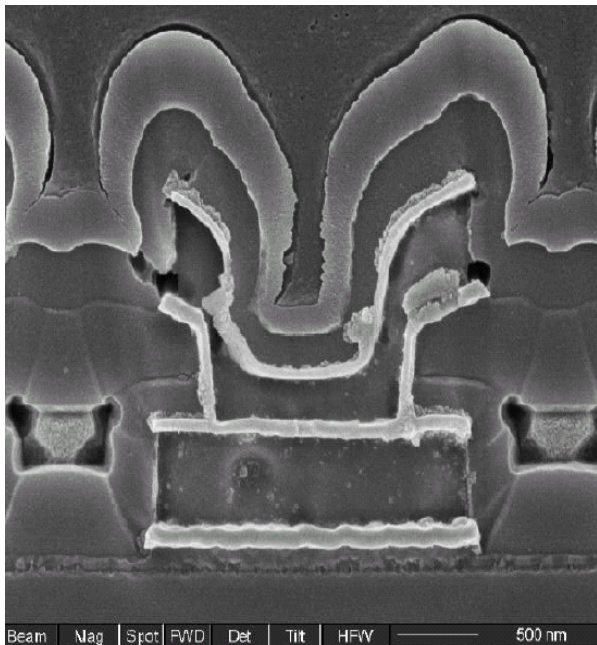
- **BPSG Reflow**
  - Smooth step but not planar
- **Hot Metal Dep.**
  - Acceptable metal step coverage at 50%
- **SOG Gap Fill**
  - Acceptable planar surface, but not good enough to shrink



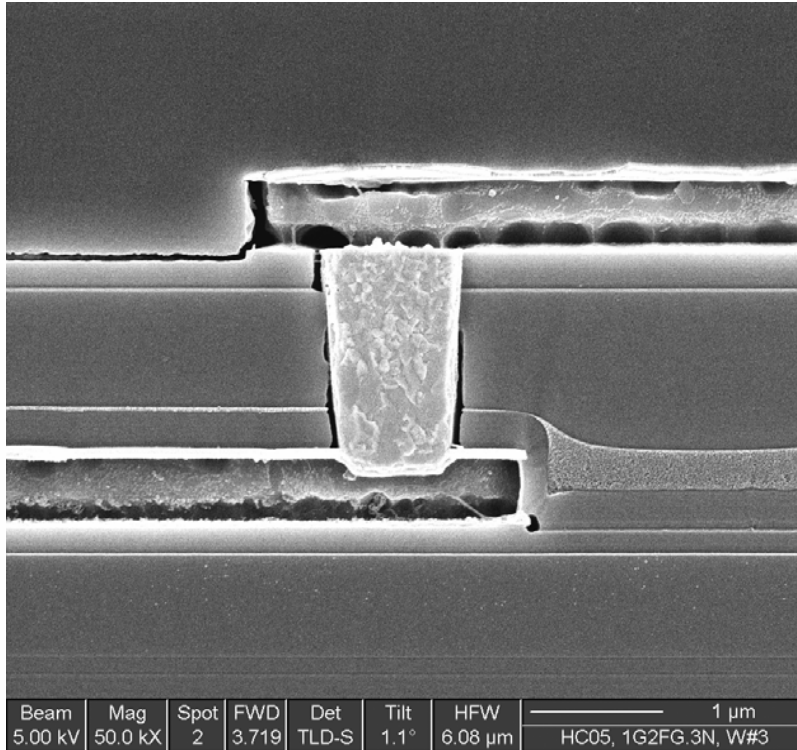


- **Good Contact to Substrate**
- **Ultra Flat BPSG**
  - **Photolithography is improved.**
  - **Planarization is improved**

- **Thinning over step.**
  - **Less than 20% coverage on corners**

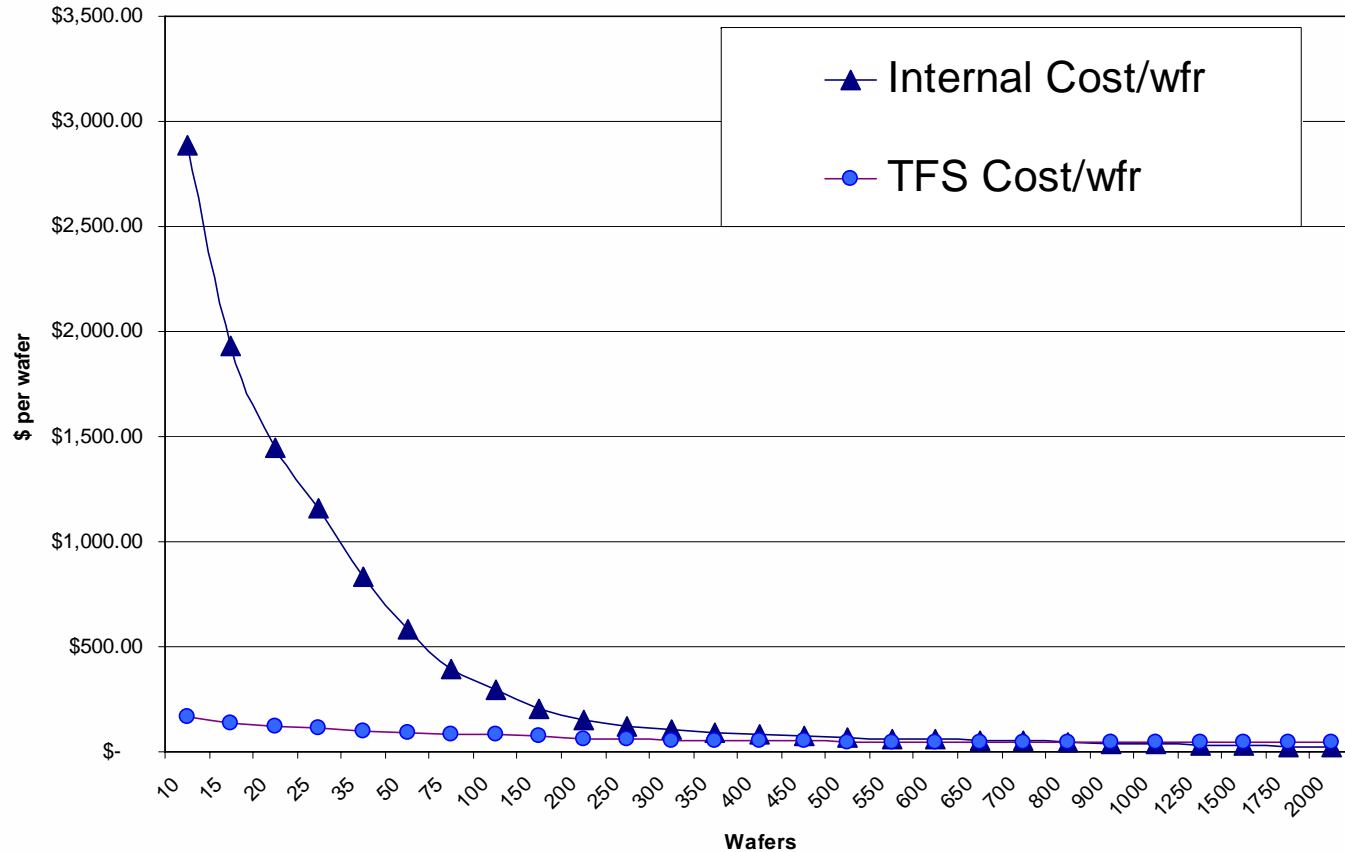


- **Poor ILD Planarization.**
  - **Has negative impact for photolithography.**
  - **Limits design flexibility.**



- Step coverage no longer an issue.
- Ultra flat surface.
  - Enhances photolithography.
  - More flexibility in design.

# Cost Per Wafer comparison:



Total Fab Solutions CONFIDENTIAL

Oct. 20

**Bottom Line: Low volume cost differential is enormous**  
**High volume cost differential is minimal**



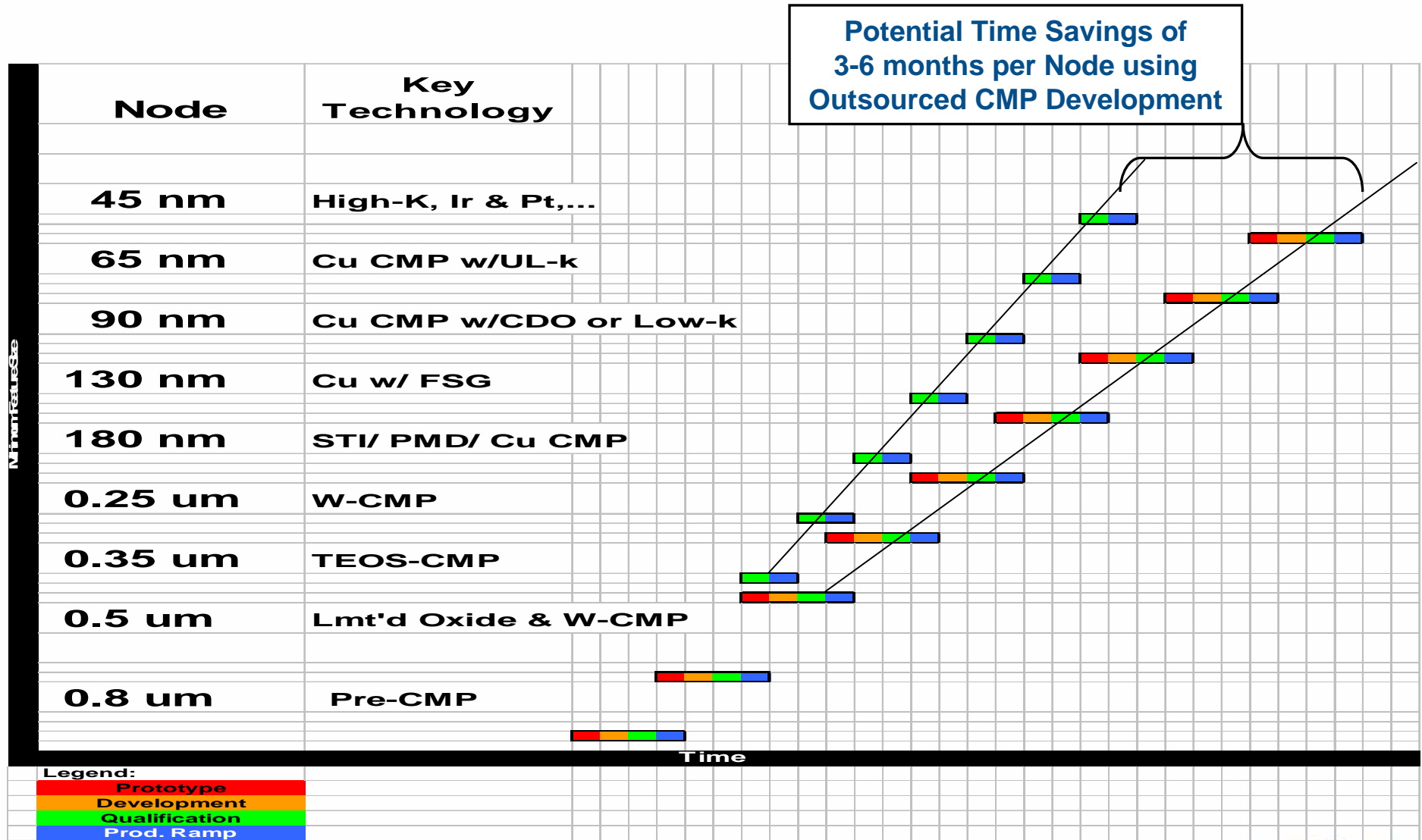
# Impact of Development Cycles

- **Internal development requires additional investments for each node :**
  - **Dedicated development teams for each node**
  - **Increasing investment in new equipment and facilities dedicated to new materials: Oxide, W, STI, Cu...**

**Or...**

- **Outsourcing development leverages processes and integration expertise of the outsource provider:**
  - **Reduces time to qualify new process by 6-18 months**
  - **Eliminates capital investment**
  - **Reduces risks by using proven solutions**

# Impact of Repeated Development Cycles



Proven Processes	200 mm	150 mm	125 mm	100 mm
Oxide (TEOS, thermal, LTO, etc.)	✓	✓	✓	✓
Doped Oxide (PSG, BPSG, etc.)	✓	✓	✓	✓
Shallow Trench CMP	✓	✓	✓	✓
Tungsten	✓	✓	✓	✓
Copper	✓	✓	✓	✓
Polysilicon	✓	✓	✓	✓
Si, Ge, and various III-V materials	✓	✓	✓	✓
Silicon Carbide, Sapphire, DLC	N/A	✓	✓	✓
Backside stress relief polish	✓	✓	✓	✓
Custom thin films	✓	✓	✓	✓
Custom bulk materials	✓	✓	✓	✓

\* Other sizes (2", 3", etc.) and custom shapes can be accommodated with advanced notice

# Summary:

## Reasons to outsource CMP

- **Lower Risk**
  - Immediate access to proven process technology and expertise
  - Minimize complexity associated with polishers, cleaners, chemical delivery, filtration, metrology, consumables, etc.
- **Faster Execution**
  - Rapid prototyping, development projects or process qualification
  - Reduce implementation time an average of 12 to 18 months
- **Substantial Cost Benefits**
  - Reduce or eliminate capital expenditures
  - Lower unit costs
- **Production Impact**
  - Perform engineering trials without taking your polishers off line
  - Flexible manufacturing capacity when you need it

- Entire staff at Entrepix, with specific thanks to the following individuals:
  - Jeanie Simmons
  - Patrick Grimes
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  - Michael Leone
  - Mike Bowman
  - Roy McCoy
  - Jim Dekarske
  - Tim Knippa
- psiloQuest, Inc.
  - Tony Clark, Ed Atkinson, John Bare, and Dan Marks
- Medtronics, Inc.
  - Ralph Danzl
- Many other customers who, though unnamed here, have helped us prove that CMP outsourcing is a viable and cost-effective business model.

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