# Technological Breakthrough in Pad Life Improvement and its Impact on CMP CoC

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## Abstract

Many IC fabs have expressed a great deal of interest in CMP pad life improvement with the expectation that improved pad performance will reduce process variability and improve CMP cost-of-consumables (CoC). Critical parameters that impact grooved-pad life and that can reduce pad life variability have been identified through designed experiments performed on a multiple head/platen CMP tool. The most important parameters effecting pad life are groove quality and groove size. New technologies have been developed to control these critical parameters in conjunction with extensive process optimization. Lathing technology (in tools and processes) plays a critical role in achieving high groove quality and desirable groove size. In many extended wafer runs and several accelerated pad wear runs, pad life was more than doubled by optimizing these critical parameters on polyurethane-based grooved-pads. Low defect counts of <20 at 0.2 µm, low within wafer non-uniformity (WIWNU) of 4% with a 5 mm edge exclusion, and a stable removal rate of >2750 Ang./min. were achieved for thermal oxide CMP in the extended runs. The new pads double pad life when used with optimized processes, and achieve planarity comparable to conventional pads. Significant pad life improvement was attributed mainly to the implementation of larger and more consistent grooving, and optimized pad conditioning and polishing processes for the CMP tool.

In general, the pad cost contributes approximately one third of the total CMP CoC. In this case study, average CMP pad life was found to be 250 wafers/pad with a variance of 100 to 400 wafers/pad. Pad CoC significantly increases for pad lives < 350 wafers/pad. The pad CoC at 350 wafers/pad is half of that at 225 wafers/pad. Based on several extended runs, new pads coupled with an optimized polish process demonstrated the feasibility of more than 500 wafers/pad. At this longer pad life, the potential to reduce CoC is even greater.

## Introduction

Increasing CMP polishing pad life reduces costs of consumables (CoC) by allowing users to replace pads less frequently. Replacing pads less frequently not only reduces the number of pads required for a given wafer output, but also reduces the total amount of time required to re-qualify a tool after a pad change. This improvement in tool availability is the real benefit obtained from longer pad life. This paper summarizes the efforts made to develop a new longer-life pad, the Rodel® IC1010-DV, and presents performance data demonstrated in both laboratory and field settings.

The Rodel® IC1000 is an industry standard pad. However, pad life is relatively short (250 wafers/pad on average on the Applied Materials Mirra® CMP polisher) and can exhibit pad life variability of between 100 to 400 wafers/pad. Figure 1 shows the results from a case study on pad life.

This paper will first present results of pad experiments conducted to determine the parameters that effect and control pad life. Data from these experiments were used in the development of the IC1010-DV pad. The paper next presents process data for several extended runs that demonstrate excellent process performance and stability over the life of the pad. The IC1010-DV demonstrates a 2X increase in pad life when compared to IC1000, the reference pad for IC1010-DV development. Finally, a cost analysis is presented comparing CoC for the IC1010-DV and IC1000 pads.

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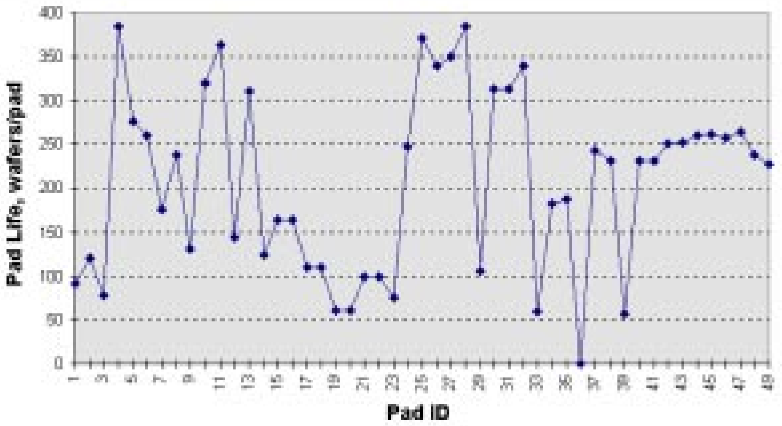


Figure 1. IC1000 pad life averages about 250 wafers/pad but exhibits a high level of variability.

In terms of physical make-up, the IC1010-DV is similar to the IC1000 in many ways. For example, both pads incorporate the same hard polyurethane top pad adhered to a soft felt bottom pad. However, there are several significant differences, such as top pad thickness, groove dimensions, and different groove lathing techniques as shown in Table 1. The IC1010-DV pad features (1) improved grooving quality resulting from an improved grooving process, (2) tighter top pad specific gravity control/spec, (3) increased groove depth and (4) a thicker top pad.

Table 1. Comparison of IC1010-DV and IC1000 pads.

| ***Pad Parameter*** | ***IC1010-DV**** | ***IC1000*** |
|---|---|---|
| Top Pad | 80 mil A2 Style Polyurethane | 50 mil A2 Style Polyurethane |
| Bottom Pad | 50 mil SUBA IV | 50 mil SUBA IV |
| Nominal Groove Dimensions – depth (mils) | 30 | 15 |
| Ratio of width/depth/pitch: same for both pads | | |
| Top Pad Specific Gravity Specification (g/cc) | 0.78 - 0.84 | 0.74 - 0.85 |

*The IC1010-DV pad has the following characteristics:
Unique concentric grooving configuration with 0.030” depth
Prestacked
PSA V bonding IC1010-DV top pad to Suba IV sub pad
PSA II on Suba IV for adhesion to platen
Improved cake uniformity
Improved groove depth uniformity

## Pad Life Factors and the Design of IC1010-DV

To determine the factors that affect and control pad life, many different pad experiments were conducted and pad properties measured. Of these efforts, two experiments produced surprising results: the grooving bit age experiment, which studied effects of groove quality, and grooving gradient experiments, which studied the effect of groove dimensions. The details and results of these two experiments are summarized below. These experimental results were critical in discovering the dimensions and developing the improved grooving techniques used to manufacture the new IC1010-DV pad.

### Impact of Grooving Quality

An experiment was designed using the IC1000 and executed to determine the effects of poor groove quality on pad performance and pad life. By using manufacturing bits of different wear/age, standard “K” grooves were cut into pads adjacent to each other within a specific pad lot, to minimize pad material variation. The grooves were visually examined and found to vary with the age of the cutting bit. The newer bit produced clean high-quality grooves of proper dimensions, but the older bit produced rough-edged grooves with some noticeable residual debris within the grooves. Both pads were tested under the same controlled conditions. Figure 2 shows rate and WIWNU for extended runs conducted on three different pads. Figure 2 shows that WIWNU drifted out of control much earlier on the pads manufactured with the old bit compared to the high-quality new bit grooved pad and a standard reference pad. Results also show WIWNU stayed in control until the grooves on the pad started to disappear. This result shows a pad should provide stable process performance until the grooves begin to disappear.

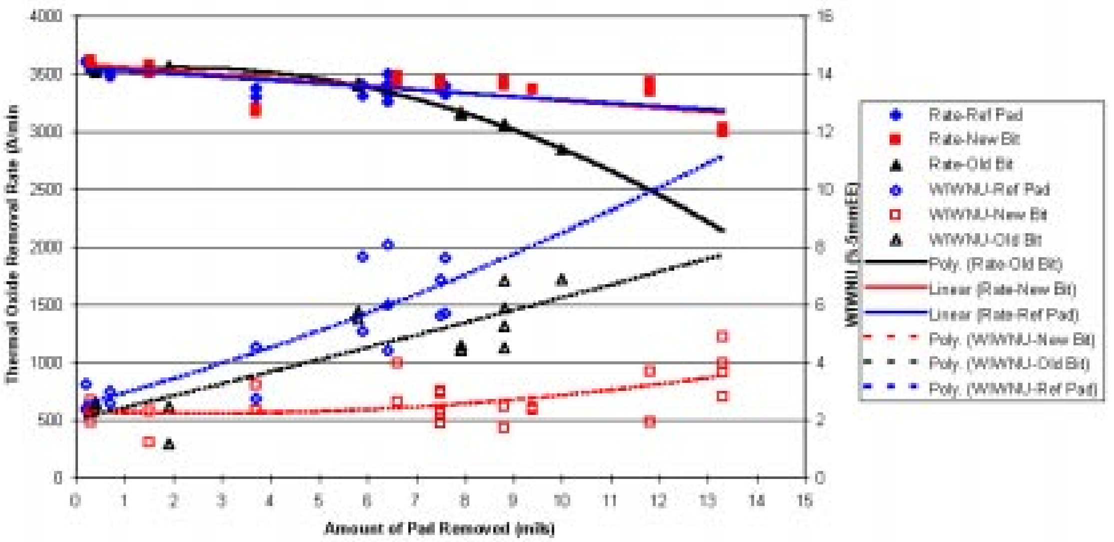
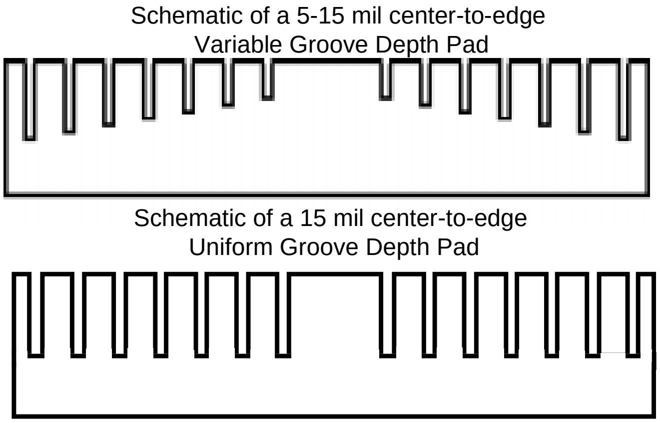


Figure 2. Rate and WIWNU as a function of wafers polished using IC1000 pads from three different lots.

### Impact of Grooving Dimensions

An experiment was designed and executed using the IC1000 to determine the effect of groove dimension and variation on pad performance and pad life. A pad lot was grooved with varying depth dimensions as a function of radius. Figure 3 depicts the two types of pads tested. Pad 5-15 is an exaggerated representation of the typical groove pattern profile on standard IC1000 pads. Figure 4 presents rate and WIWNU data associated with each of these pads over 1200 wafers. Results show that process is not affected by groove depth variability if there is sufficient groove depth over the entire pad. However, the results also show that when the grooves wear away on any part of the pad, process performance is affected and WIWNU drifts out of control.


Schematic of a 5-15 mil center-to-edge
Variable Groove Depth Pad

Schematic of a 15 mil center-to-edge
Uniform Groove Depth Pad

Figure 3. Schematic pad profiles used to test the effect of groove depth on pad life.

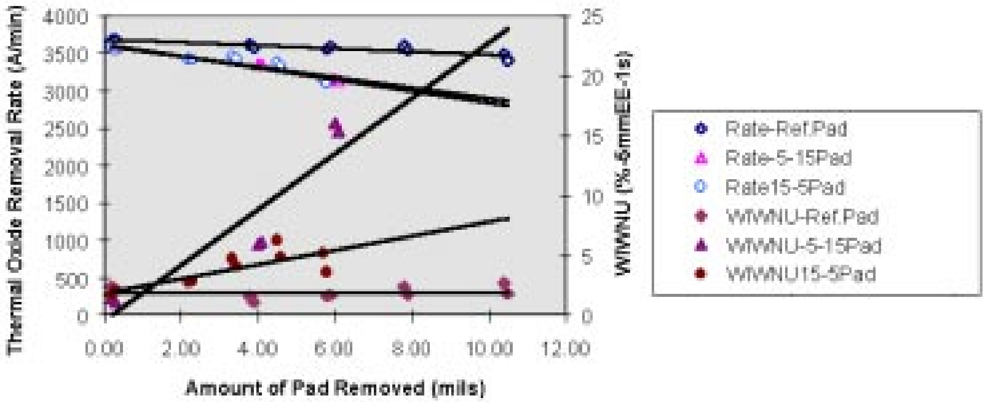


Figure 4. Rate and WIWNU as a function of IC1000 pad wear

### Design of IC1010-DV

Results of these two experiments led to the following guidelines:

- pad life is defined by minimum groove depth on the pad and pad wear rate,
- groove quality affects process performance and stability, and can cause premature end of pad life,
- groove depth variation and quality does not affect initial process qualification.

Using these guidelines, the IC1010-DV was designed with the goal of increasing pad life by 2X. While typical IC1000/K-groove depth is 15mils and top pad thickness is 50mils, IC1010-DV groove depth is 30mils and top pad thickness is 80mils. The IC1010-DV pad groove depth of 30mils was selected to offer twice the groove depth/life of K-groove. Pad thickness was increased from 50 to 80mils to ensure that pad compressibility at the end of IC1010-DV pad life is less than or equal to the pad compressibility at the start of IC1000 pad life (80mil thick pad minus 30mil grooves leaves 50mil pad thickness).

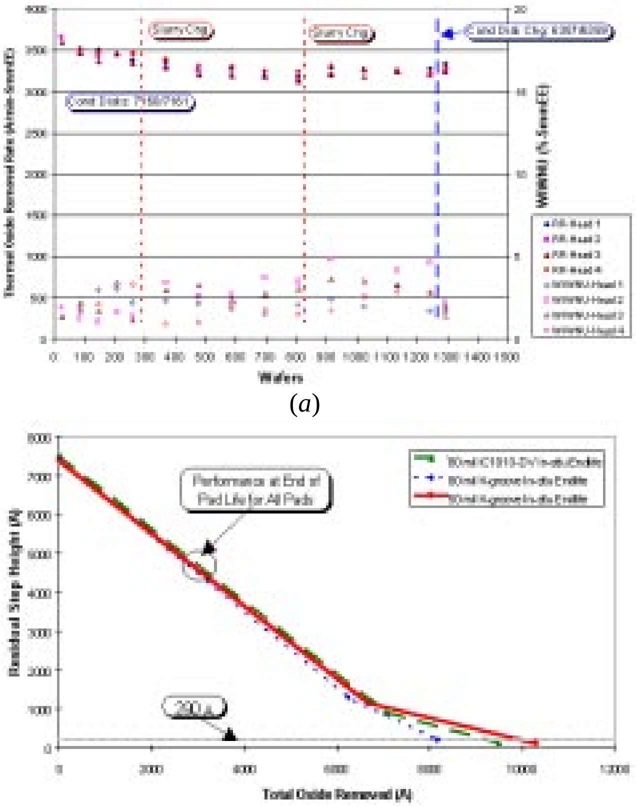
### Extended Run Process Results for IC1010-DV

The fourteen extended runs completed using IC1010-DV pads show equivalent or better process performance than that generated by IC1000 pads. IC1010-DV pads have been tested successfully at several IC fabs as a replacement for the IC1000 pad. The 2X increase in pad life was demonstrated consistently. Table 2 summarizes process performance results. Figures 6-7 show excellent rate, WIWNU, and defect performance and stability over >500 wafers/pad. The average pad life for the IC1000 is 250 wafers/pad when under conditions similar to those used to evaluate the IC1010-DV. Figure 6 also shows planarity performance for the IC1010-DV pad was comparable to performance obtained using the IC1000 pad.

Table 2. Summary of process performance achieved on the IC1010-DV Pad as compared to the IC1000 pad

| Result | Run #1 | Run#2 | Compared to IC1000 |
|---|---|---|---|
| Wafers Polished (per 2 pad set) | 1100 | 1300 | ~ 2X pad life |
| Average RR (Å/min) | 3537 | 3320 | Comparable |
| Average WIWNU (5mm EE) | 2.7 | 2.5 | Comparable with process change |
| Average WTWNU (5mm EE) | 2.2 | 4.0 | Comparable with process change |
| Average HTHNU (5mm EE) | 1.6 | 1.3 | Comparable with process change |
| Others | | | Planarity equal or better than IC1000.<br>Defects better than IC1000 at the end of pad life.<br>Pad life variability improved.<br>Pad wear rate depends strongly on conditioning disk type. |

Significant pad life improvement coupled with comparable or improved polishing performance was attributed mainly to the IC1010-DV's larger and more consistent grooves, uniform pad wear, uniform transportation of slurries and polishing bi-products to and from polishing zones, and uniform temperature distribution on the wafers during polishing.



(*a*)

(*b*)

Figure 6. IC1010-DV pad extended run removal rate, WIWNU (*a*) and planarity data (*b*)

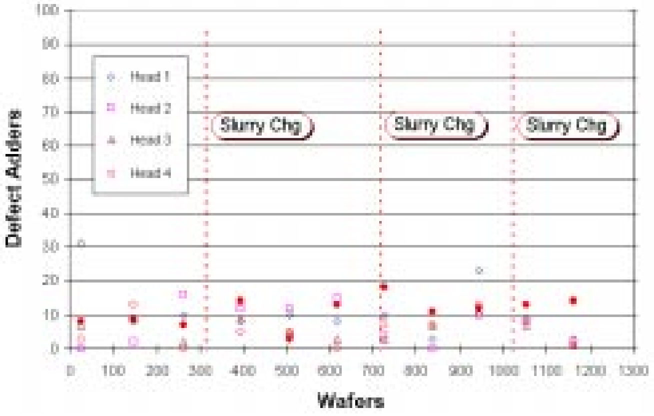


Figure 7. IC1010-DV pad extended run 6420-adders defect data

**CoC, Relative Tool Availability, and Throughput –IC1010-DV vs. IC1000**

Longer pad life reduces the costs associated with a significant CMP consumable item – the pad. Figure 8 shows the results of a pad CoC analysis based on Mirra CMP polisher experience and calculated using an Applied Materials cost model based on the SEMATECH cost of ownership model. CoC is shown to exhibit a strong sensitivity to pad life at lower pad life times (<350 wafers/pad). The impact of pad life on CoC becomes far less significant at longer pad life times. Pad CoC significantly increases at pad lives < 350 wafers/pad. Pad CoC at 350 wafers/pad is half of that at 225 wafers/pad.

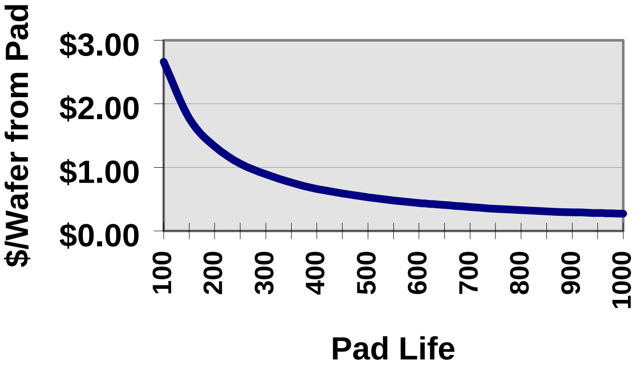


Figure 8. Pad CoC as a function of pad life.

The net benefit of longer pad life is a reduction in the time spent on CMP tool re-qualification after pad changes. Fewer pad changes could also lead to better process stability by reducing the contribution of pad-to-pad variation. In a volume production fab, pad life significantly affects CMP tool availability as shown in Figure 9. And pad life has a much greater impact on tool availability and wafer output as throughput increases.

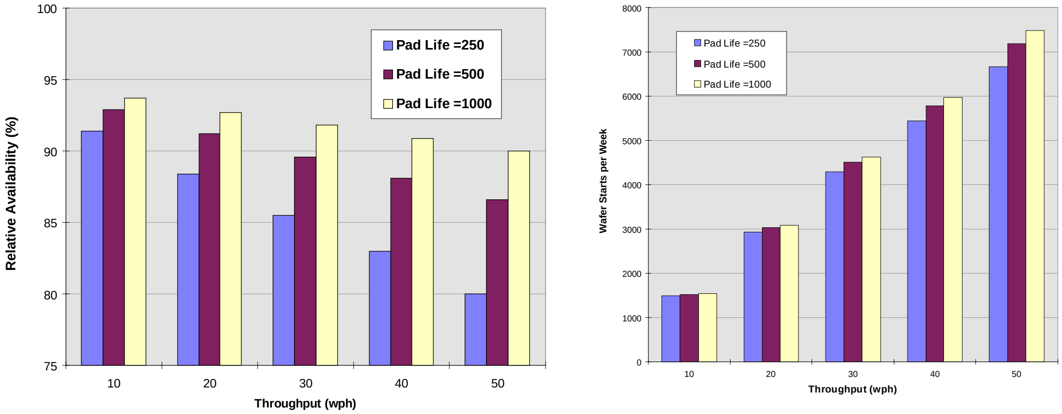


Figure 9. Pad life effect on tool availability and output as a function of throughput.

## Conclusion

A longer-life polishing pad – the IC1010-DV has been successfully developed. On the Mirra CMP polisher, the IC1010-DV pad exhibits twice the pad life of the standard IC1000 pad, and equivalent or improved polishing performance. Low defect counts at the end of pad life, improved or equivalent planarity, and equivalent removal rate and non-uniformity were achieved by using IC1010-DV pads. These results have been achieved on Mirra CMP systems installed in both lab and field environments. Significant pad life improvement was attributed mainly to the implementation of larger and more consistent grooving during pad manufacture, and optimized pad conditioning and polishing processes for the Mirra CMP system.

Longer and more consistent pad life reduces pad consumables cost in CMP operations and improves CMP tool availability and wafer output because less time is spent on pad changing and CMP tool requalification.