Tailored Acicular Mullite Substrates for Multifunctional Diesel Particulate Filters

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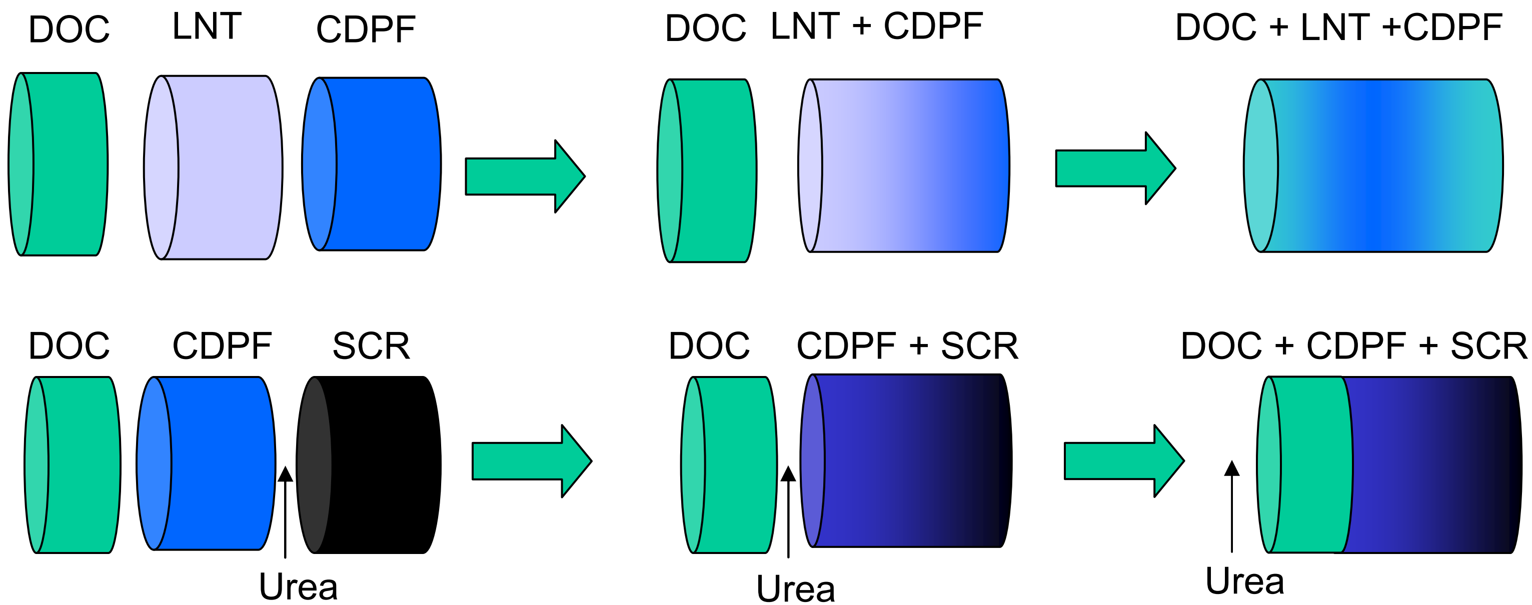
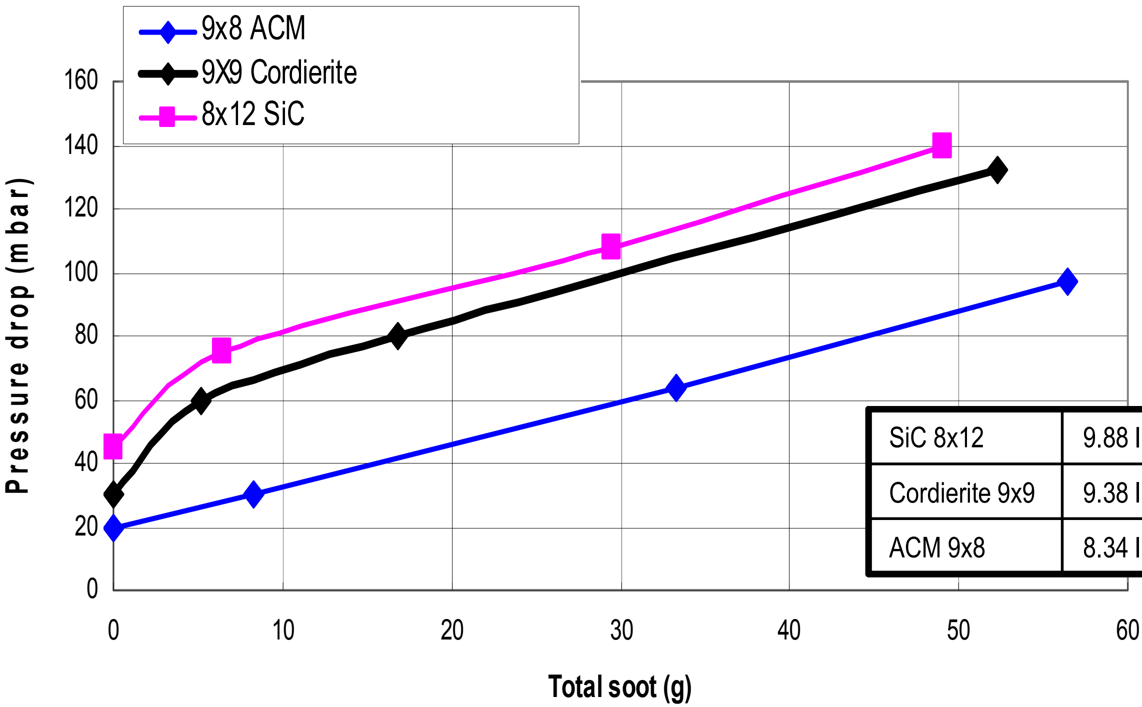
Emerging Multifunctional Diesel Particulate Filters



- The promise of multifunctional diesel particulate filters:
  - Reduced volume and weight
  - Reduced system cost
    - * Fewer cans, canning operations, materials, etc.
  - Reduced total system pressure drop
  - Higher working temperatures for improved catalytic activity

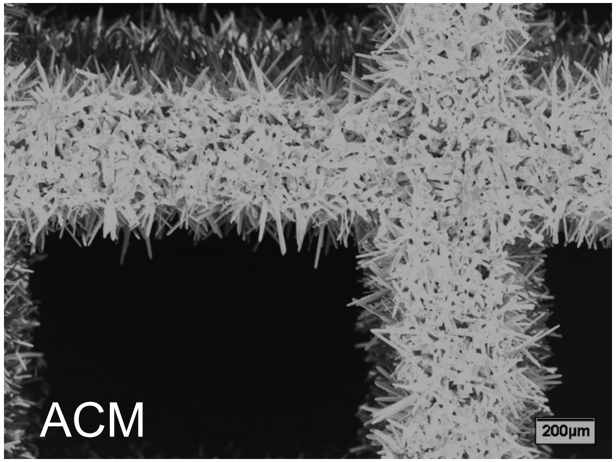
- Key limitation for substrates to practical implementation:
  - Excessive filter pressure drop with high catalyst loads

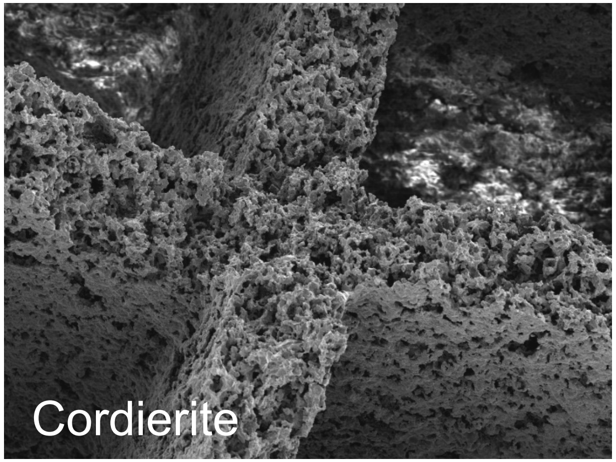
DPF Based on Acicular Mullite (ACM): Low Pressure Drop and Linear PD vs Soot Mass



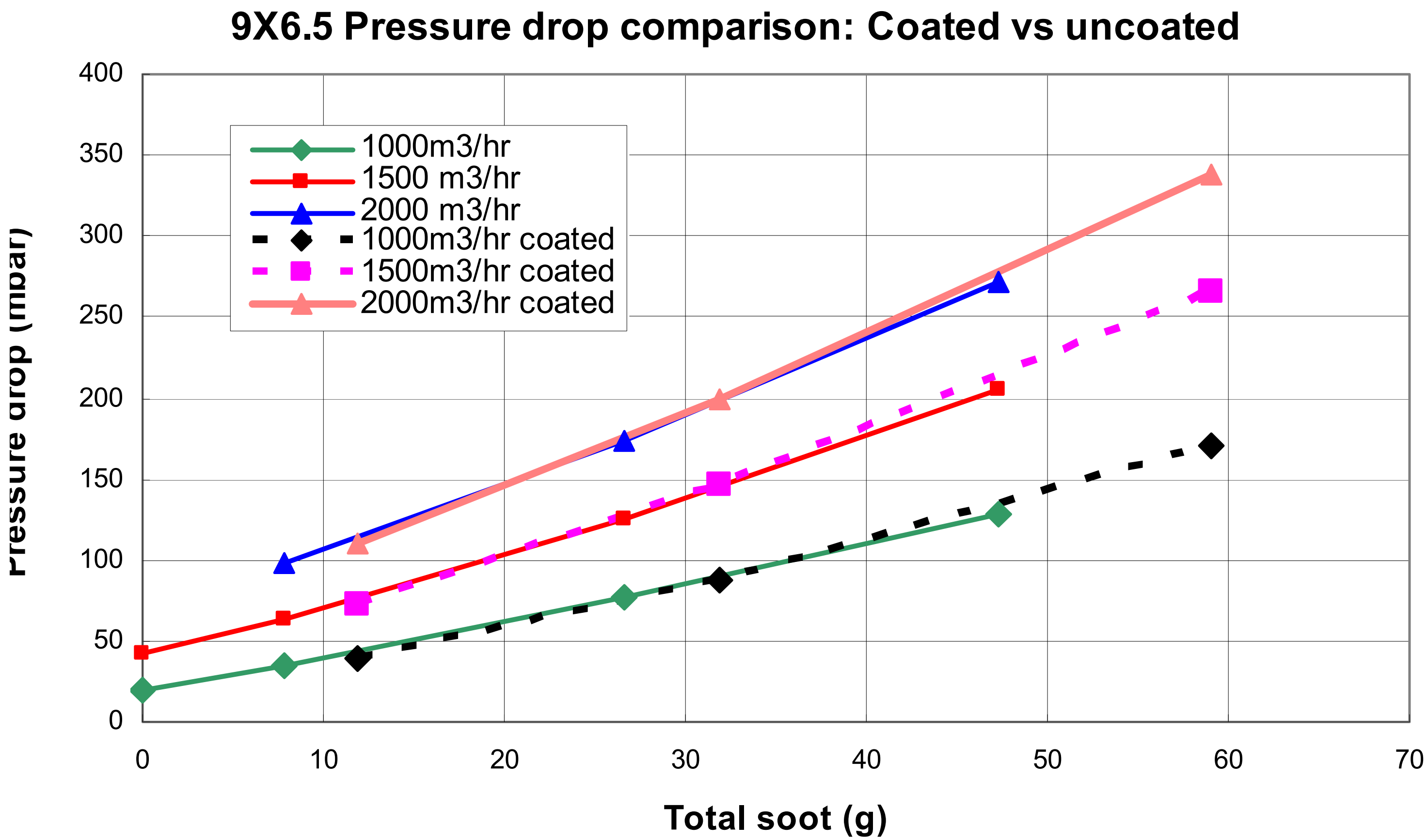
SiC 8x12	9.88 l
Cordierite 9x9	9.38 l
ACM 9x8	8.34 l

ACM microstructure provides unique combination of gas permeability, catalyst coatability, and substrate strength





No Increase in Pressure Drop with Catalyst Coating Standard CDPF Applications



ACM microstructure and enables high catalyst coating capacity

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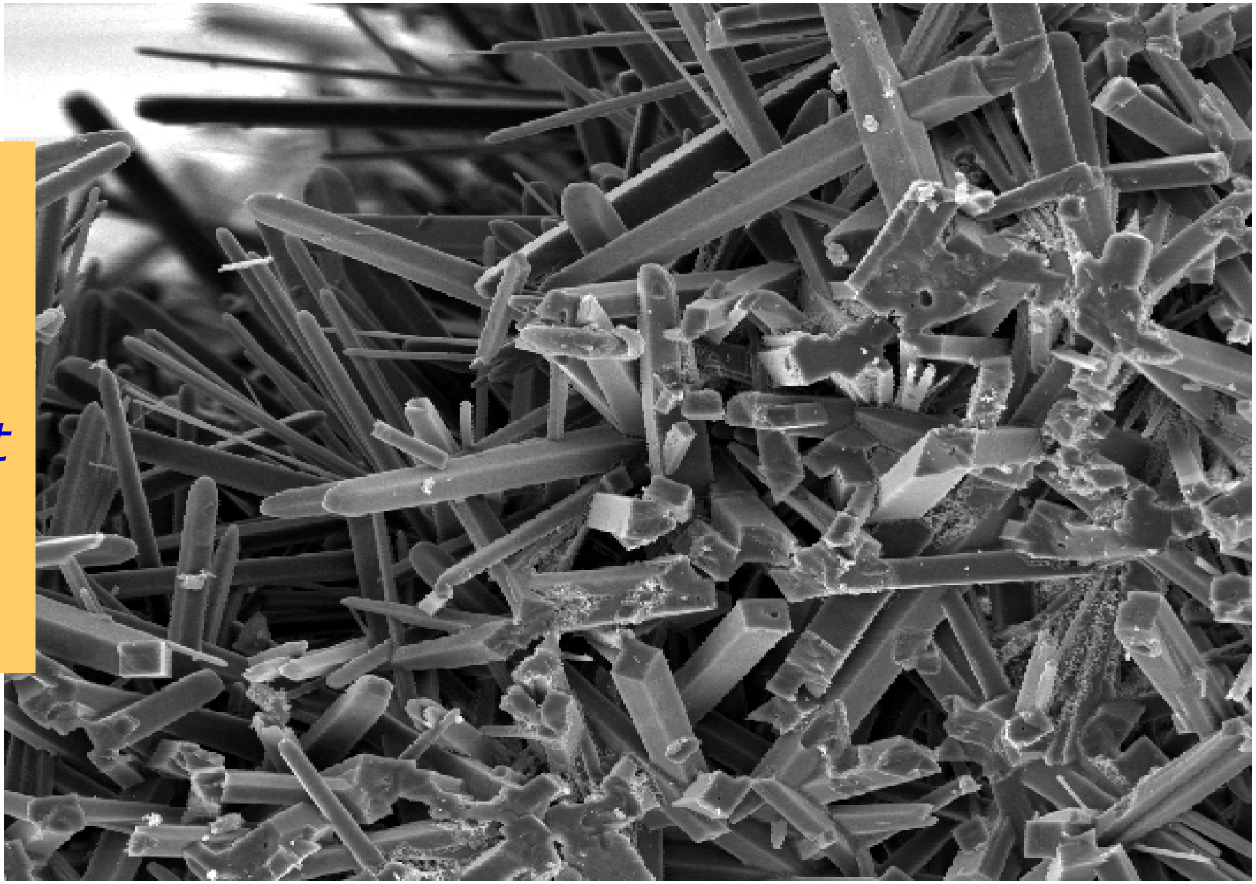
Catalyzed ACM DPF Microstructure

SEM analysis showed that ACM DPF can be coated with relatively high catalyst washcoat without significantly affecting the porosity or pore size Therefore, it maintains a low back pressure performance at very high catalyst

- *ACM DPF was coated with 80g/l or 2264g/cu.ft catalyst*

(200x SEM)



ACM Synthesis

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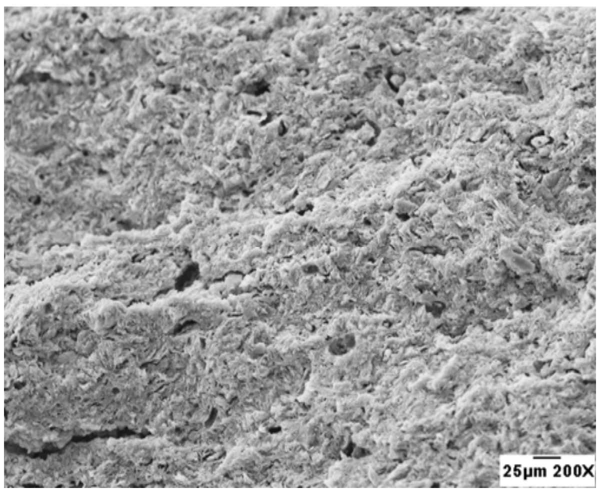
Mullite Precursor → (+ SiF_4, ~700C) → **Fluorotopaz** → (- SiF_4, ~1100C) → **Acicular mullite**

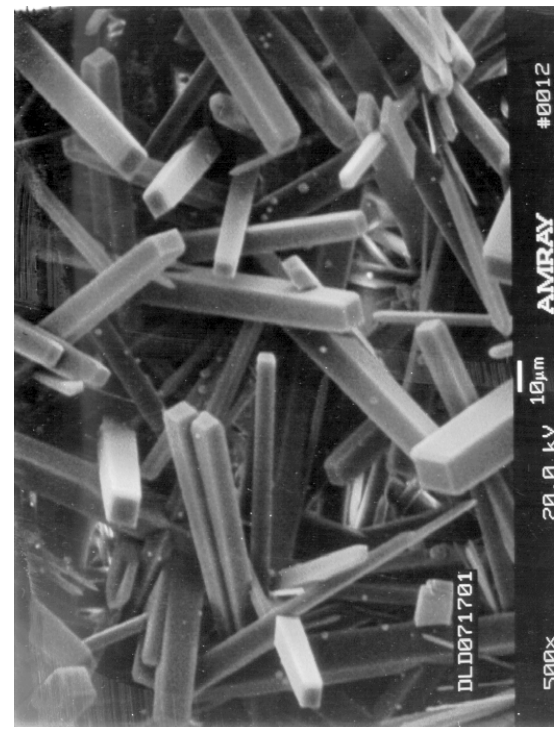
Alumina + Clay

$(\sim 1.7Al_2O_3 \cdot SiO_2)$ → $(Al_2SiO_4F_2)$ → $(\sim 1.7Al_2O_3 \cdot SiO_2)$



After calcination, prior to conversion to Topaz

Honeycomb macrostructure created by extrusion, drying, and calcination



Porous microstructure created by reaction conversion to acicular mullite

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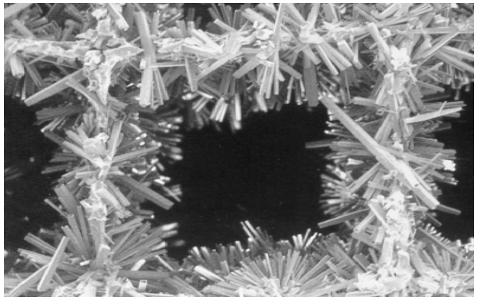
Controlled ACM Microstructure Allows Tailored Catalyst + DPF Substrate

ACM Process allows control over <u>pore size</u> and <u>porosity</u>
Through control of free volume and morphology of microstructure in the walls

30 micron



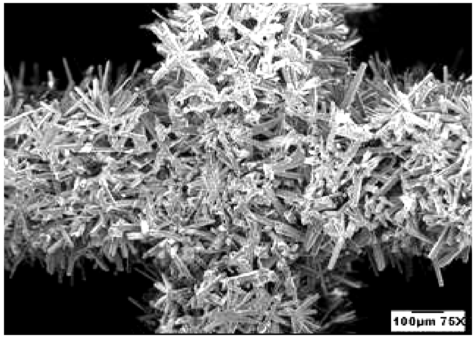
80 %

Average
Pore
Size

Average
%
Porosity

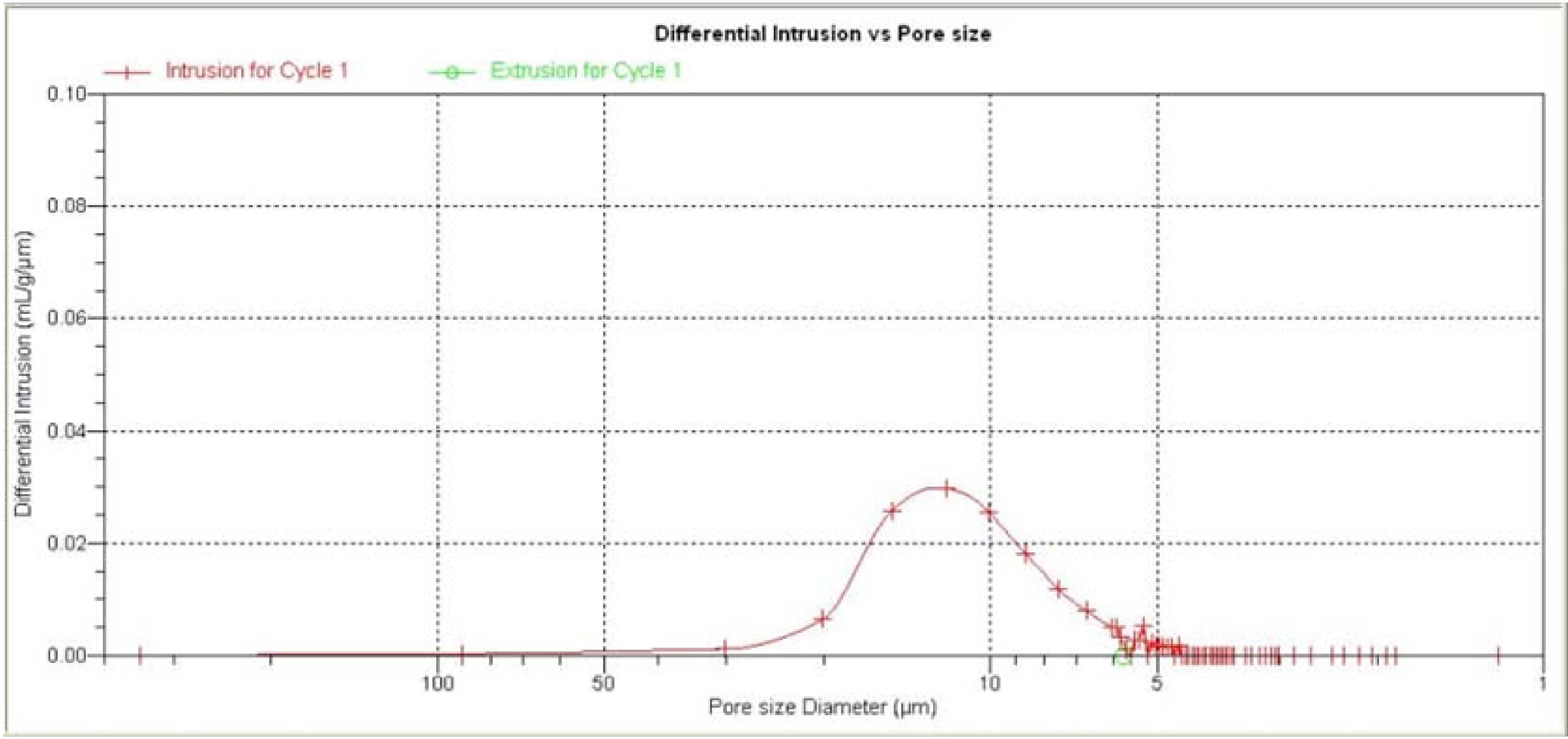
9 micron

50 %



Typical Pore Size Distribution in ACM

Average Pore Size is controlled with relatively narrow distribution through control of The morphology and any added porogens.



"Tailored" Filter Substrate Evaluation

Simulated "Wash Coat" Loading

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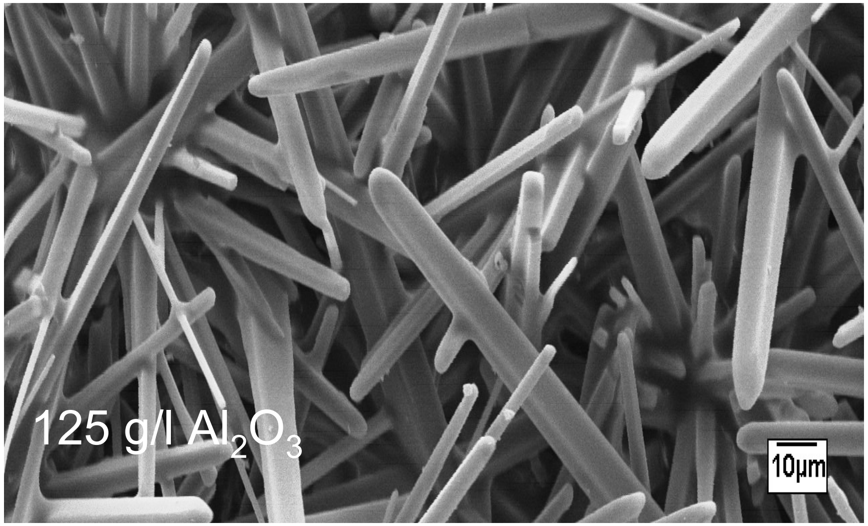
Prepare a Series of Pore Sizes and Porosities for ACM

- Microstructures with pore size from 9-23 um (64% average porosity)
- Porosity from 64-80% (18 um average pore size)



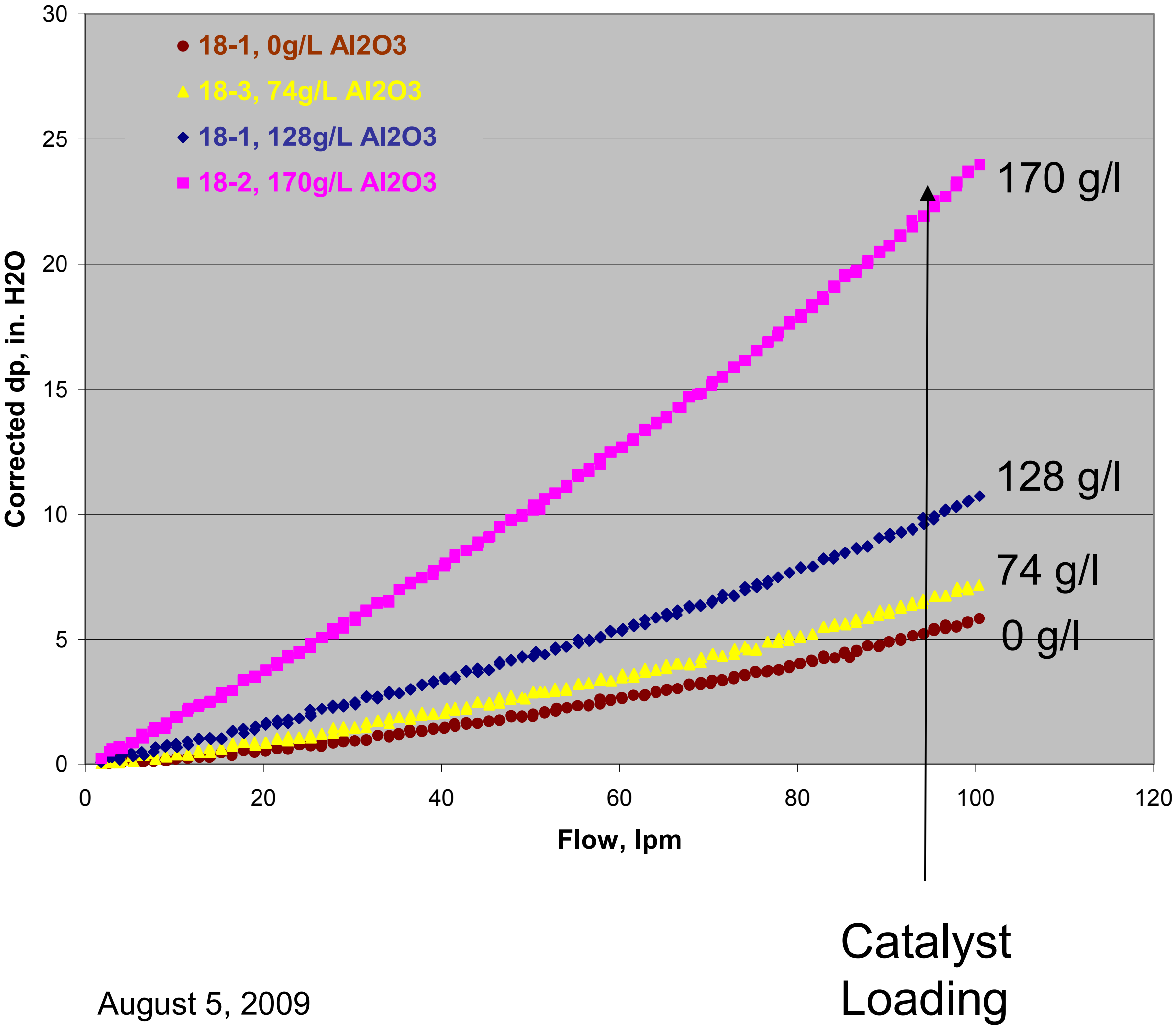
Example of Coated Substrate

Coating Procedure

- Filter was immersed in 20 wt% colloidal alumina
- Excess removed by forcing air through the filter
- Gas flow used to dry the filter
- Calcine

- Uniform coating of the microstructure vs. layer on channel surface
- Reproducible process using common catalyst material
- Ability to apply multiple coats to assess pressure drop dependence on loading

Pressure Drop Dependence on Coating for 64% Porosity ACM DPF



CDPF Applications

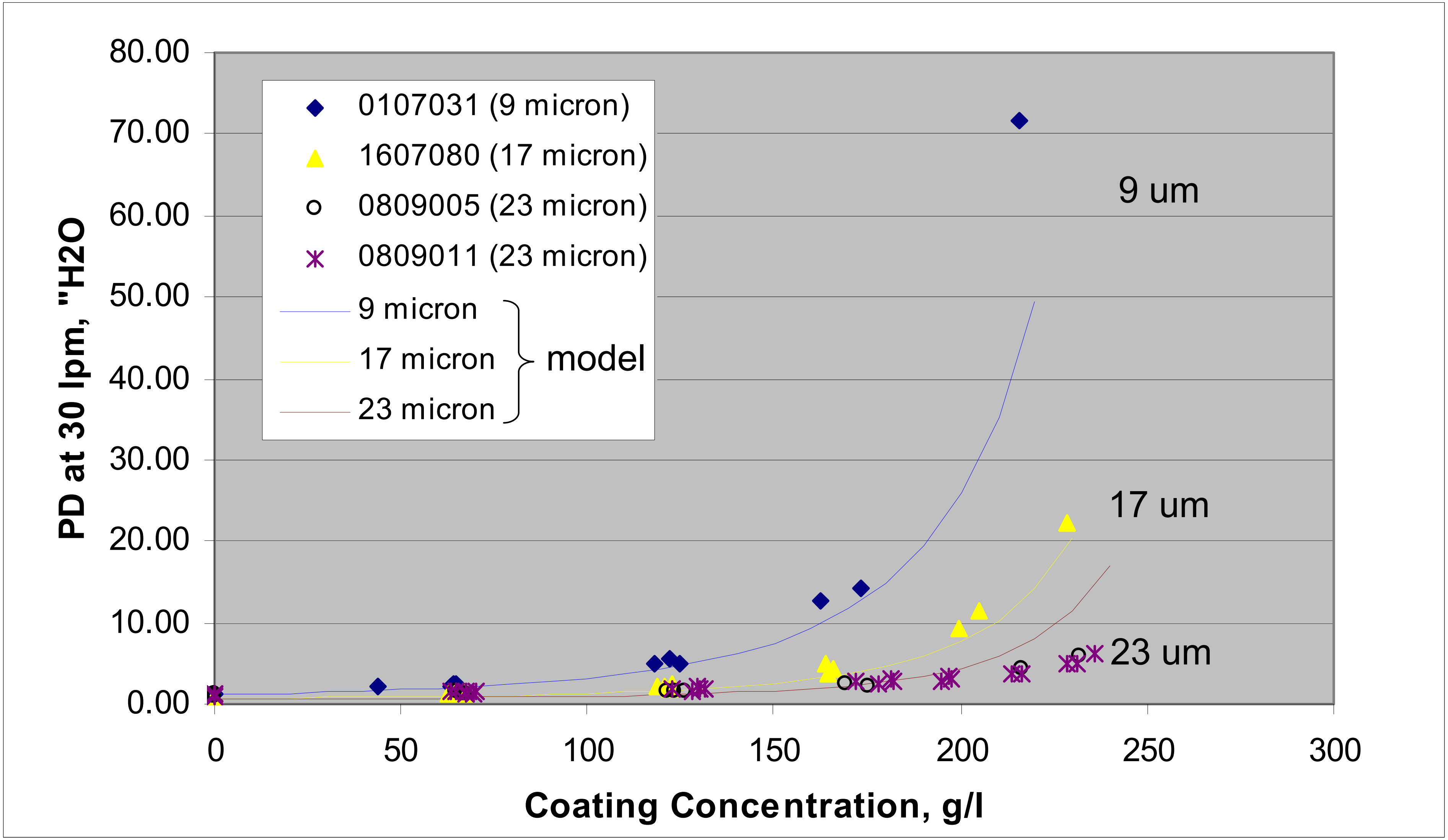
- *Catalyst loadings 20-40g/L*
- *No PD increase on ACM at 64% porosity*

NOx Control Systems

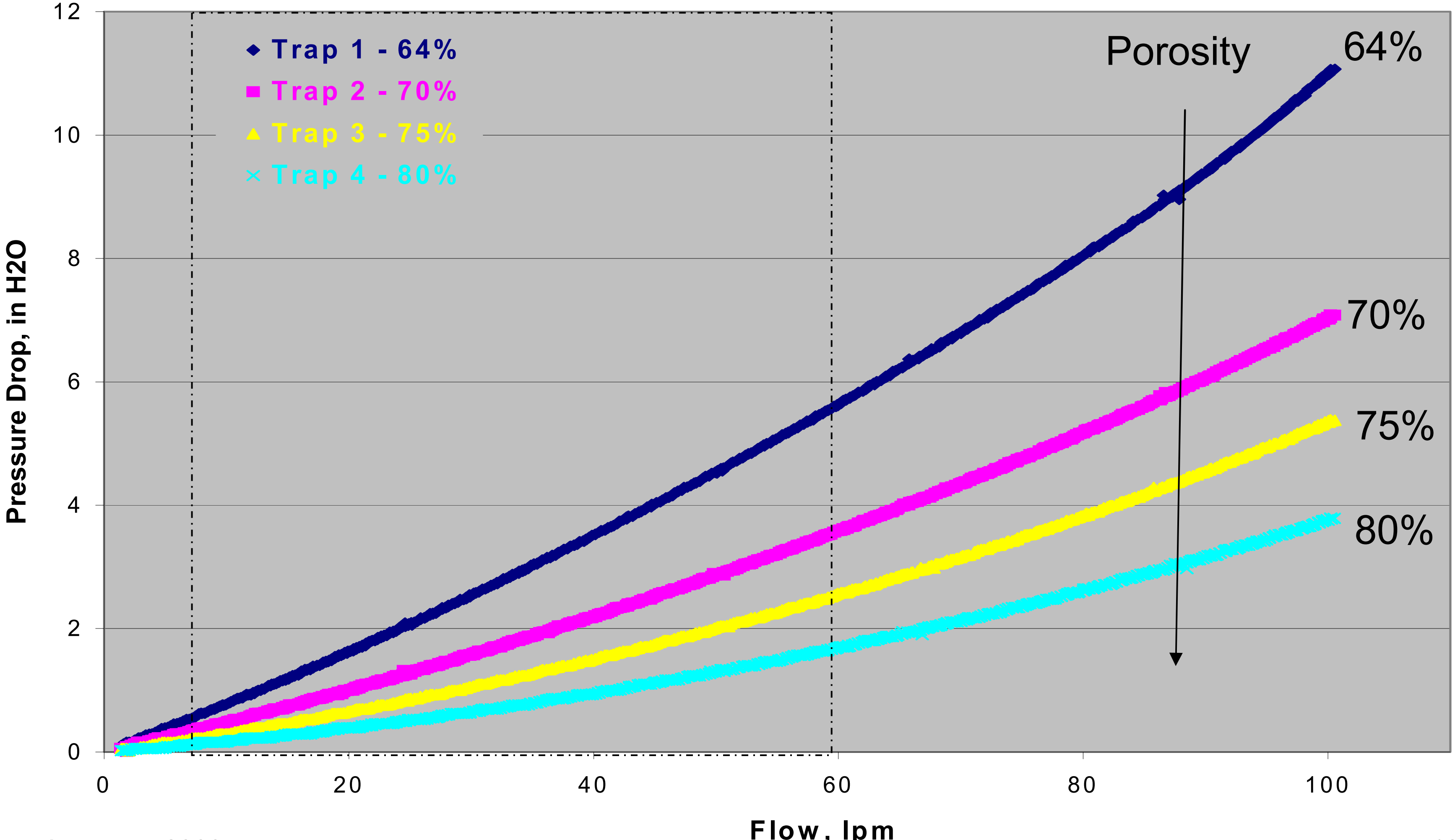
- *Catalyst loading determines NOx storage capacity or NOx reduction efficiency and time between regenerations*
- *Catalysts loadings100-200g/L*
- *PD increase at 64% porosity*

Pressure Drop vs Alumina Wash Coat Loading for a Series of Pore Sizes

ACM, 200 cpsi, 0.355 mm wall thickness, 64% porosity

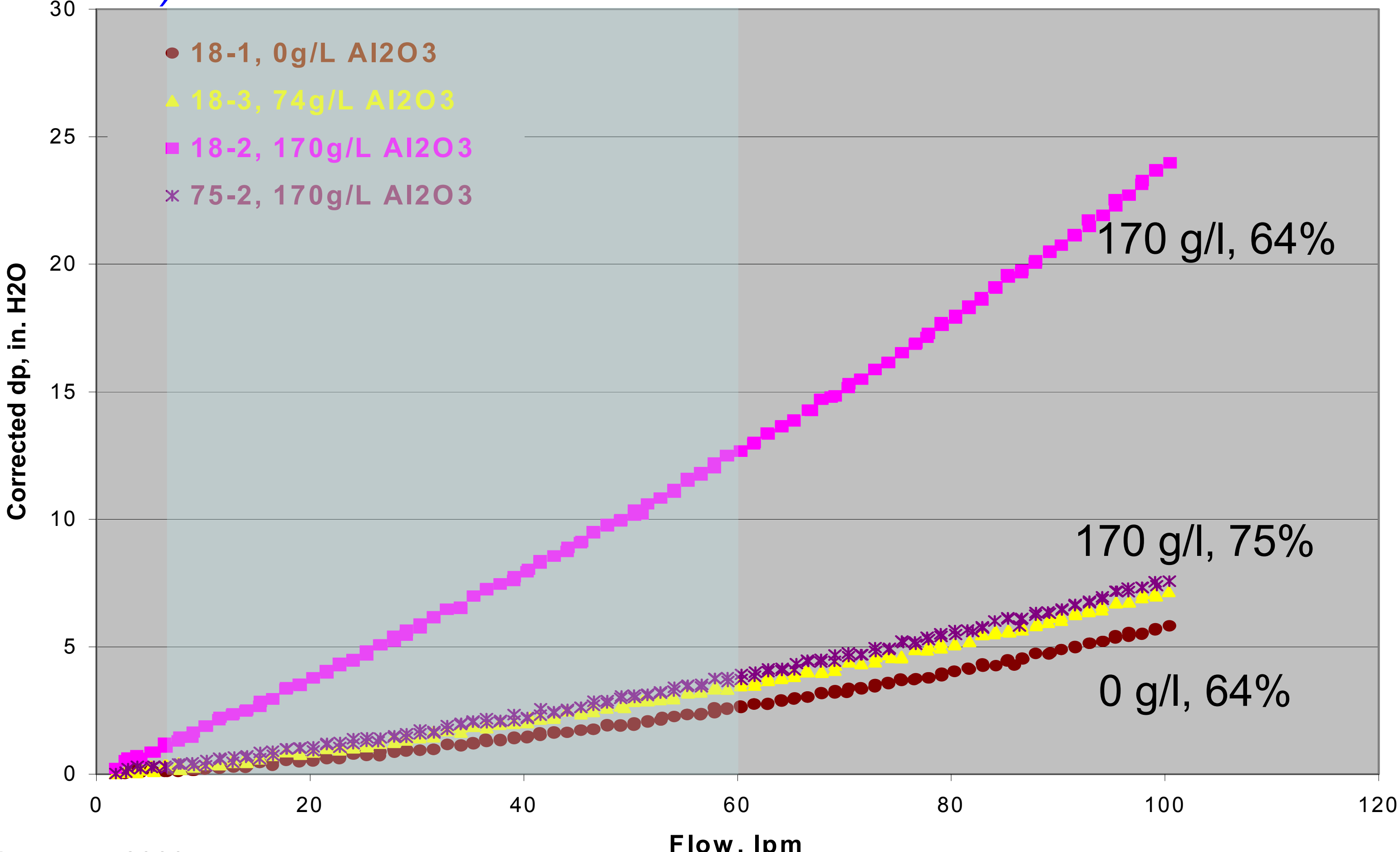


ACM DPF Pressure Drop Dependence on Porosity at 125g/L Al_2O_3 Loading

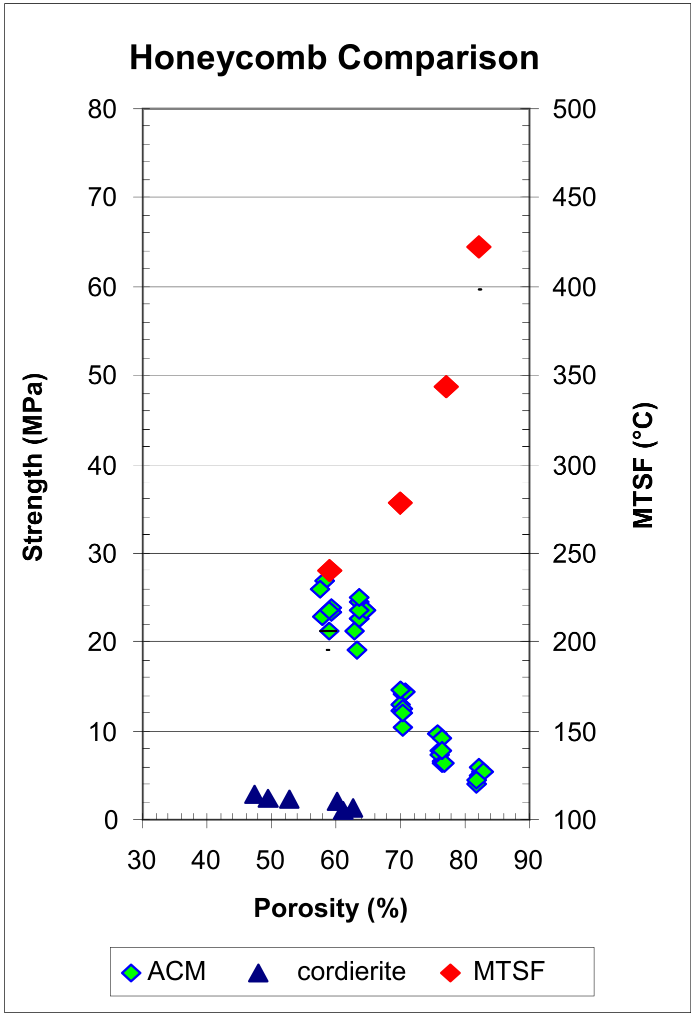


Increased Porosity Reduces ΔP at High Al_2O_3 Loading

An increase of porosity from 64% to 75% allows a doubling of the catalyst loading (75 to 150g/L alumina) with small increase in pressure drop. (constant pore size)



Strength and MTSF Dependence on Pore Volume Fraction in ACM Honeycombs



Failure stress was determined using the method outlined in ASTM C 1674-08 "Flexural Strength of Advanced Ceramics with Engineered Porosity (Honeycomb Cellular Channels) at Ambient Temperatures". (4-point bend test)

Elastic modulus was tested following the method outlined in ASTM C 1259-94, "Standard Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio for Advanced Ceramics by Impulse Excitation of Vibration".

$$MTSF = \frac{\sigma}{E\alpha}$$

Cordierite data: G.A. Merkel, et al., "New Cordierite Diesel Particulate Filters for Catalyzed and Non-Catalyzed Applications," Proceedings of the 9th Diesel Engine Emissions Reduction Conference August 24-28, 2003, Newport, Rhode Island

Tailored Acicular Mullite Substrates for Multifunctional Diesel Particulate

- ACM microstructure and morphology allows for unique control of pore sizes and porosity.
- Larger pore sizes allow high catalyst loads with significantly lower back pressures.
- High porosity enable high catalyst loads with minimal pressure drop increase
- Optimization of these parameters along with wall thickness and CPSI can create a catalyst/DPF substrate with improved multifunctional capability.