Characteristics of a Novel CVD Diamond Pad Conditioner

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Overview

- CMP Consumables: Applications Trends
- CMP Pad Conditioners: Challenges and Objectives
- Current Pad Conditioners: Performance Attributes
- Development of A New CVD Diamond Conditioner
- CMP Pad and Conditioner Characterization
- Results from Pad Conditioner Evaluations
- Summary and Conclusions

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CMP Consumables: Applications Trends

- Increasing Intensity and Complexity of Next-gen CMP
  - Planarization needs growing - enabling process for many devices
  - 29 steps in a 65 nm Logic device and 47 steps in a 16 nm device
  - Most stringent specifications of CMP for 22 nm and smaller nodes
- Emerging New Applications, Tools and Consumables
  - New applications have unique CMP, PCMP cleaning, and metrology needs
  - Thinner/larger wafers, copper, ultra low-k, high-k, and other new materials
  - FinFETs, 3D-ICs, TSVs, FUSI RMG, Novel Memory, MEMS, Bio Sensors
- Pads & Conditioners Must Improve to Meet CMP Needs
  - Narrow window of operation – demands tighter lot-to-lot and with-in lot variation
  - Pads and conditioners must provide longer lifetime and consistent performance
  - Joint development/evaluation can minimize optimization time for the end users

CMP Pad Conditioners: Challenges and Objectives

- New conditioners should be significant cleaner – ppb/ppt level extractable and not adding any contamination to CMP process.
- Stringent abrasive features size and shape control – To create and maintain consistent pad surface morphology over lifetime.
- Tunable in nature - Applicable in many different processes and contributing to increase in CMP device yield and reduced CoO.
- Tighter control of pad and conditioner materials and dimensional properties, including -
  - Pads:
    - Hardness, SG, and other properties – lot-to-lot/with-in lot/with-in pad
    - Surface pore structure/morphology/surface roughness/asperities
    - Groove pattern, depth, groove-base roughness, wall edge uniformity
  - Conditioners:
    - Abrasive/feature size/shape/density/uniformity/surface morphology
    - Diamond/feature characteristics – strength/activity/wearing or breaking
    - Substrate characteristics – nature/consistency/process compatibility

Current CMP Pad Conditioners

- Conventional pad conditioners use diamond grit, 35 micron – 250 micron size, randomly/structurally arrayed on a substrate, brazed, electroplated or sintered in place
- Above 4” disks may have between 20,000 – 300,000 diamonds, with < 20 % active
- Diamond and Performance Concerns:
  - Breaking / release
  - Size, shape, and height variability
  - Wide pad cut-rate range
  - Chemical compatibility
  - Shorter lifetime

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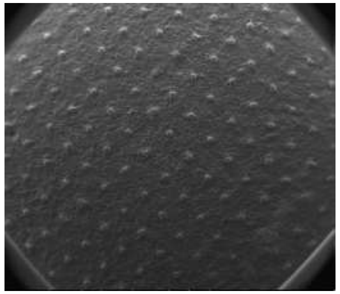
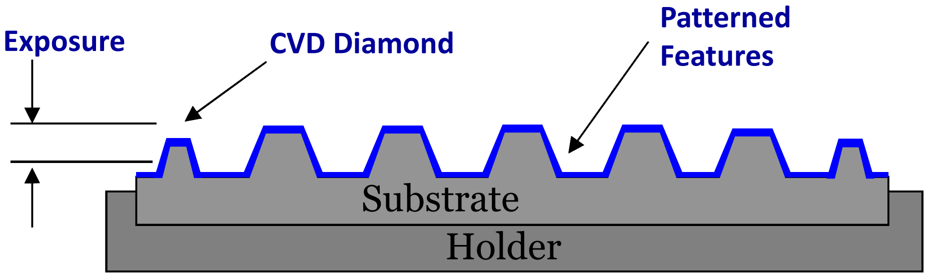
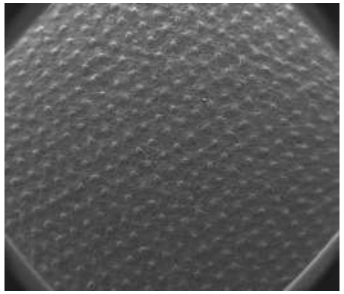
Development of a New CVD Diamond Conditioner





Entegris Planargem® Pad Conditioner



Planargem Design Attributes and Benefits

Attributes	Benefits
CVD Diamond Coated Features Integral Part of Substrate →	No Diamonds-Fallout Failure Mode
Feature Size/Protrusion/Density Consistency →	Stable Pad Ra & Cut-Rate, Consistent WRR
	Increased Pad and Conditioner Lifetime
Highly Automated/Repeatable Feature Patterning Process →	Batch to Batch Product Consistency
	Full Range of PCR and Ra for All Pad Types
Relatively Stable/Inert Material of Mfg →	Stability in Extreme pH Solutions

CMP Pad and Conditioner Characterization

- Pad Conditioning Goals
  - Optimum aggressiveness conditioning - longer pad lifetime and consistent Ra over lifetime
  - More effectiveness conditioning – shorter pad break-in (Ra stabilization) time
- Key Measurement Parameters
  - PCR, pad surface morphology (Ra, Sa, pad surface height pdf)
  - Pad conditioner coefficient of friction (COF) and features interaction
- Pad Conditioning Marathon Tests
  - PCR and Ra consistency is quantified for different consumables set
  - Full size pad and small pad used in 6 - 12 hours marathon tests
- Chemical Cleanliness of Conditioners
  - Extraction in acidic/alkaline solutions, or CMP slurry blends
- Pad/Conditioner Characterization
  - Lab scale pad conditioning optimization can provide valuable insight
  - Result in significantly reduced fab evaluation time

Results from Pad Conditioner Evaluations

- Study 1: Typical Extractables Testing for Different Pad Conditioners (Table 1):
- Study 2: PCR and Ra Consistency Test for a Planargem Conditioner (Figures 1 and 2):
  - 30 hour run on a benchtop polisher with IC1000™ pad.
- Study 3: Pad Conditioning Evaluation of a New CMP Pad "A" using a Planargem Disk (Figures 3 to 4):
  - PCR, Ra, Sa, pad surface imaging and height pdf measurements made during 17 hr run
  - Disk created and maintained a consistent pad Ra and surface morphology during the test
- Study 4: PCR and Ra Consistency Study for 3 Conventional Commercially Available Diamond Disks (C1, C2, and C3) and a Planargem Disk (Figures 5 and 6):
  - 10 hour runs on a benchtop polisher with IC1000 pad.

Case Study 1: Typical Extractables Data for Different Conditioner Designs (Table1)

Extraction 24 Hour Soak	Brazed Conditioner Submerged pH3 HCl	Planargem Segments Surface Extracted pH3 HCl	Planargem Conditioner Submerged pH3 HCl	Planargem Conditioner Submerged Aluminum Slurry
Na (ug/device)	0.162	0.169	0.199	0.470
Mg (ug/device)	0.078	0.041	0.129	0.315
Al (ug/device)	0.705	0.028	0.454	0.289
K (ug/device)	0.120	0.148	0.178	0.098
Ca (ug/device)	2.198	1.573	3.669	3.486
Ti (ug/device)	0.014	0.003	0.103	0.002
Cr (ug/device)	3.079	0.002	0.086	0.940
Mn (ug/device)	3.051	0.001	0.507	1.431
Fe (ug/device)	21.965	0.064	3.422	10.954
Ni (ug/device)	432.716	0.002	1.610	0.570
Co (ug/device)	0.103	0.000	0.030	0.053
Cu (ug/device)	0.007	0.441	0.748	2.244
Zn (ug/device)	20.171	0.028	0.711	1.842
Ag (ug/device)	0.000	0.000	0.030	0.047
Ba (ug/device)	0.021	0.002	0.032	0.015
Pb (ug/device)	0.016	0.000	0.030	0.011
Total (ug/device)	**484.407**	**2.502**	**11.937**	**22.767**

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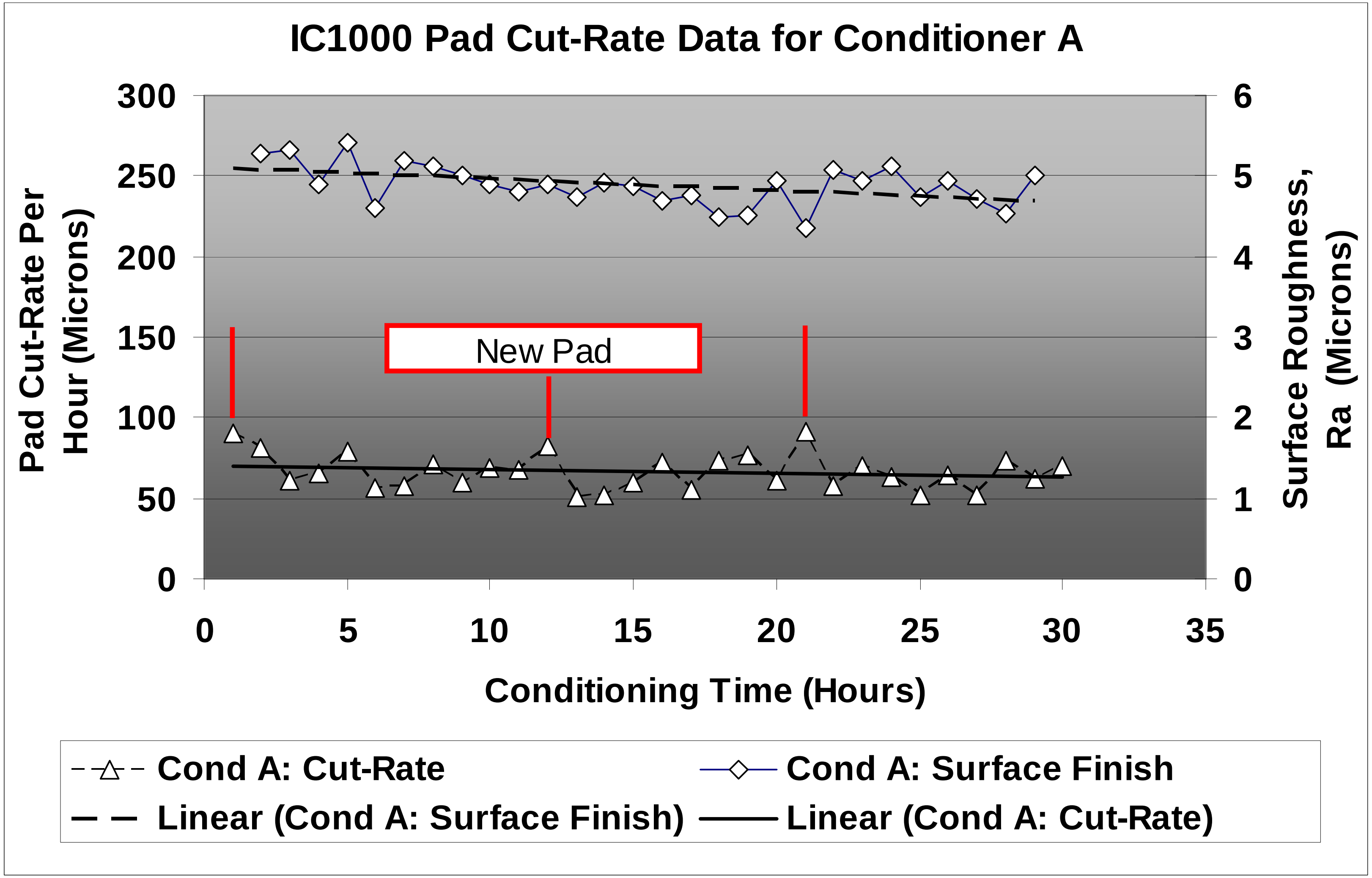
Case Study 2: PCR and Ra Data for 30 Hour Marathon Test for a Planargem Disk: Benchtop Polisher (Figure 1)



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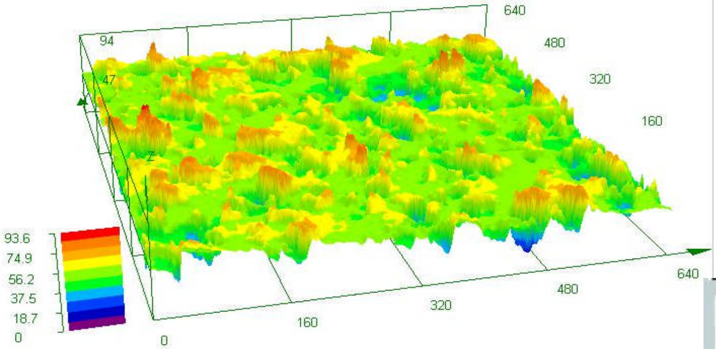
Case Study 2: Pad Ra Data after 30 Hour Pad Conditioning: Confocal Microscope Data (Figure 2)



The pad surface roughness after 10 Hrs has an Sa of 6.777 µm

Setting information	
Analysis date	4/29/2011 10:38:09 AM
Evaluation area	647 µm x 643 µm
Cutoff	λc -- µm
	λs -- µm
	λf -- µm
Filter	Gaussian Filter
Analysis parameter	All parameter (R)
Objective lens	x20

Analysis parameter			
Sq	8.971 [um]	Ssk	-0.159
Sku	3.701	Sp	37.036 [um]
Sv	39.222 [um]	Sz	76.258 [um]
Sa	6.777 [um]	Sk	17.778 [um]
Spk	10.916 [um]	Svk	11.648 [um]
SMr1	12.488 [%]	SMr2	83.916 [%]
Sxp	17.550 [um]	Vvv	1.239 [um³/um²]
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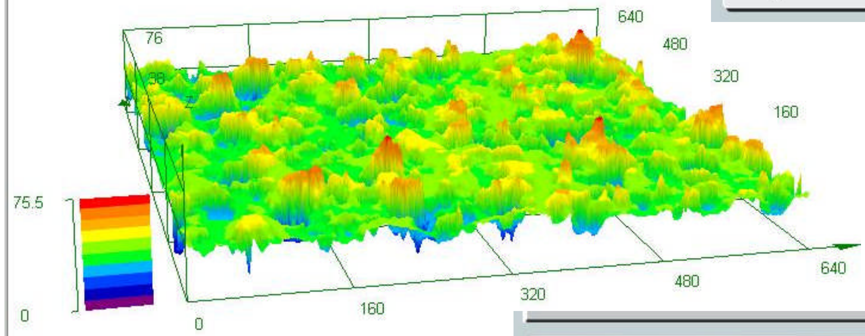

The pad surface roughness after 30 Hrs of conditioning (Sa of 5.698 µm) is nearly identical to the new conditioner

Setting information	
Analysis date	4/29/2011 10:47:00 AM
Evaluation area	647 µm x 643 µm
Cutoff	λc -- µm
	λs -- µm
	λf -- µm
Filter	Gaussian Filter
Analysis parameter	All parameter (R)
Objective lens	x20

Analysis parameter			
Sq	7.562 [um]	Ssk	0.075
Sku	3.979	Sp	33.332 [um]
Sv	33.900 [um]	Sz	67.232 [um]
Sa	5.698 [um]	Sk	15.991 [um]
Spk	9.737 [um]	Svk	9.637 [um]
SMr1	13.187 [%]	SMr2	88.312 [%]
Sxp	14.782 [um]	Vvv	0.978 [um³/um²]
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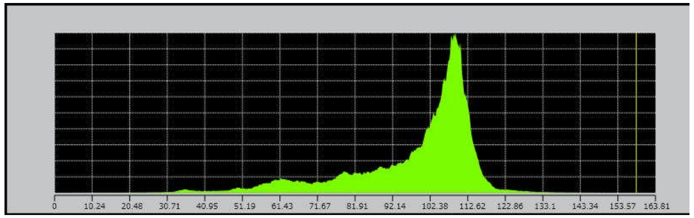
Case Study 3: Pad "A" Conditioning Test with a Planargem Disk – Benchtop Polisher Test (Figure 3)

Experimental Data:

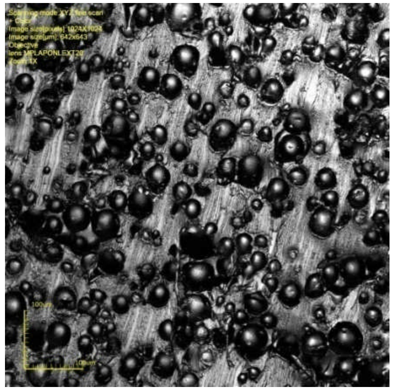
- (1) New Pad "A":

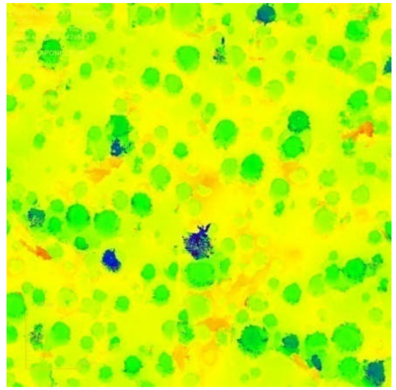
  New Pad Ra = 4.6 microns, New Pad Sa = 9.9 microns

  Fig 3a. New pad height probability density function (pdf) and LCM images.



New Pad



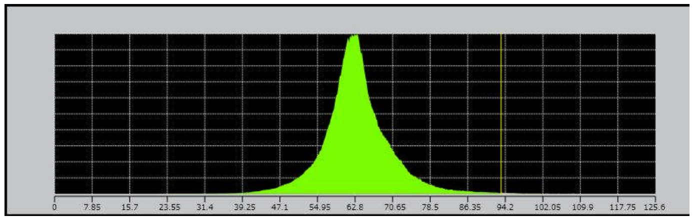


- (2) Benchtop Polisher Conditioned Pad "A":

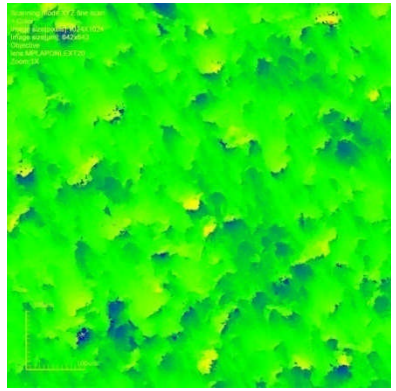
  Planargem: PCR = 52 microns/hr, Ra = 3.3 microns,

  Sa = 5.1 microns (after ½ hour test; pad break-in process)

  Fig 3b. Planargem conditioned pad height pdf and LCM images.



Pad after ½ hour conditioning



Case Study 3: Pad "A" Conditioning Test with a Planargem Disk - Benchtop Polisher Test (Figure 4)

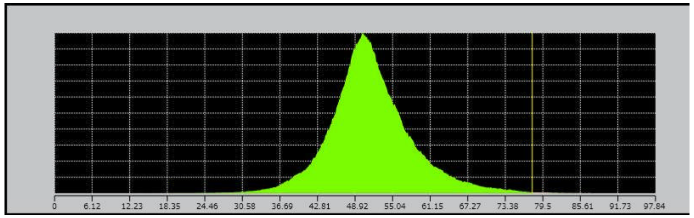
Experimental Data (Contd…):

- (3) Benchtop Polisher Conditioned "A" pad:

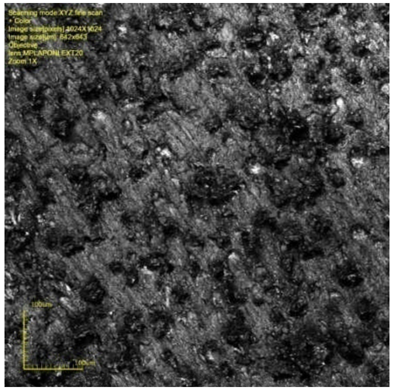
  Planargem Conditioning: PCR = 34 microns/hr, Ra = 3.5 microns,

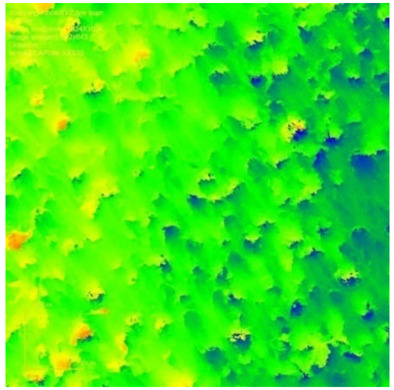
  Sa = 5.0 microns (after 10 hour test)

  Fig 4a. Planargem conditioned pad height pdf and LCM images.



Pad after 10 hour conditioning



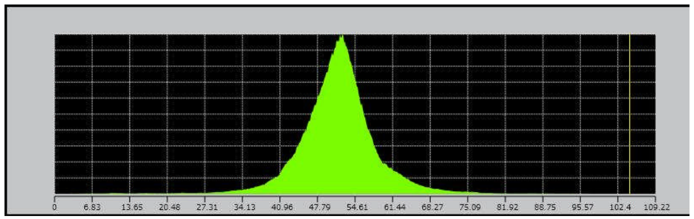


- (4) Benchtop Polisher Conditioned "A" pad:

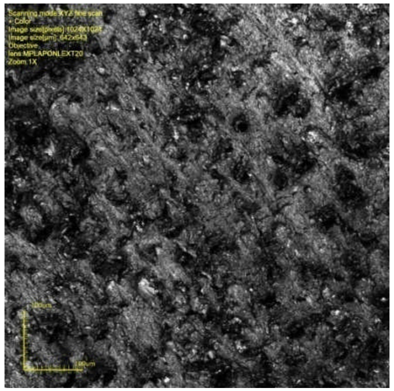
  Planargem Conditioning: PCR = 29 microns/hr, Ra = 3.3 microns,

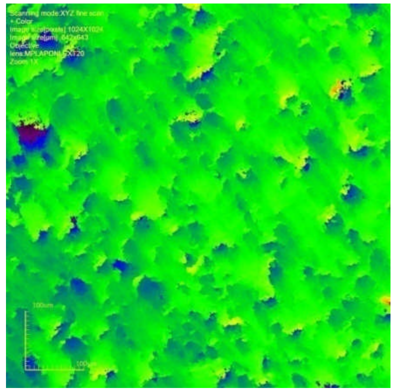
  Sa = 4.7 microns (after 17 hour test)

  Fig 4b. Planargem conditioned pad height pdf and LCM images.



Pad after 17 hour conditioning





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Case Study 4: IC1000 Conditioning Test with Conventional Diamond Disks "C1" and "C2"- Benchtop Polisher (Figure 5)

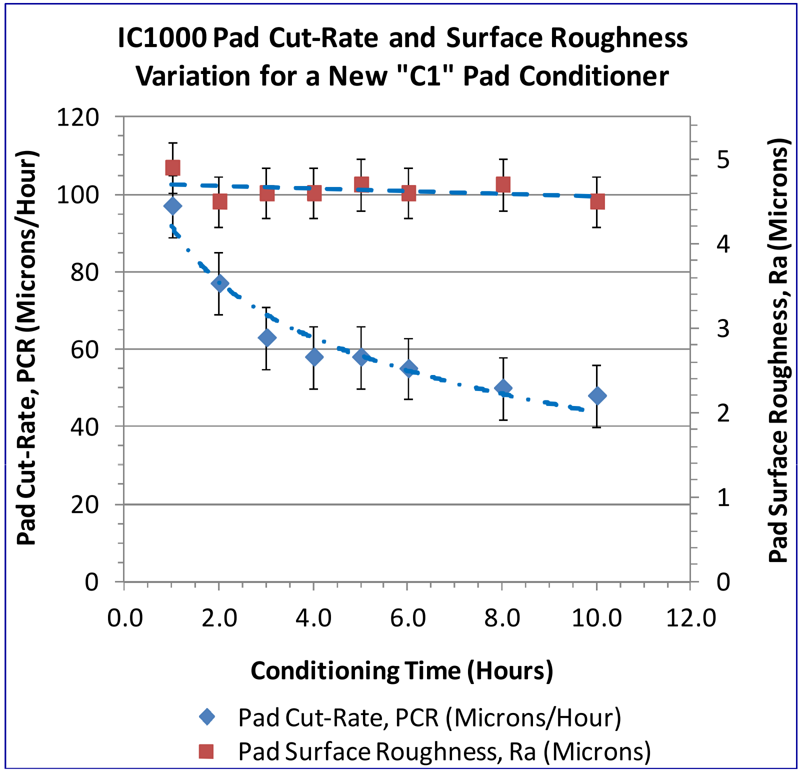

Figure 5a. Pad cut-rate data for a new "C1" disk show ~ 50 % drop over 10 hour run in a benchtop polisher test. Pad Ra remained nearly constant, within experimental uncertainty. Mean COF for new "C1" disk was 0.49. This dropped to 0.46 after 2-1/2 hour testing.

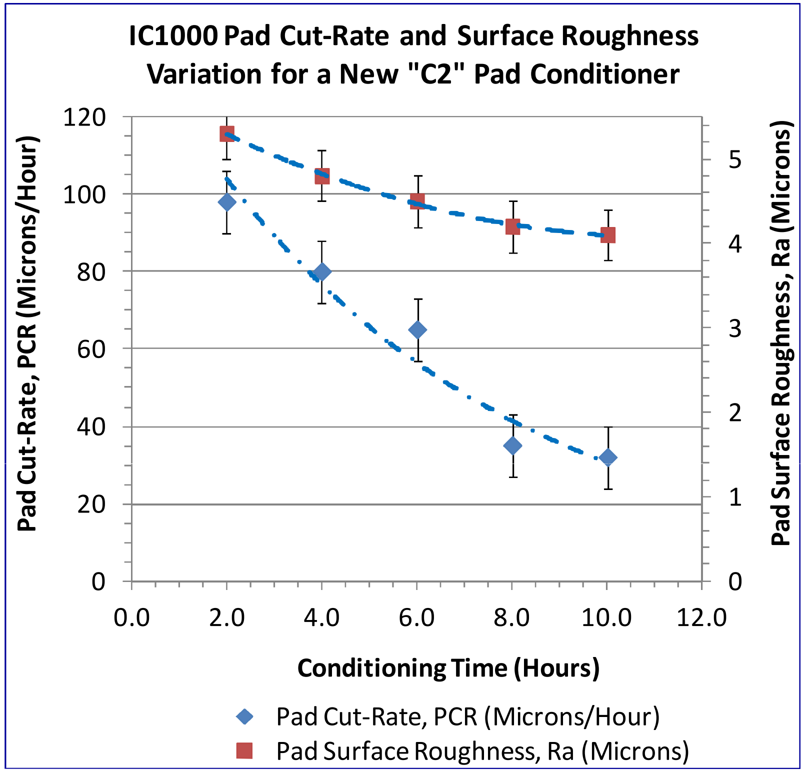

Figure 5b. Pad cut-rate data for a new "C2" disk show ~ 67 % drop over 10 hour run in a benchtop polisher test. Pad Ra dropped ~ 23 % over the test period. Mean COF for new "C2" disk was 0.52. This dropped to 0.47 after 2-1/2 hour testing.

Case Study 4: IC1000 Test with a Conventional Disk "C3" and a Planargem Disk - Benchtop Polisher (Figure 6)

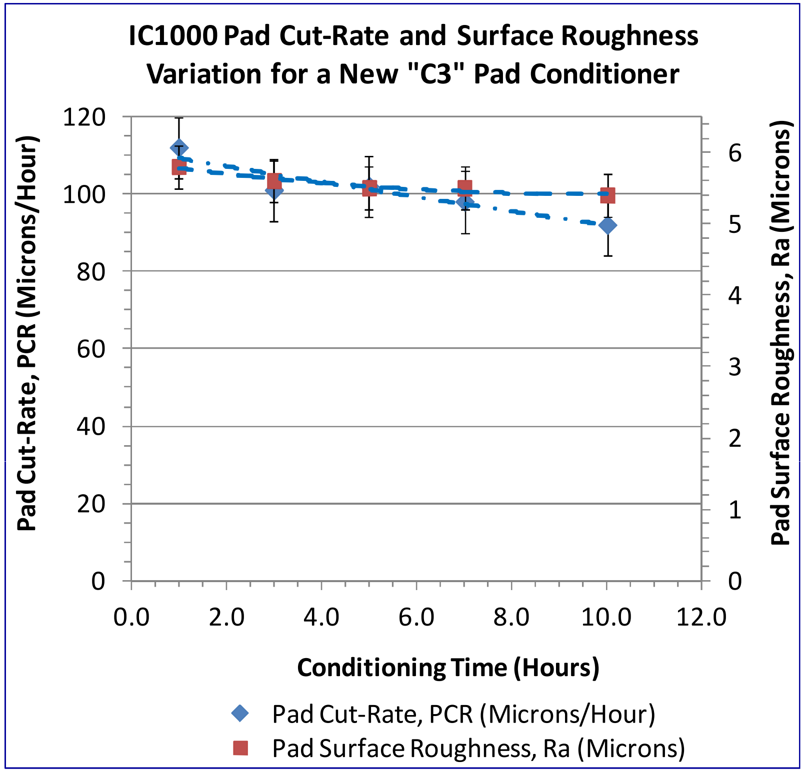

Figure 6a. Pad cut-rate data for a new "C5" disk show ~ 9 % drop over 10 hour run in a benchtop polisher test. Pad Ra remained nearly constant (~7 % drop in 10 hours), over the test period.

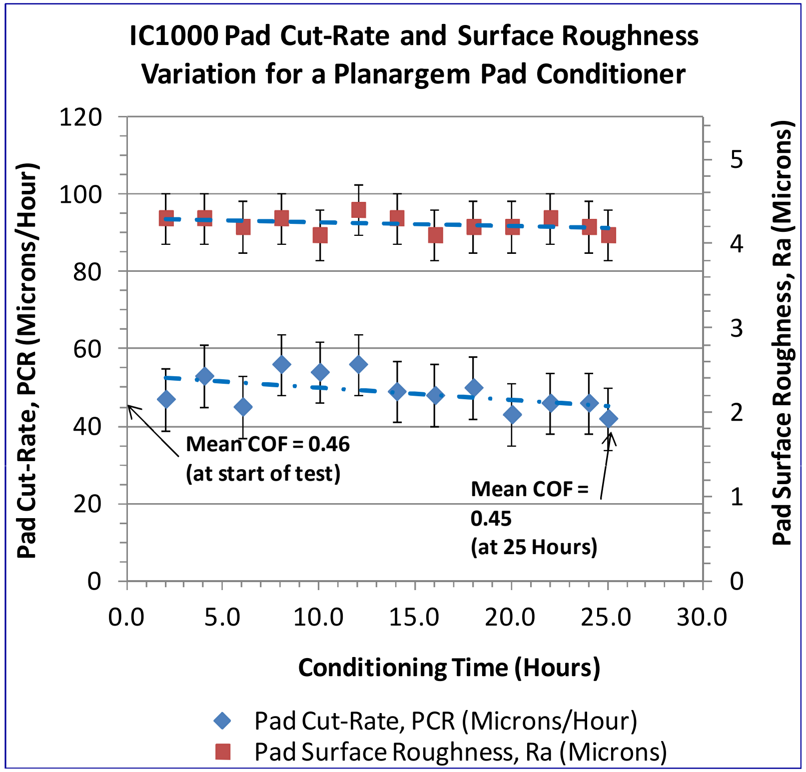

Figure 6b. Pad cut-rate for a Planargem disk show insignificant drop over 10 hour run and ~11 % drop in 25 hours in a benchtop polisher test. Pad Ra remained nearly constant over 25 hour test. Mean COF for the new disk was ~0.46. COF was ~0.45 at the end of 25 hour test.

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Summary and Conclusions

- Characteristics of a new CVD diamond pad conditioner are presented. This design provides higher level of consistency and extended lifetime to meet the challenges of next-gen CMP applications.
- The results presented demonstrate the advancements and opportunities we are developing for characterization of pad conditioners
- Further testing is continuing to quantify the effects and interactions of the different pad and conditioner design parameters, including pad hardness, specific gravity, conditioner abrasive features size, shape, and distribution.
- The quality and consistency of pad and conditioner materials have an ever increasing role in CMP process stability. It is essential to control the consistency of final product to meet tighter specifications.

Acknowledgments

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Thank You!

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