Catalytic Filter for Diesel Exhaust Purification

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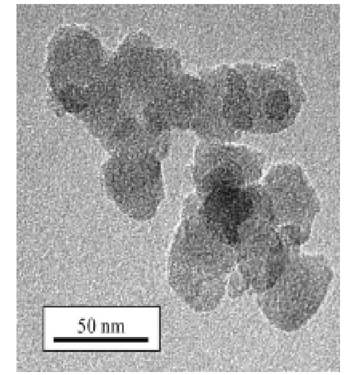
ASPEN PRODUCTS GROUP, INC.

Aspen Products Group, Inc.

- Develops materials and systems that promote efficient and clean liquid fossil fuel use
  - Hydrogen generation, hydrogen purification, sulfur removal
  - Catalytic combustion
  - Exhaust clean-up
- Products developed for military and commercial customers
- Business strategy to become component manufacturer & supplier

Motivation

- Particulates emitted from diesel engines pose significant health hazards
  - lung cancer
  - cardiovascular disease
  - asthma



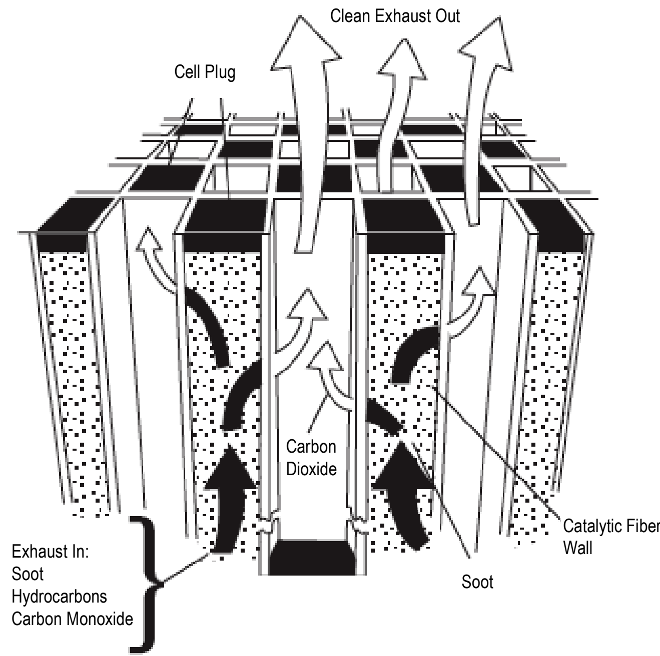
- Stricter particulate emissions regulations being implemented worldwide
- While conventional passive and active particulate filters can achieve desired particulate reductions, they:
  - are expensive (Pt loading, control systems)
  - reduce engine fuel economy (exhaust backpressure, parasitics)
  - require frequent maintenance

Objective & Technical Approach

To develop a precious metal-free passive DPF

Approach

- Wall flow filter comprising nano/microfibers that catalyze soot oxidation
- Continuously oxidize trapped particulate matter with oxygen present in exhaust at typical exhaust temperatures



Benefits

- reduced filtration system cost
- reduced operating cost
- increased PM capture efficiency

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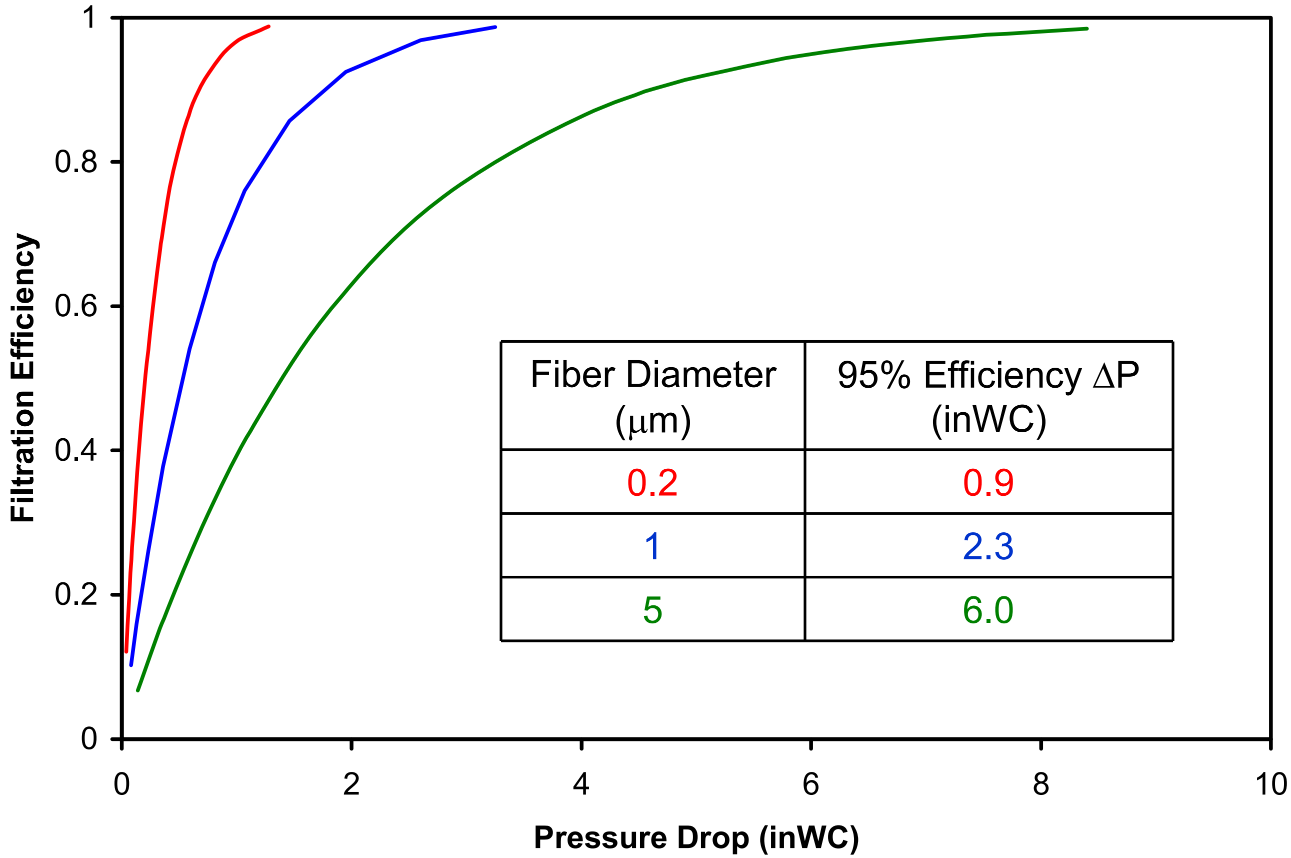
Nano/Microfiber Filtration Efficiency



Fiber Diameter (μm)	95% Efficiency ΔP (inWC)
0.2	0.9
1	2.3
5	6.0

Depth filtration (no soot cake formation)

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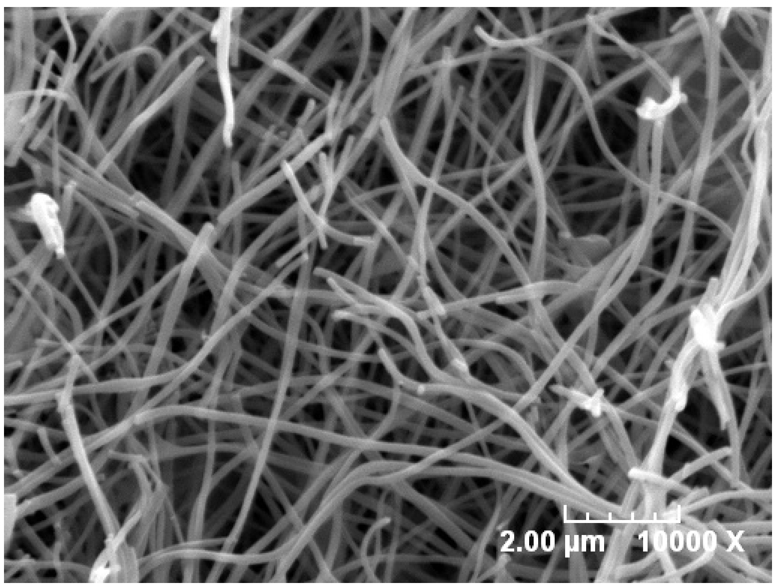
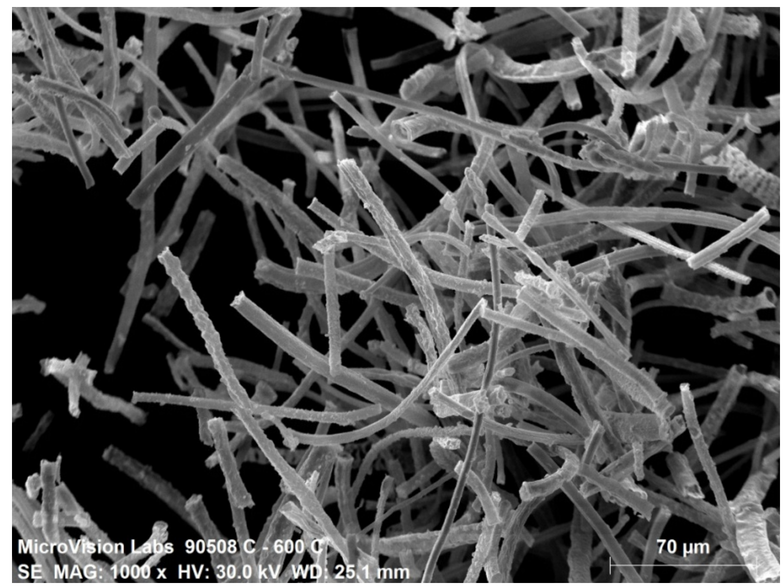
Fiber Preparation

- Metal oxide catalytic fibers prepared by wet chemical technique
- Precious metal-free catalyst formulations
- Mean fiber diameter controllable between 0.1 and 10 micron



0.1 μm mean diameter



7.2 μm mean diameter

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Catalytic Fiber Stability

Treatment	Fiber Diameter (μm)	
	Nanofiber	Microfiber
600°C air	0.1	7.3
600°C simulated exhaust	-	7.6
800°C air	0.1	-
900°C air	-	5.3
1000°C air	N/A	-

Fibrous morphology maintained at moderately high temperatures

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Catalytic Activity Screening

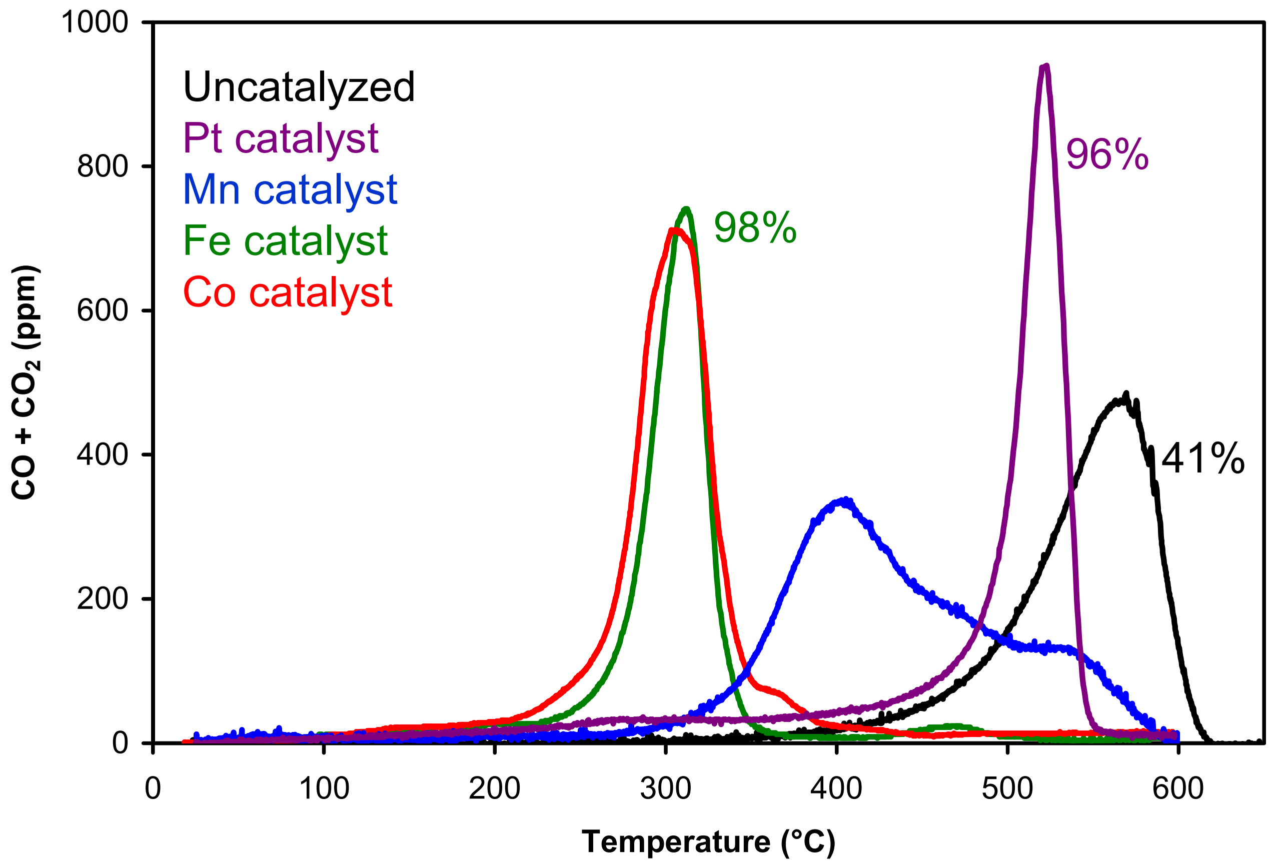
Evaluate catalyst activity by heating catalyst-soot mixture in air

- Printex U amorphous carbon (Evonik)
- 20:1 catalyst:soot ratio
- Ramp 2.5°C/min to ≥600°C
- Monitor CO and CO_2 in effluent with NDIR

Determine:

- Onset temperature (10% of soot oxidized) and completion temperature (90% of soot oxidized)
- $CO_2/(CO_2+CO)$ ratio

Catalytic Soot Oxidation



- Soot oxidation temperature reduced by ~250°C

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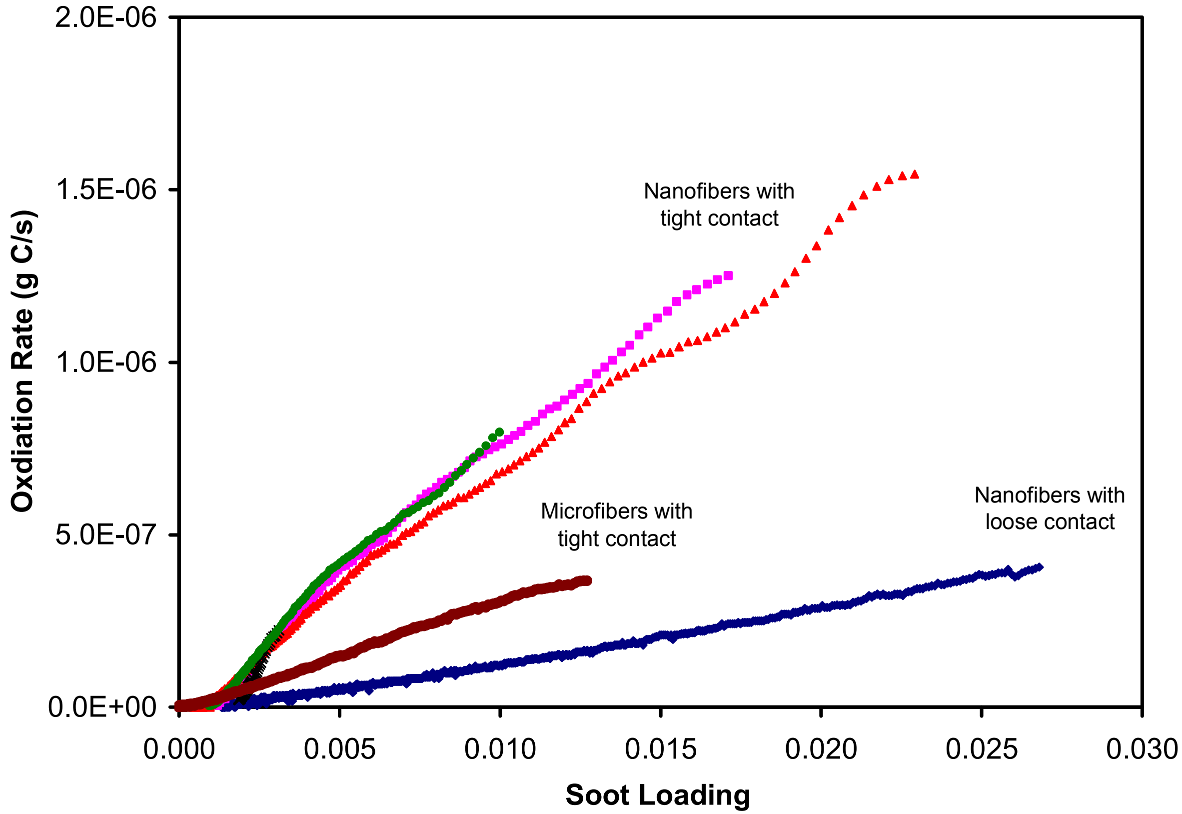
Nitric Oxide Effect

Composition	air		500 ppm NO/air	
	T10 (°C)	T90 (°C)	T10 (°C)	T90 (°C)
no catalyst	471	583	440	581
Fe-based catalyst	309	432	245	362
Co-based catalyst	254	353	174	367

- No upstream NO oxidation catalyst
- NO significantly reduces soot light-off temperature
- NO does not affect temperature required for complete soot elimination

Isothermal Catalytic Oxidation Rate



- Complete soot oxidation achieved at 300°C
- Degree of soot-catalyst contact affects oxidation rate

Predicted Catalytic Filtration Performance

Balance soot inflow, soot outflow, soot oxidation, and soot accumulation

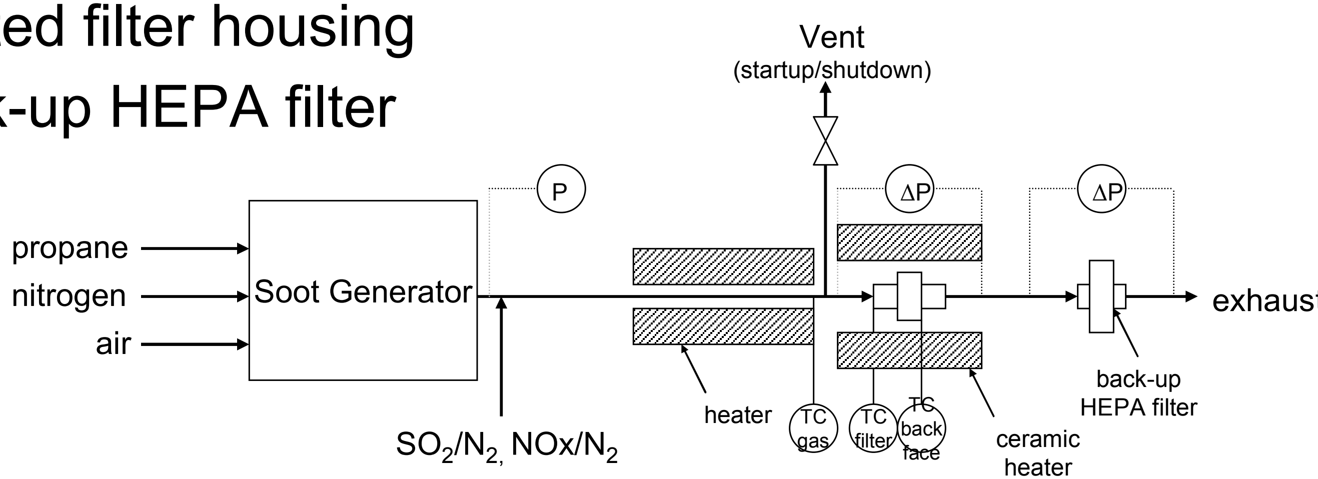
$$V_{in} \cdot C_{in} - V_{out} \cdot C_{out} = A \cdot e^{-Ea/RT} \cdot \varepsilon^{n} \cdot SA \cdot \rho \cdot V + \rho \cdot V \cdot d\varepsilon/dt$$

Soot loading, ε, is predicted to remain below 0.01 $g_{soot}/g_{catalyst}$ under expected inflow conditions

Initial Filtration Testing

Bench-scale filter apparatus

- Jing miniCAST soot generator (quenched diffusion flame)
- Heated filter housing
- Back-up HEPA filter



Measure temperature, pressure drop, exhaust constituents

Typical conditions:

- Flow velocity 0.03 m/s (STP)
- 40 mg/m^3 soot, 12% O_2, 2% CO_x

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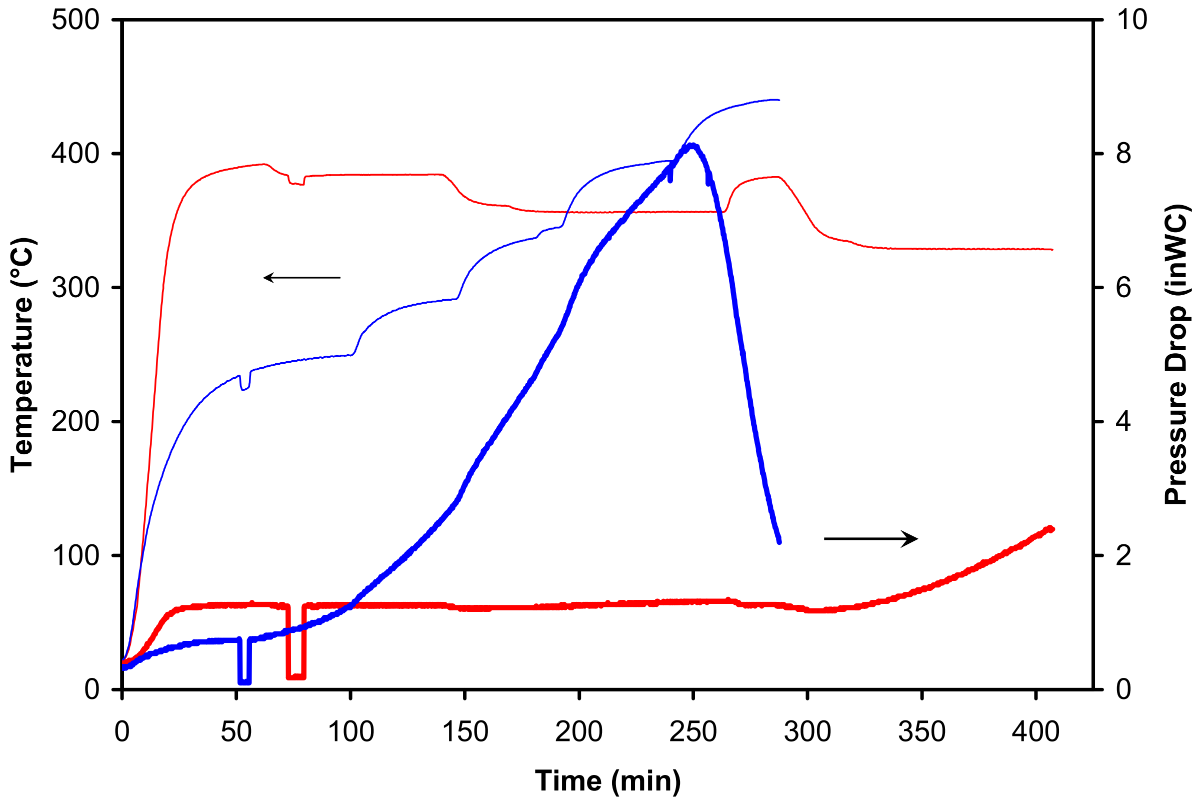
Catalytic Filtration Performance



- No measurable particulates downstream of filter
- Balance point temperature of ~350°C

Catalytic Filter Scale-Up

High geometric surface area wall flow filter

- Coat catalytic fibers onto existing wall flow filter substrate (low pressure drop, low-cost)
- Form catalytic fibers into self-supporting media

Catalyst may also be used to enhance performance of flow through filters

Conclusions

Nano/microfiber catalytic soot filters offer potential for improved DPF performance

- Complete soot oxidation at 300°C
- High filtration efficiency achieved at low pressure drop
- No precious metals
- No NOx/PM ratio requirement

Durability and engine-based performance need to be assessed

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