

# ENHANCED MELT-BLOWN FILTRATION FOR NEXT GENERATION CMP SLURRIES AND APPLICATIONS

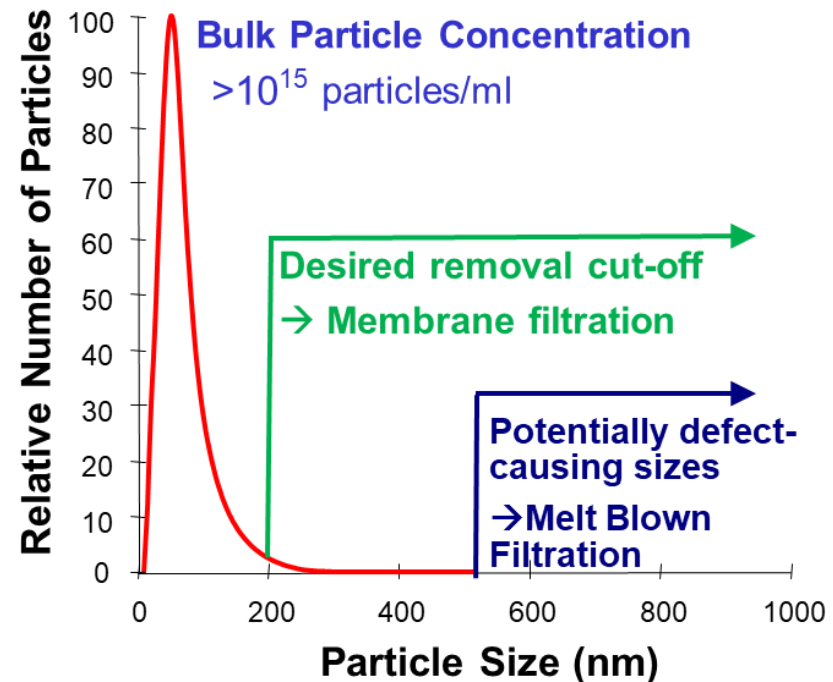


# Outline

- Background
- Filter design aspects for CMP
- Melt-blown polypropylene filtration
- Achieving design goals
- Characterizing filter construction
- Performance characteristics
- Conclusions
- *Acknowledgements*

# Background: Motivation & Challenges

- As microelectronics move to smaller nodes and more complex devices the following is true of CMP:
  - ↓ abrasive particles size
  - ↑ # of CMP steps
- Achievement of the goal shown at right leads to the need for ever finer filtration
  - But this must be achieved without excessive pressure drop and with no negative impact on the slurry



***We will describe herein the development of advanced CMP slurry filtration, building on existing technology, that achieves these goals***



# Critical Aspects of Filter Design for CMP Applications

## Medium and device retention characteristics

- **Large particle reduction *and* fine particle transmittance**

## Surface chemistry of filtration medium

- **Chemical nature—specific functional groups present (interaction w/ additives?)**
- Zeta potential
- Surface energy
  - Native, and potential changes based on chemistry encountered

## Specific filter medium pore morphology

- **Is there adequate area to provide suitable life?**
- Can pore structure facilitate shear agglomeration?

## Filter cleanliness

- In terms of organics and metal extractables and particle release

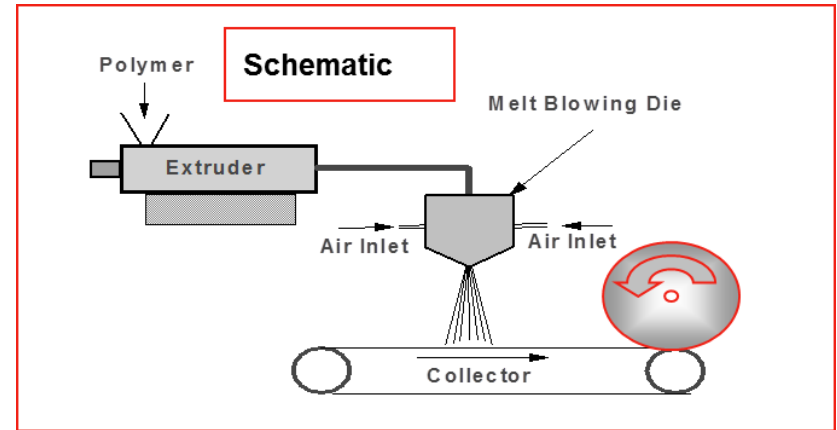
## Filter medium compatibility

- Becomes a concern as media other than polypropylene gain use
  - Especially as slurry chemistry becomes more complicated

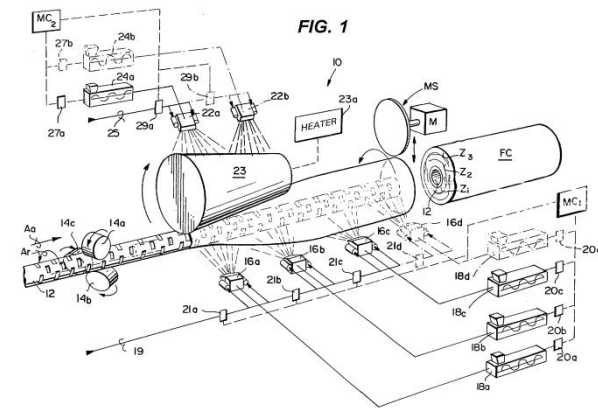
# Melt-Blown Polypropylene Filtration for CMP Slurry

- There is a long history of the successful use of melt-blown polypropylene medium for filtration of CMP slurries
  - The processes for producing flat sheet medium capable of corrugation in a filter, and for producing depth filters are shown at right
- The behavior of polypropylene is well-understood with respect to tunability for retention and flow, and for chemical resistance, cleanliness, and inertness for use in modern, advanced slurry formulations

***This presentation focuses on adaption of polypropylene melt-blown filter design to achieve next-generation performance***



Flat sheet roll manufacturing



3-D depth cartridge manufacturing

U.S. Patent Jan. 7, 1997 Sheet 1 of 11 5,591,335

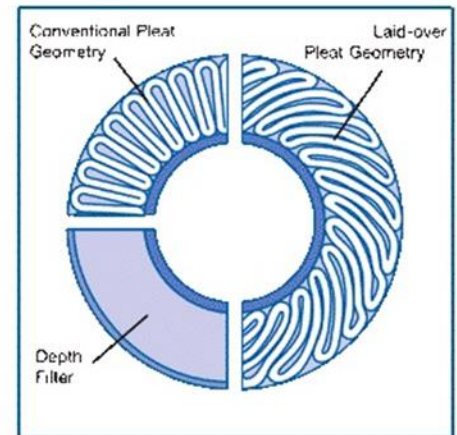


# Filter Structures with Melt Blown Media

- While melt-blown polypropylene media may occur in several pleated or pure-depth forms (as shown at right), the pure-depth format (bottom left) has found wide use in CMP slurry filtration
- Flow, retention, transmittance, and life performance are all enhanced via the use of variable fiber size—and therefore pore size—over the depth of the medium

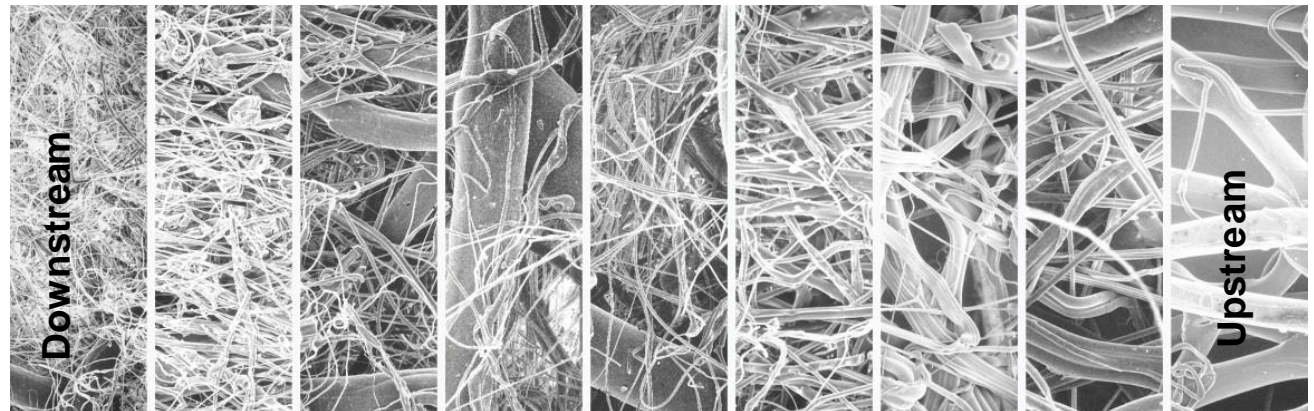
***This work focuses on an enhanced version of the pure-depth style of filter produced with melt-blown medium***

Diagrammatic Comparison of Various Filter Constructions



Depth filter X-Section

Graduated (or “profiled”) pore size filtration





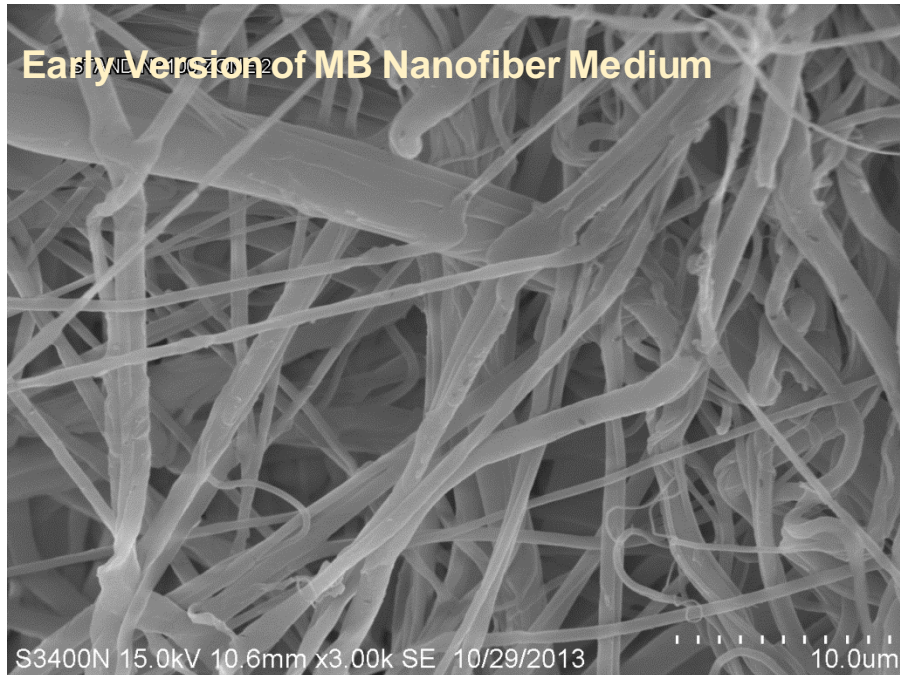
# Achieving Design Goals

- Several critical aspects of the new filter design support the goals of improved flow and retention behavior;
  - Higher void volume
  - Thinner retention layer
  - Thinner overall medium depth
  - Finer fibers
  
- These characteristics individually or in combination also address other CMP slurry filtration needs:
  - Improved life
  - Avoidance of shear agglomeration

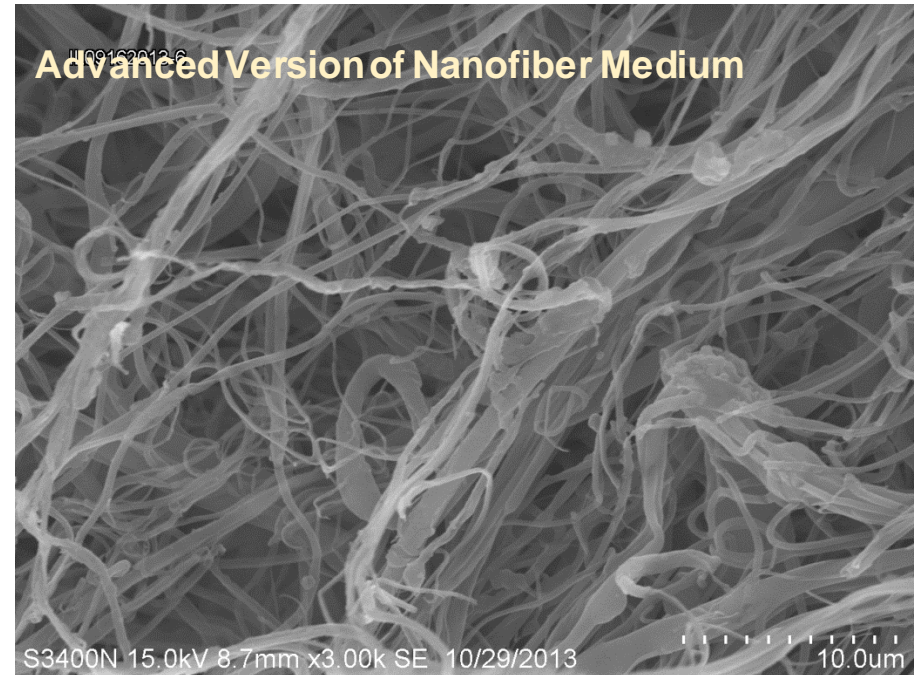
# Achievement of Finer Melt-Blown Fibers

- The images below depict the evolution of achievement of finer fibers leading to finer pores, beneficial to finer particle capture, and increased void volume beneficial to flow, life, and avoidance of shear

**Early Version of MB Nanofiber Medium**



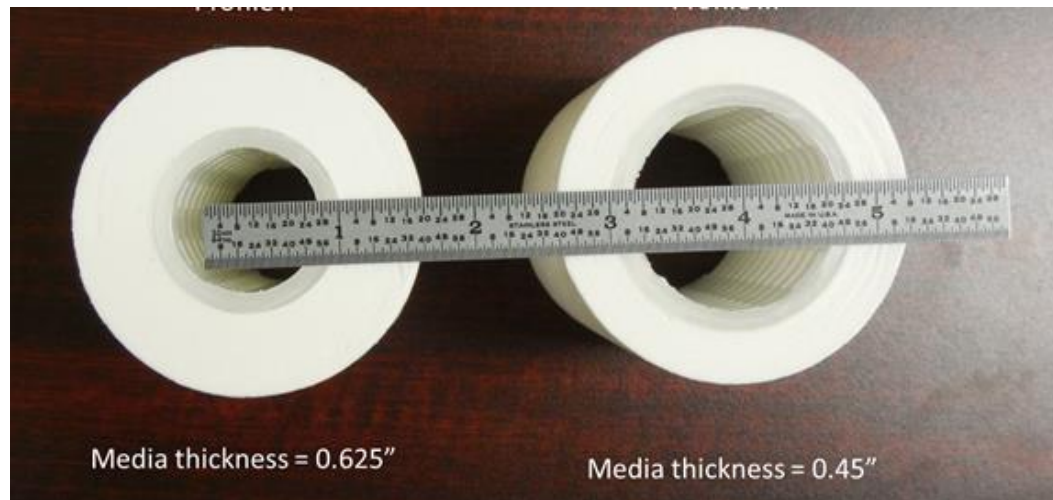
**Advanced Version of Nanofiber Medium**



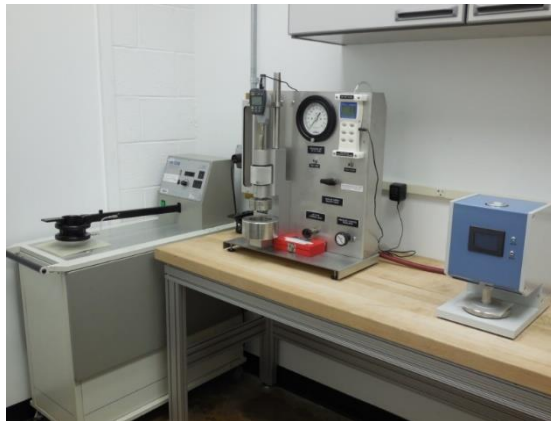
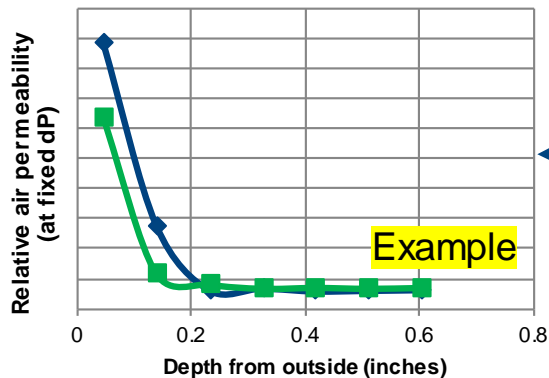
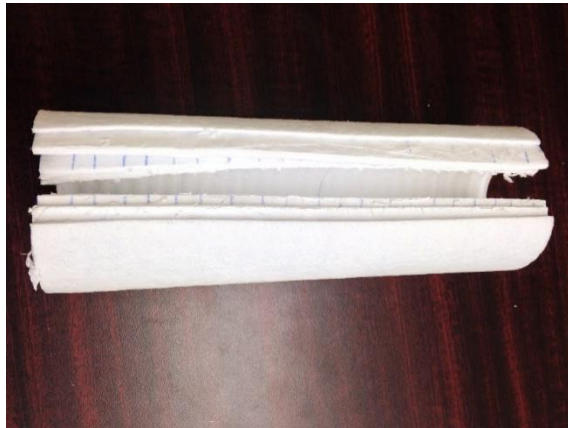


# Improved Pressure Drop via Dimensional Change

- Melt-blown *depth* filtration medium depends upon the distance a particle needs to travel through the filters, and the nature of the pores it traverses, to capture particles
- While greater depth—*for consistent pore structure*—increases the opportunity for capture, it also leads to greater pressure drop
- Through optimization of the pore structure through advanced fiber production and melt-blowing processes, it is possible to use less depth to achieve the same LPC reduction at lower pressure drop:

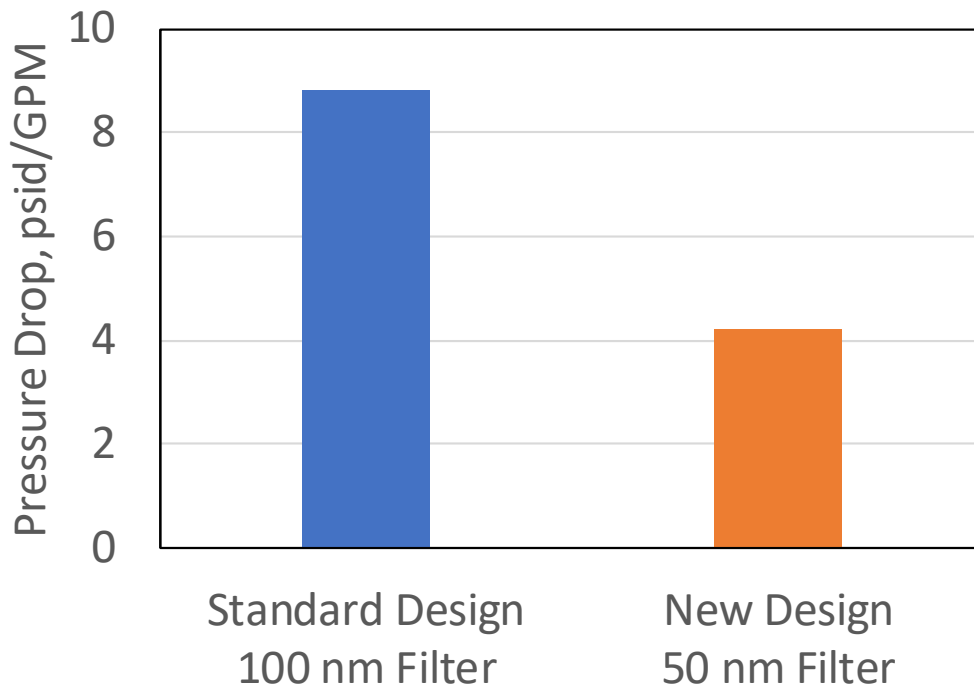


# Characterizing Filter Construction



- This design makes use of optimized, profiled fiber size leading to profiled pore size with respect to depth
- This profiling can be characterized via dissection of the filter into layers of medium whose permeability at a fixed flow rate of air can be measured to assure expected characteristics

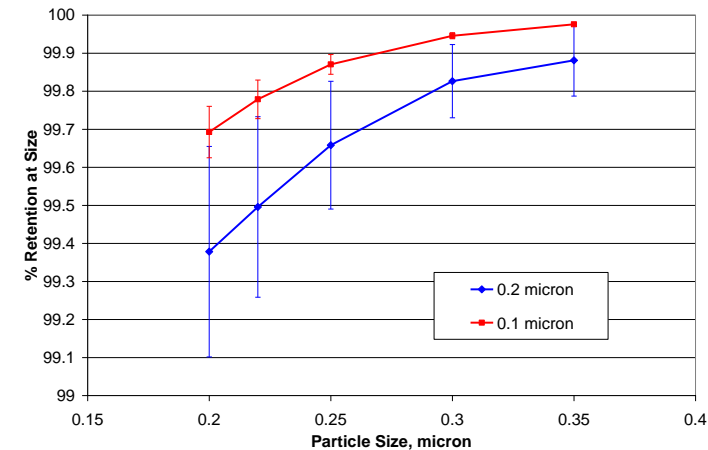
# Comparative Pressure Drop of Filters with Standard Depth and New Design



- The new design filter, while exhibiting improved fine particle retention (described later) has a normalized pressure drop that is about 50% of that of the standard design filter
  - Functions of its optimized layer structure, higher void volume, and thinner overall thickness of filtration medium

# Notes on Characterizing Retention for “Deeply” Submicron Melt-Blown Depth Filters

- We have found that in developing ever finer melt-blown product for CMP slurry, it can be difficult to show that demonstrate finer retention by “classical” challenge testing, even when other characteristics clearly indicate a finer pore structure
  - This can be seen in the graph at top right, Within uncertainty of the analysis, data overlap
  - Tests with finer kaolin and a PMS M65 counter also showed no difference
- Alternate methodology to show discrimination has been the use of PSL beads (350 nm and 125 nm )—table at bottom right indicates this clearly
  - Of course, this method *cannot* be used as an indicator of life—this must be evaluated separately (e.g. via traditional dispersion method—more on this later)



Apparent Filter Type	Test dust challenge		Kaolin challenge, cumulative retention at 65 nm	350 nm PSL bead retention (average)
	200 nm retention (average)	350 nm retention (average)		
0.3 micron	94.4%	99.0%*	99.9%	< 20%
0.2 micron	99.4%	99.9%	>99.9%	77%
0.1 micron	99.7%	>99.9%	>99.9%	96%





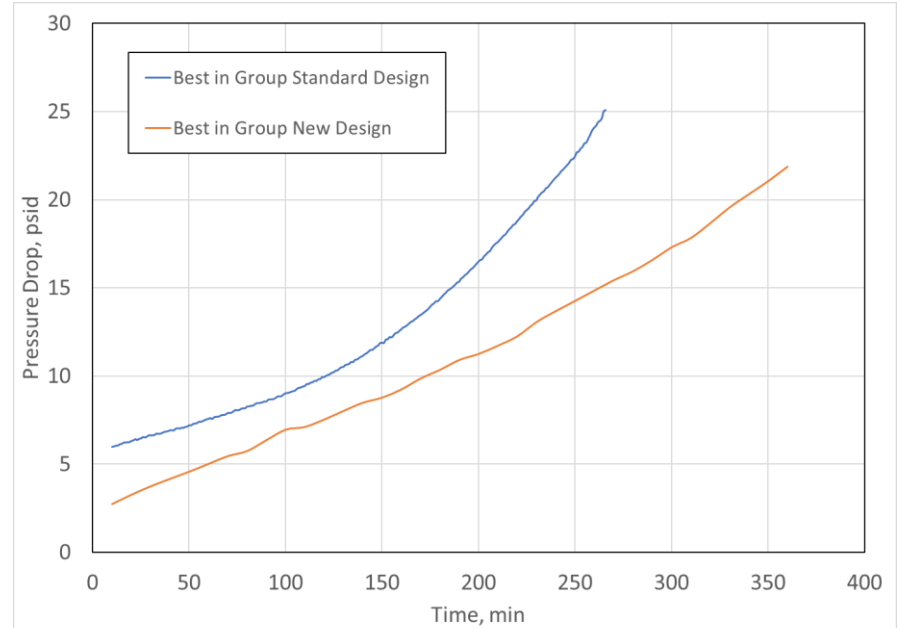
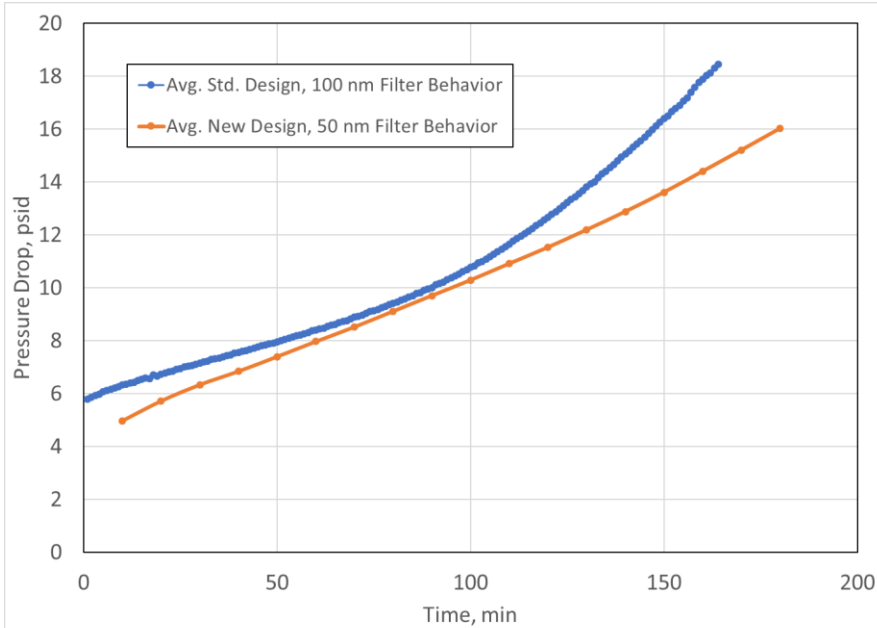
# Demonstrating Achievement of Enhanced Retention via PSL Bead Challenge

	Retention, %		
PSL Bead Size, nm	Standard Design 100 nm rated	Early Prototype, New Design	New Design, Current Product 50 nm rated
200	36	38	67
300	73	81	96
350	88	96	98

- The final version of the new product exhibits higher PSL bead retention across multiple bead sizes, a function of finer fibers and other aspects associated with the design

# Application Oriented Performance Testing

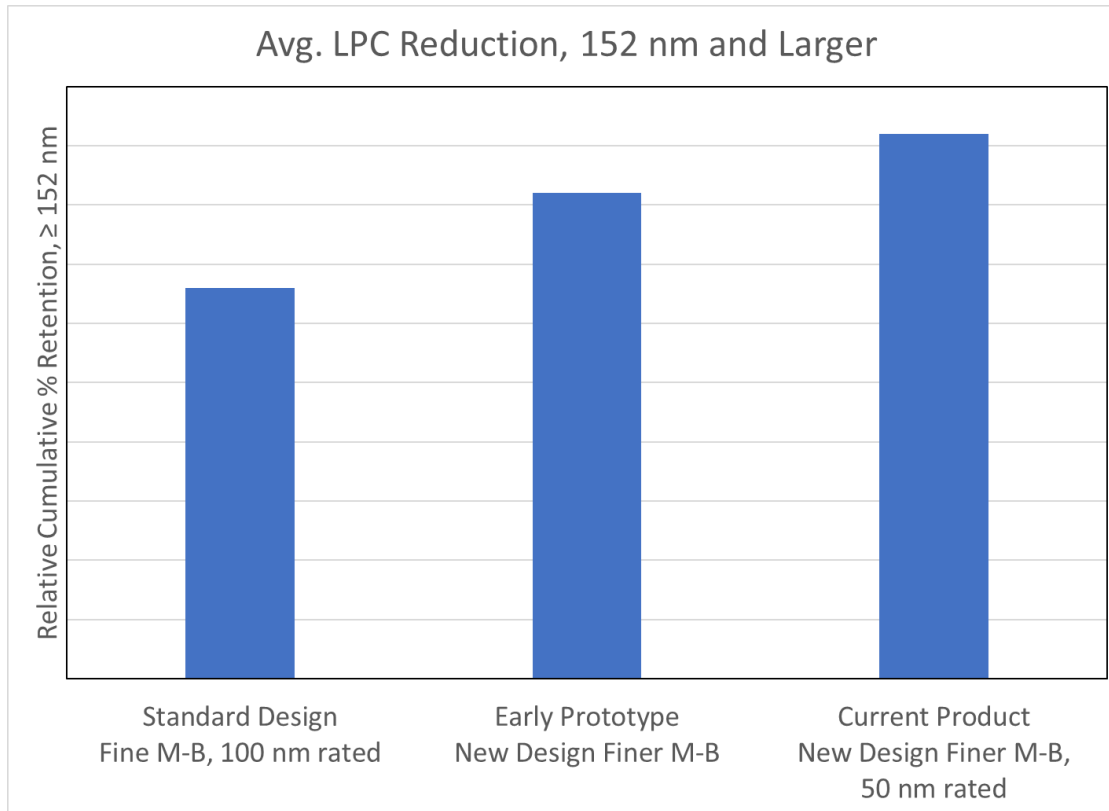
## Characterization of Relative Life



- Shown here is the relative pressure drop rise vs. time occurring for sets of six filters of a standard, 100 nm rated, and new design, 50 nm rated filters, and best-in-group for each set, tested under identical conditions in a model silica-based slurry
  - Silica-based abrasive, adjusted to pH of 10; to 25 psid terminal DP or 360 min
- The advanced design filter exhibits lower initial pressure drop, while also showing a less rapid increase in  $\Delta P$ , indicative of longer life

# Application Oriented Performance Testing

## Characterization of LPC Reduction



- In testing with model slurry, initial prototypes of the new design product exhibited an approximately 24% improvement in reduction of particles  $\geq 152$  nm compared to a previous state of the art melt-blown depth filter intended for CMP applications
  - As determined by PSS FX Nano instrument
- The final design of the product exhibits an approximately **39%** improvement in LPC reduction compared to the standard design product



## Conclusions

- CMP is an enabling technology for advanced chip manufacture, improved by the contamination control afforded by filtration
  - As CMP evolves with ever-finer abrasives and more complex formulations, CMP slurry filtration must also evolve
- We have described herein a next generation filter design for achieving improvement in several critical areas
  - This design utilizes finer fibers, increased void volume, thinner overall depth of medium, and thinner retention layer
  - These attributes have been shown to allow improvements in retention, life, and pressure drop compared to a previous advanced product for filtration of CMP slurry as used in the most advanced chip technology nodes





***Thank you!***

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