GEO2 Technologies™

Advanced High Porosity Ceramic Honeycomb Wall Flow Filters

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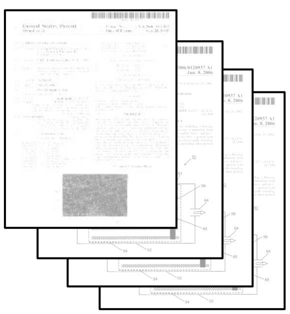
Introduction to GEO_2

Build technology platform and intellectual property

GEO2 is a material science licensing company

Technology focus: High temperature, high porosity, cellular ceramic substrates for filtration, catalytic conversion and fixed-bed reactor applications. Flexible base materials, porosity, pore size

Well-financed to build, develop and protect technology



30 patents and applications. 10 additional applications by end of 2007 covering:

- Materials and chemistry
- Process and manufacturing
- Systems integration
- Applications

License and transfer technology to partners

With more than 100 years of experience, team built to transfer:

- Ceramics
- Ceramic processing
- Catalysis
- Manufacturing
- Application engineering

Deliver scaleable processes

- To manufacturing partners
- Specific operating procedures
- Use of industry standard equipment

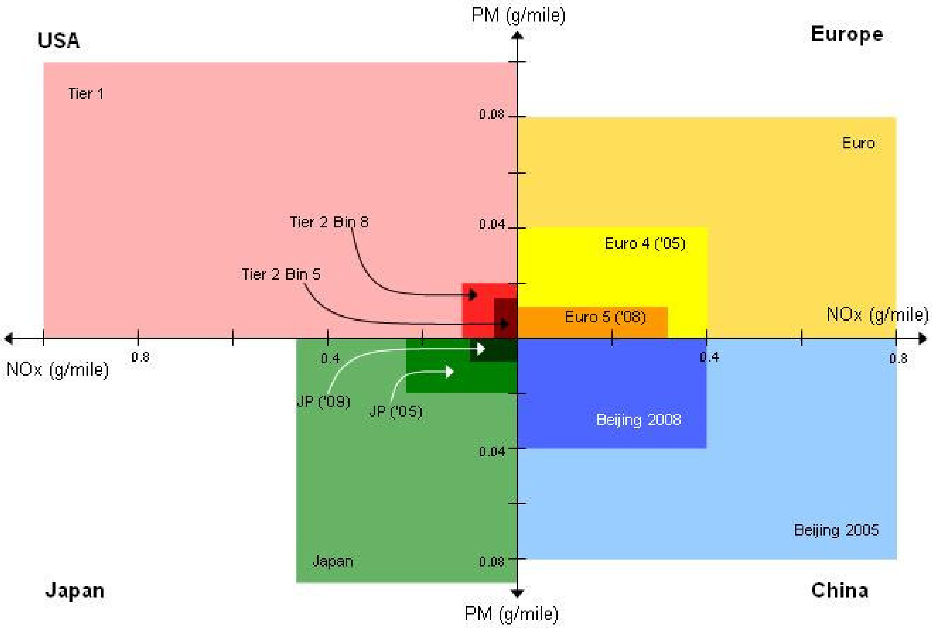
Share innovation across markets

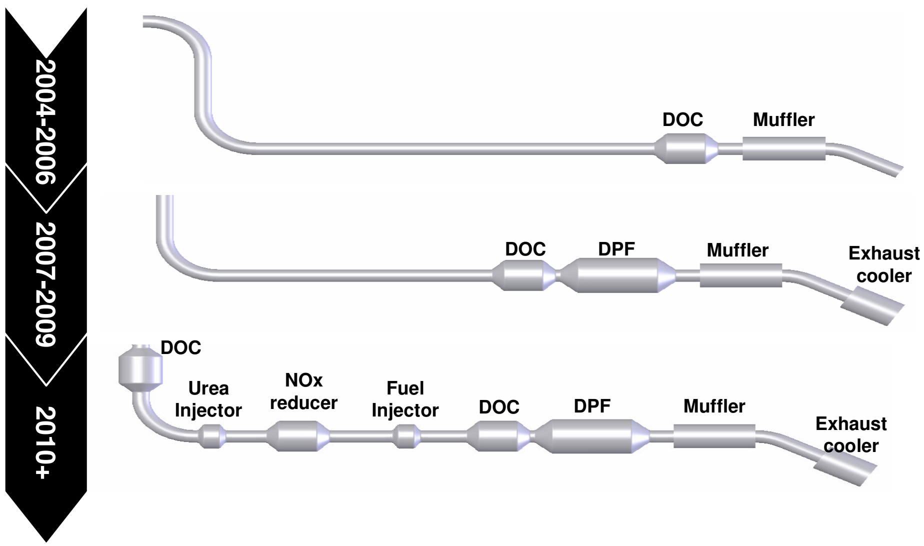
- Diesel
- 2-Stroke
- Gasoline catalytic converters
- Air-oil separators
- Chemical synthesis
- Other applications

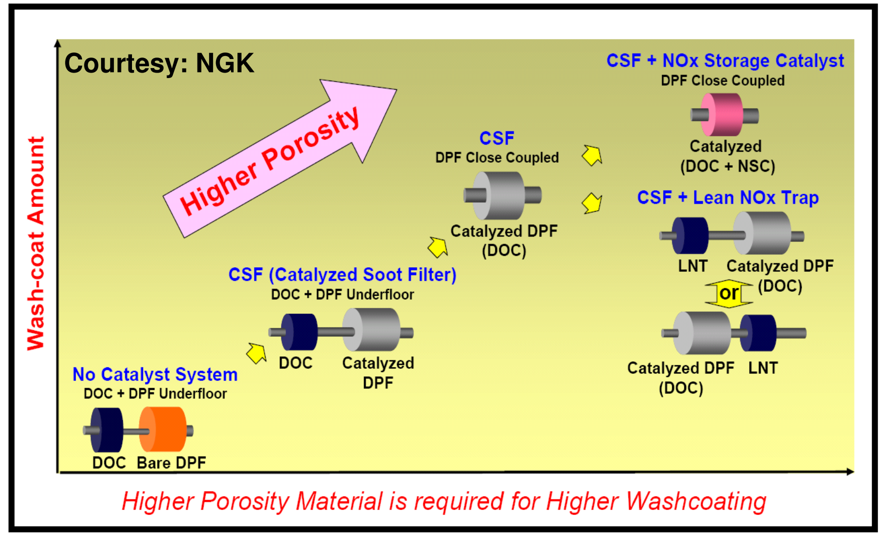
In discussions with leading ceramic and diesel application companies

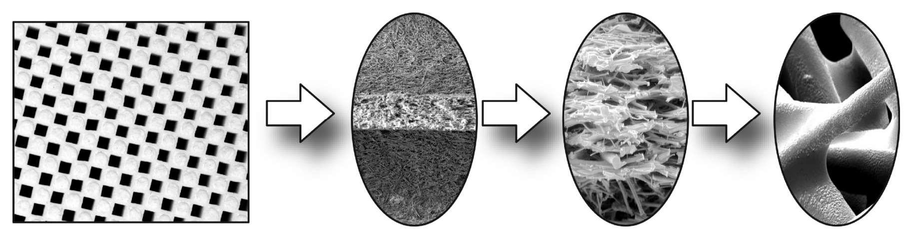
Supplement intellectual property

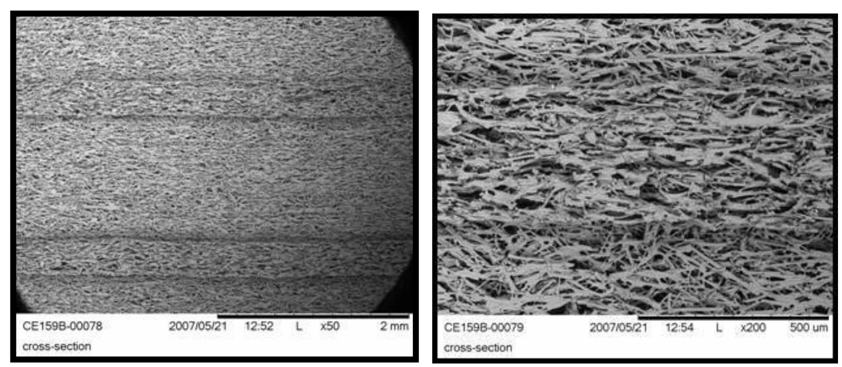
Problem Statement: Increasing complexity of emission control



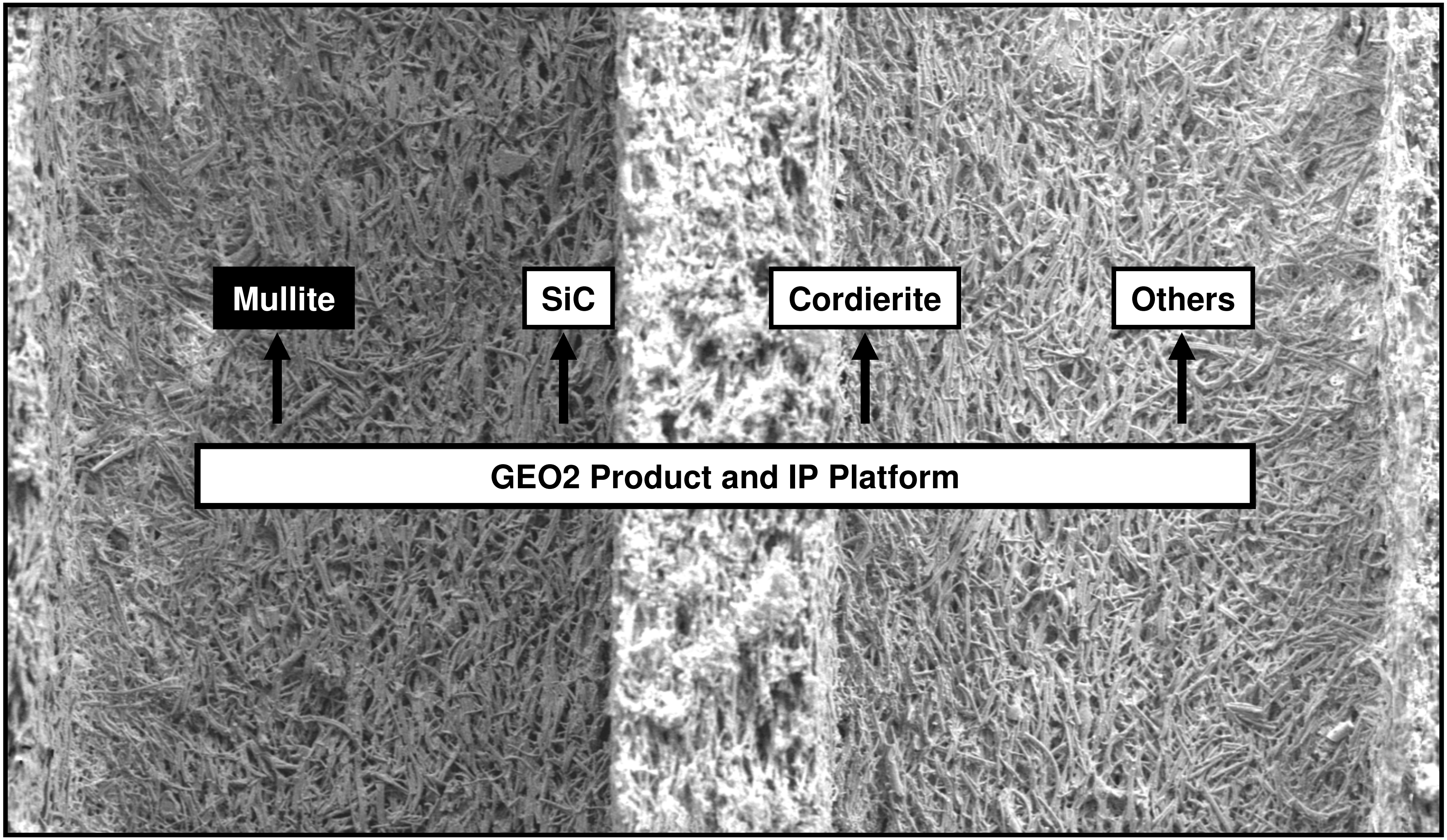




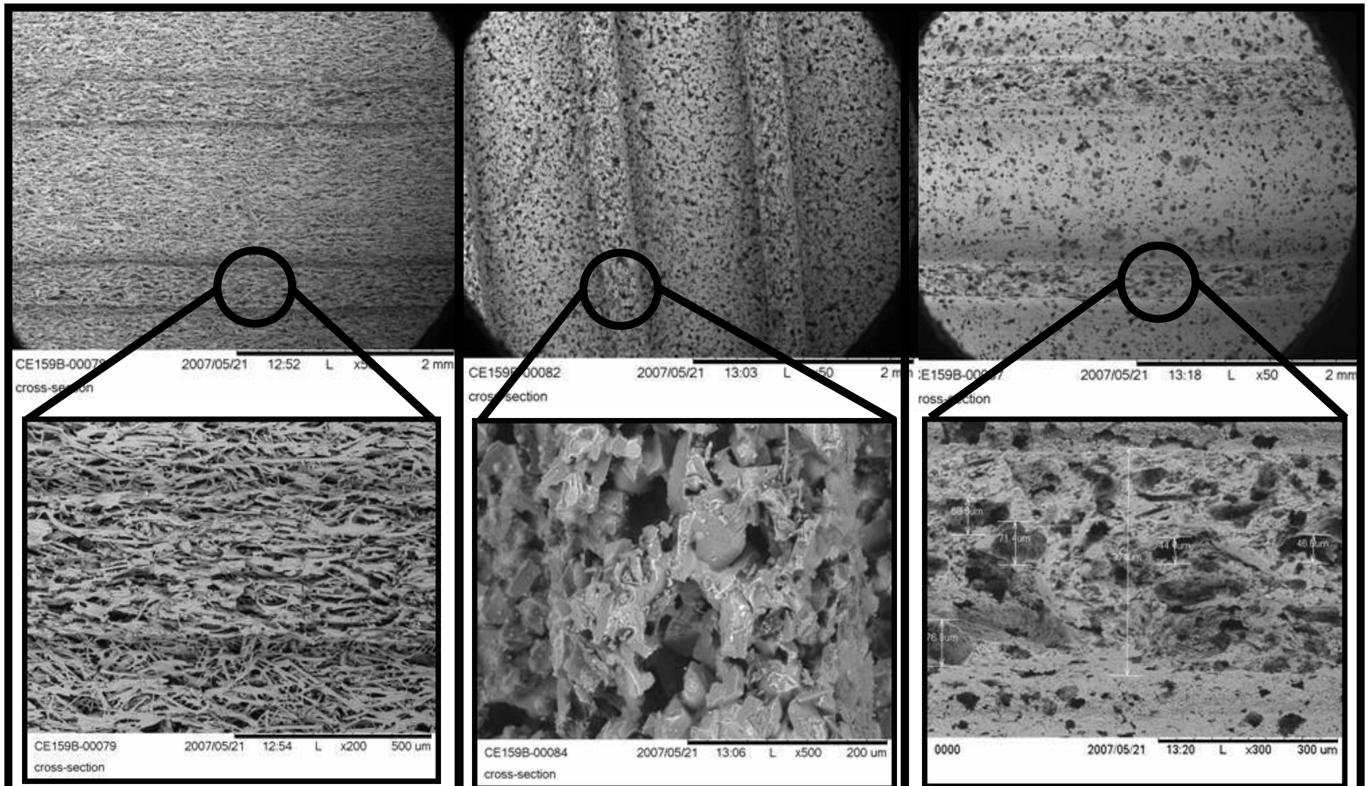




GEO_2 extruded honeycomb ceramics



GEO_2 filter has a uniform pore structure through the wall



GEO2-M (67% porosity)

Si-SiC (43% porosity)

Cordierite (46% porosity)

	GEO_{2M}	SiC *(NGK 300/12)*	Cordierite *(Corning 200/12)*
Porosity, pore-size (% | µm)	67% | 15µm	43%, | 13µm	46% | 13µm
MoR (MPa)	8.6	9.4	2.2
E Modulus (GPa)	7.8	13.3	4.8
CTE	$4.3x10^{-6}$	$4.0x10^{-6}$	$0.8-1.7x10^{-6}$

Contents

- ❑ Back pressure and filtration efficiency – steady state
- ❑ Back pressure and filtration efficiency – transient
- ❑ Uncontrolled regeneration – thermal shock resistance
- ❑ Catalyst efficiency

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- ☑ **Back pressure and filtration efficiency – steady state**
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Filtration efficiency and backpressure benchmarking against Cordierite and SiC

Sample	Description
A	**GEO_2 200 cpsi DPF (∅141mm x 153mm)**
B	**Commercial Cordierite 200 cpsi DPF (∅144mm x 152mm)**
C	**Commercial SiC-based 300 cpsi DPF (∅144mm x 153mm)**

Steady state testing:

- 1.9L TDI common-rail engine
- 1500 rpm, 45 Nm

Transient testing:

- 6 NEDC cycles

Particle instrumentation employed

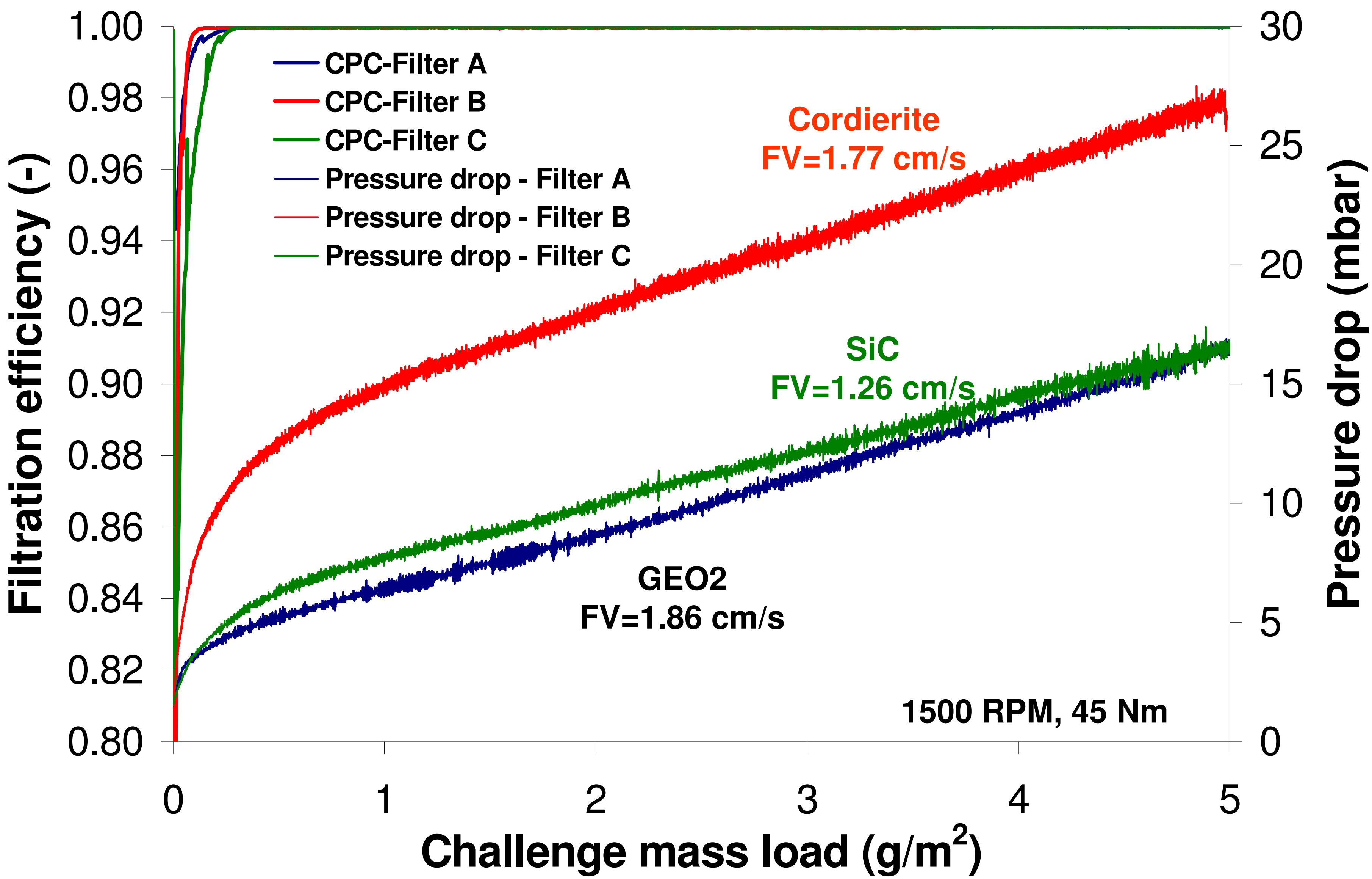
- **SMPS** - A Scanning Mobility Particle Sizing system (consisting of a Differential Mobility Analyzer and a Condensation Particle Counter); electrical mobility method; particles in the range of 10 to 430 nm.

- **ELPI** - An Electric Low Pressure Impactor; aerodynamic method ; particles in the range of 30 nm to 8 mm.

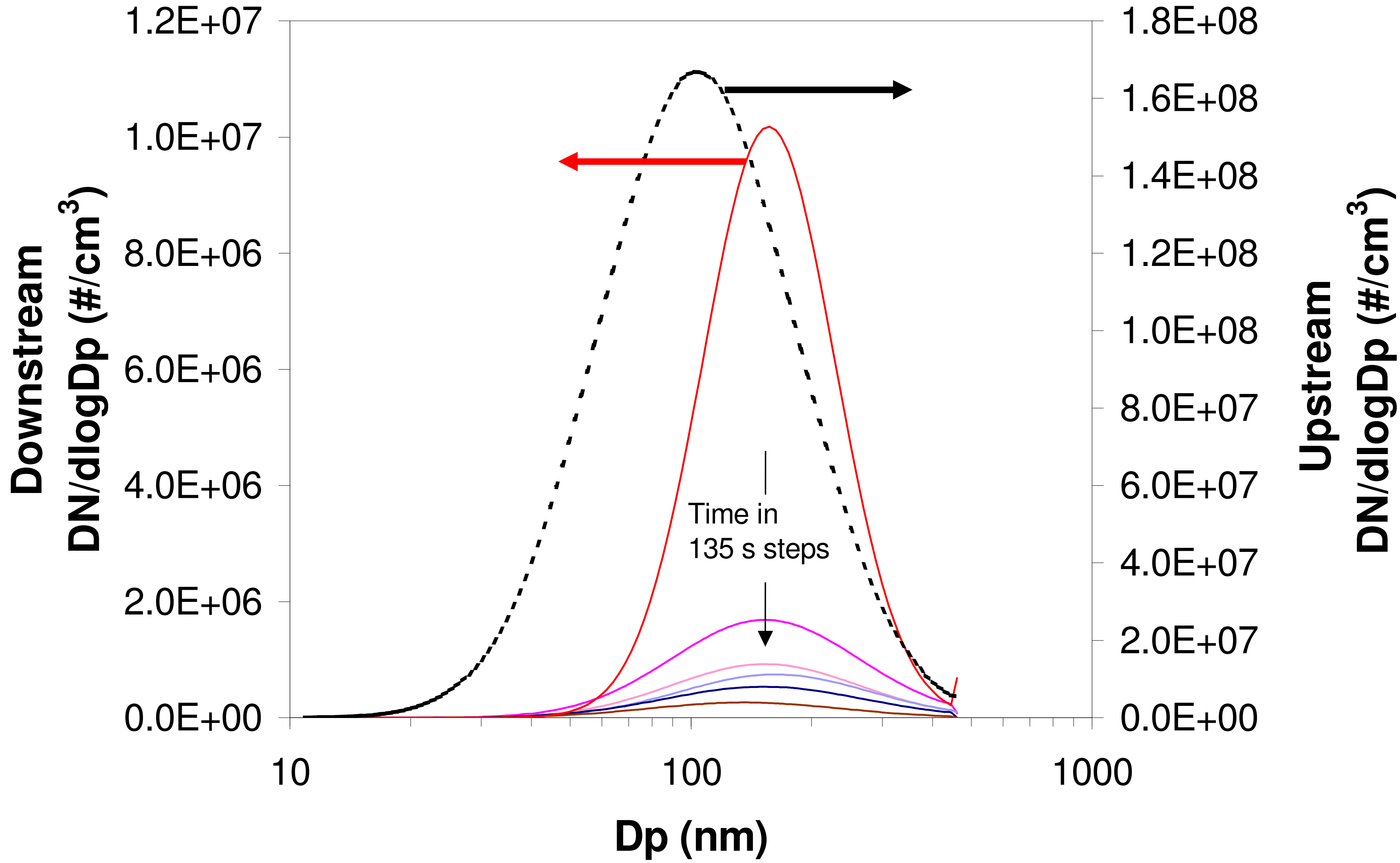
- **CPC** - An standalone Condensation Particle Counter.

Each instrument sampled through a heated two-stage mini-diluter system (190 C), with a dilution ratio of 90

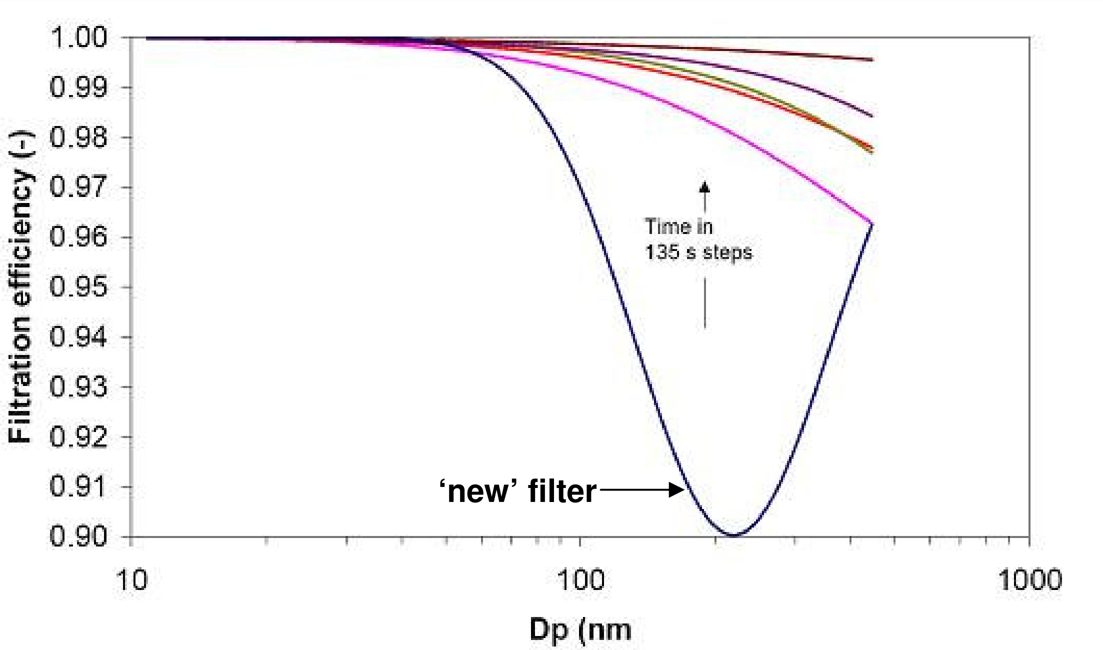
Pressure drop and filtration efficiency evolution

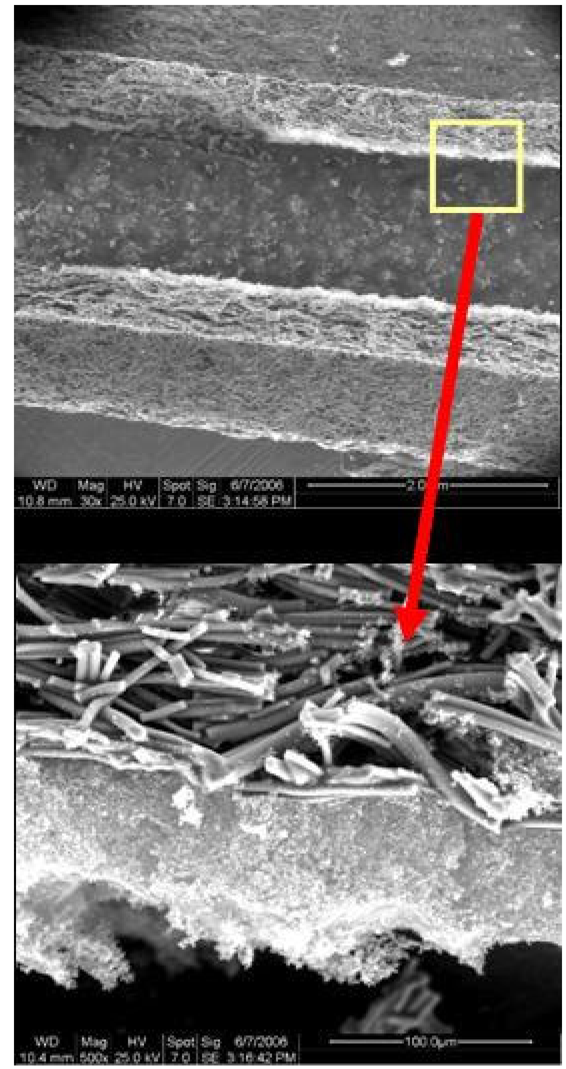


Size distributed Filtration efficiency during soot loading

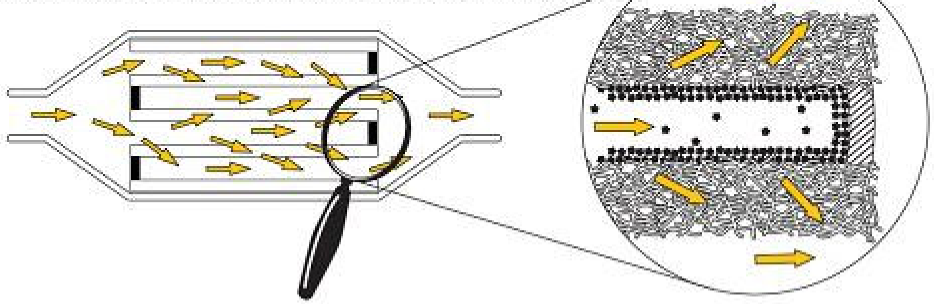


GEO_2 is a cake/surface filter with high trapping efficiency





Surface Filtration Mechanism



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- ❑ Back pressure and filtration efficiency – steady state
- ☑ **Back pressure and filtration efficiency – transient**
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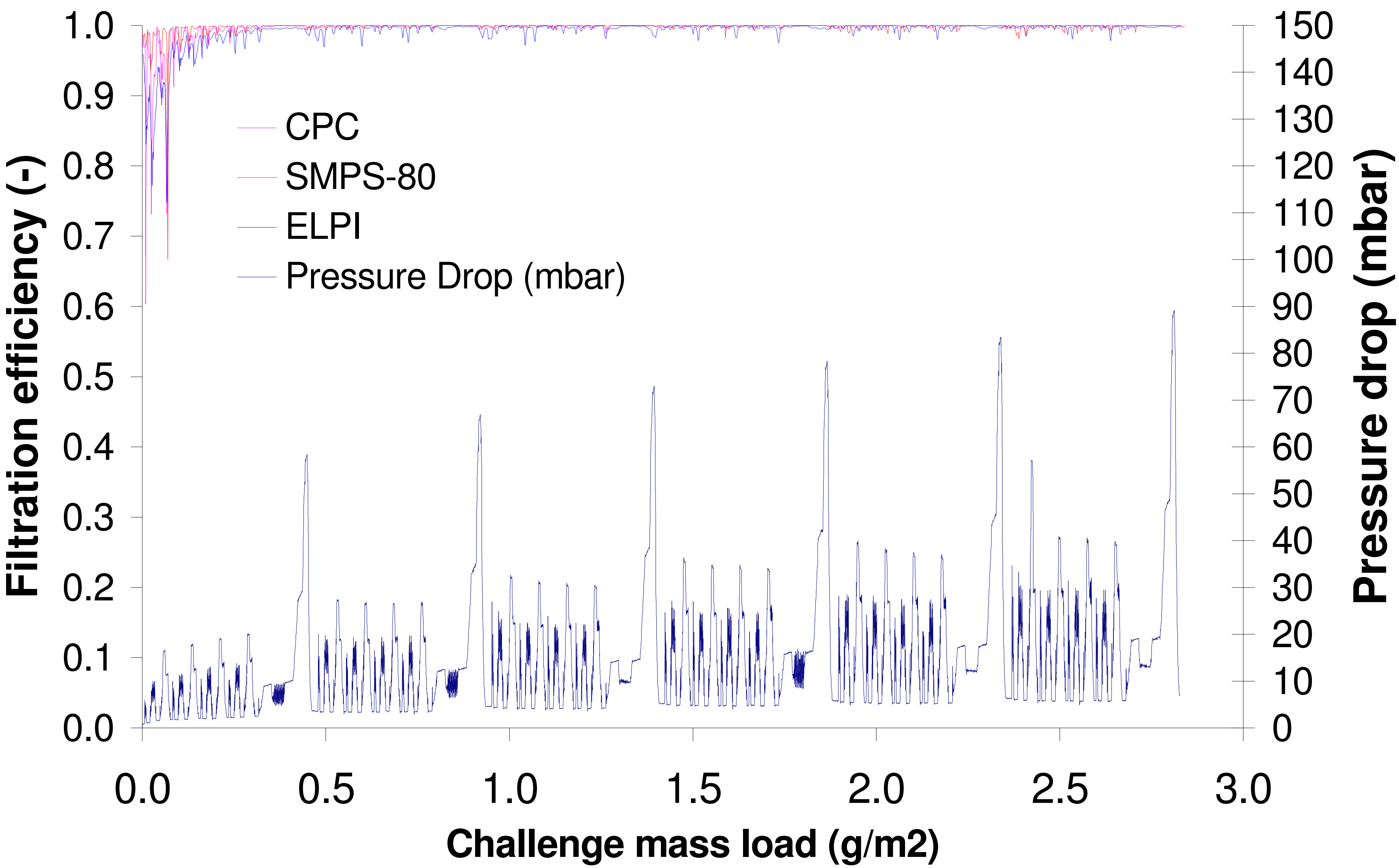
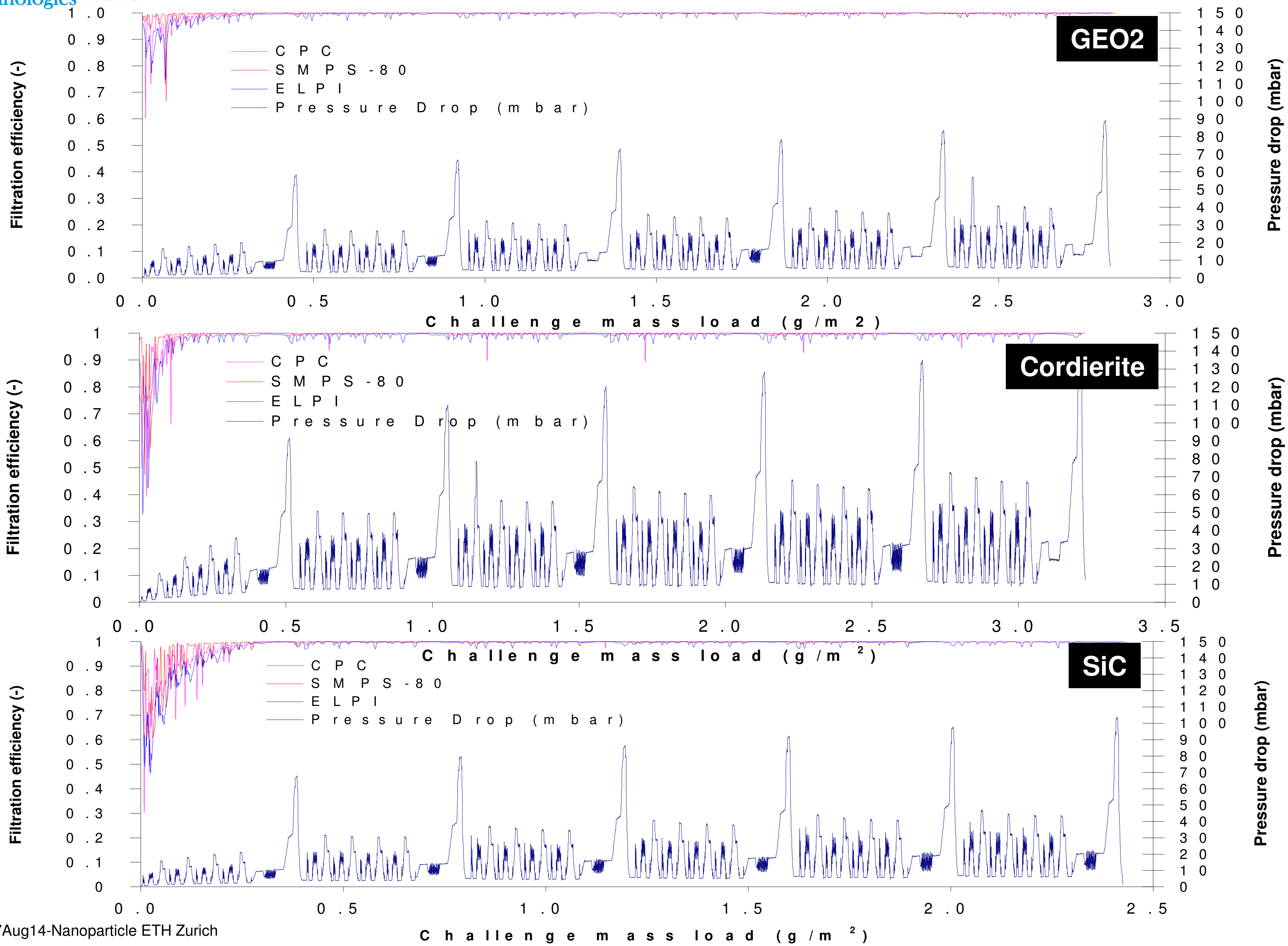
- ❑ Catalyst efficiency

Filter A: NEDC cycle soot loading, backpressure and filtration efficiency



Backpressure and Filtration over NEDC cycles



Contents

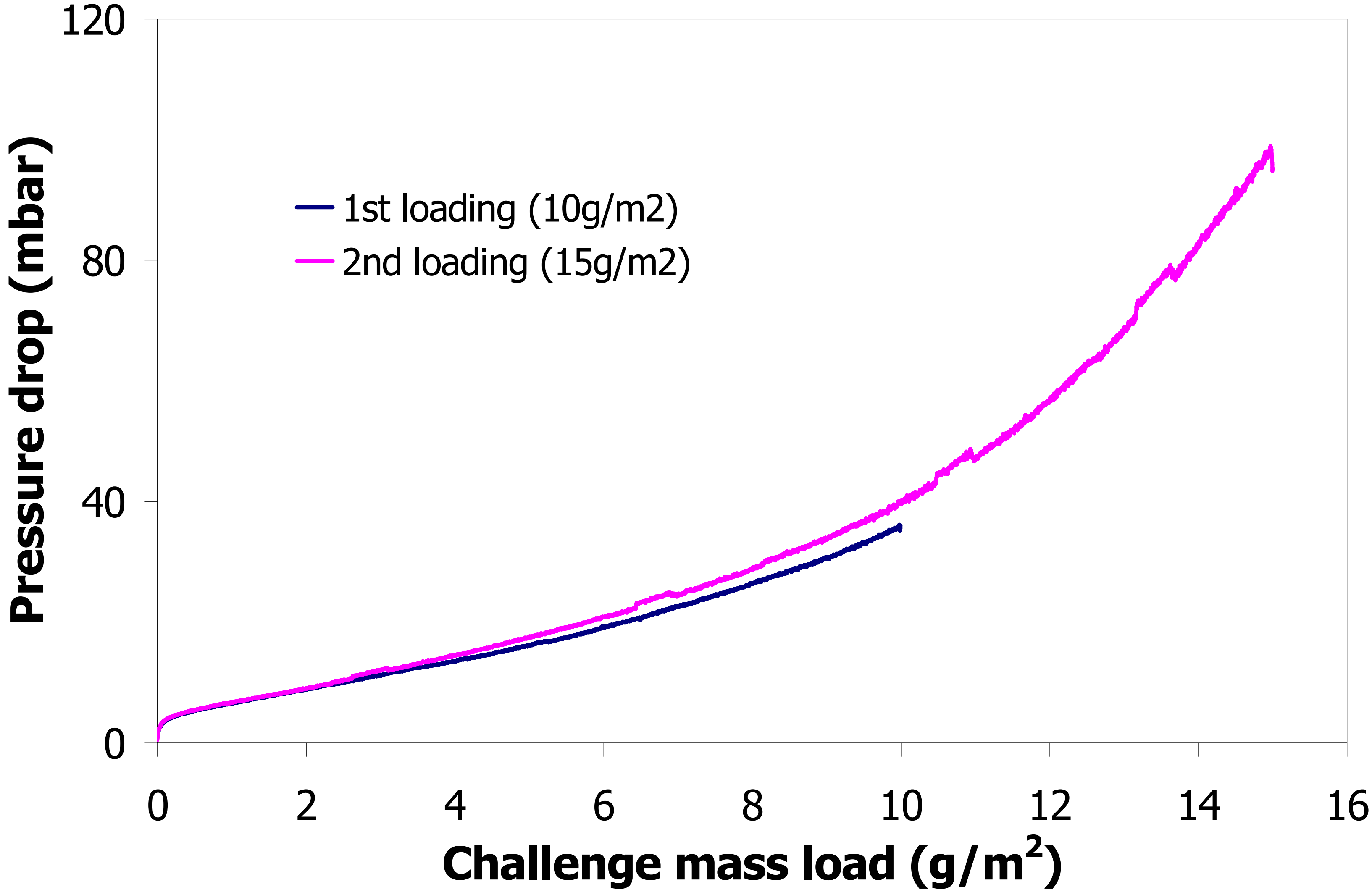
Uncontrolled regeneration (Ø141mm x 153mm)
Temperature profiles and thermal shock

Process:

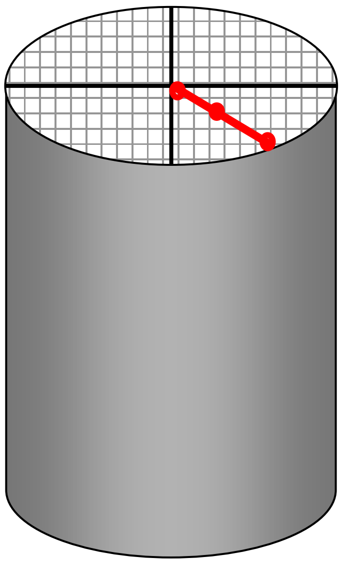
1. Load predefined soot mass load ($10g/m^2$ and $15g/m^2$) without a DOC upstream of filter
2. Place DOC upstream of filter
3. Set engine to the steady state operation point of 1500 rpm and 75 Nm BMEP (corresponding to 340ºC filter inlet temperature)
4. Engine exhaust temperature is increased to 650ºC with the means of HC port injection upstream of the DOC
5. Drop to idle

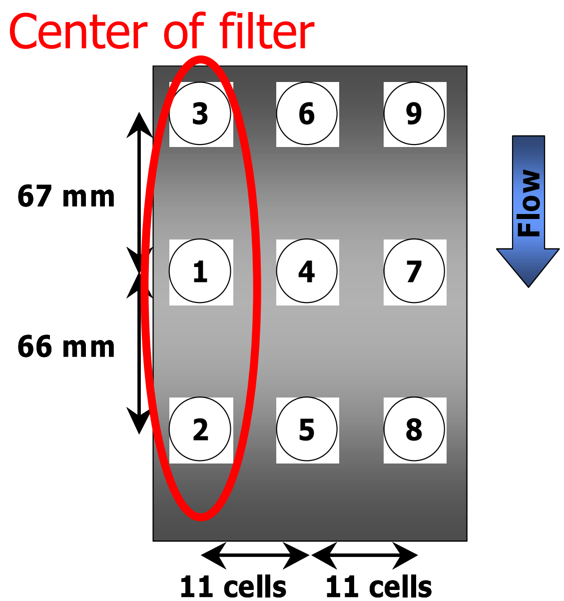
The increased exhaust oxygen content, the high filter temperature and the small exhaust mass flow rate lead to a very rapid filter regeneration (worst case regeneration).

Soot loading behavior; pressure drop vs. mass loading

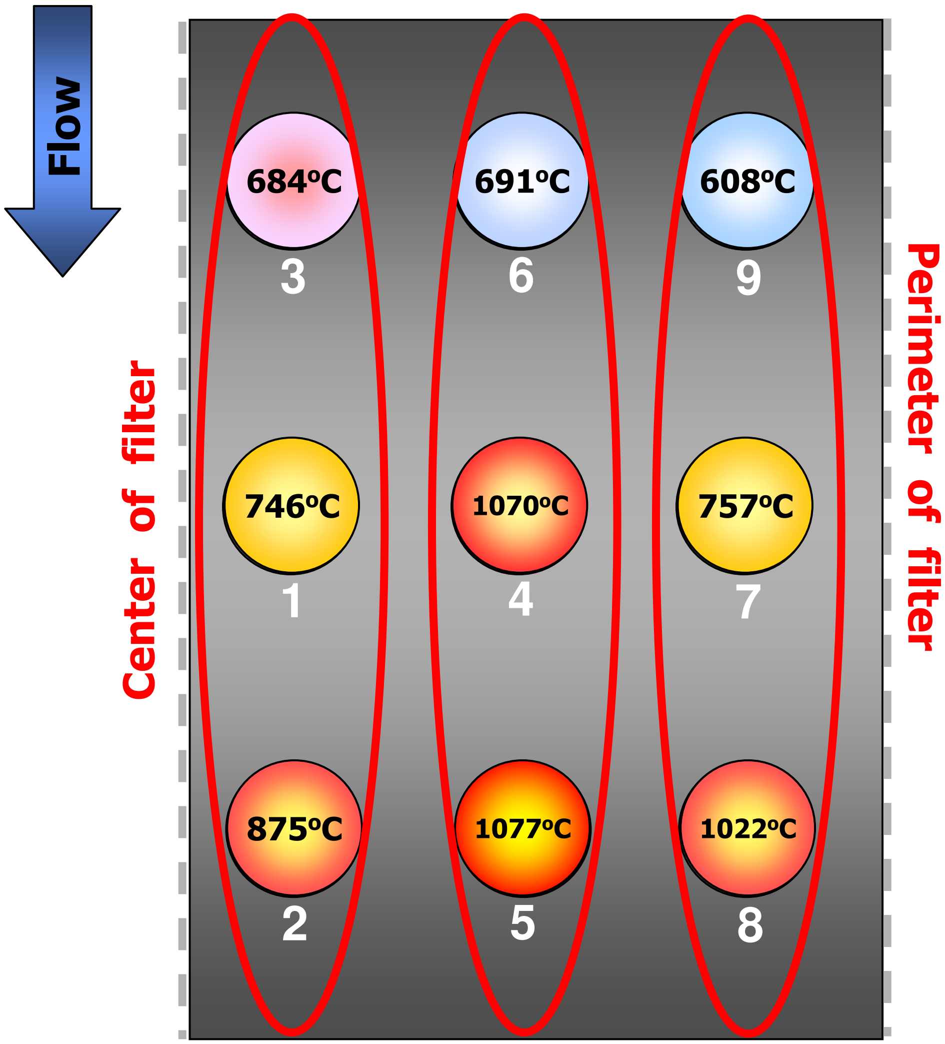


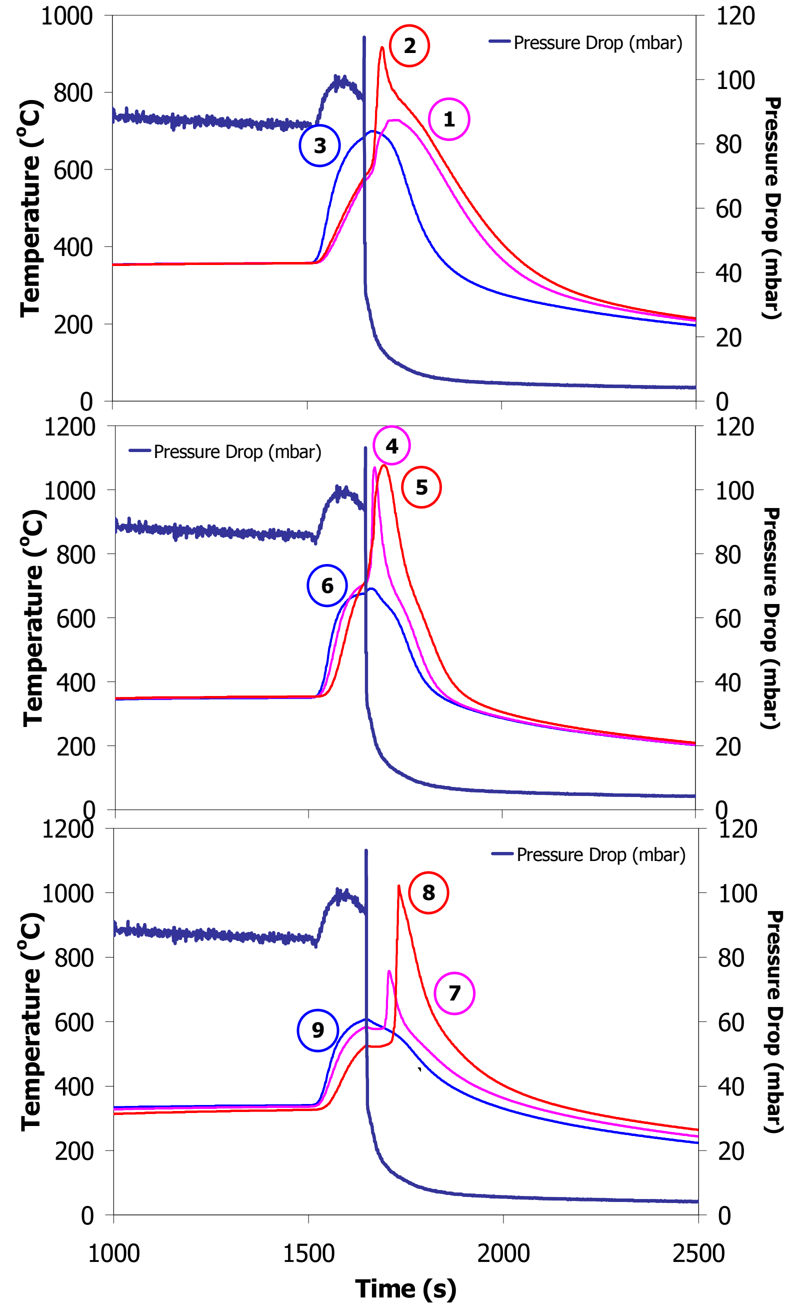
Placement of thermocouples for temperature profiling



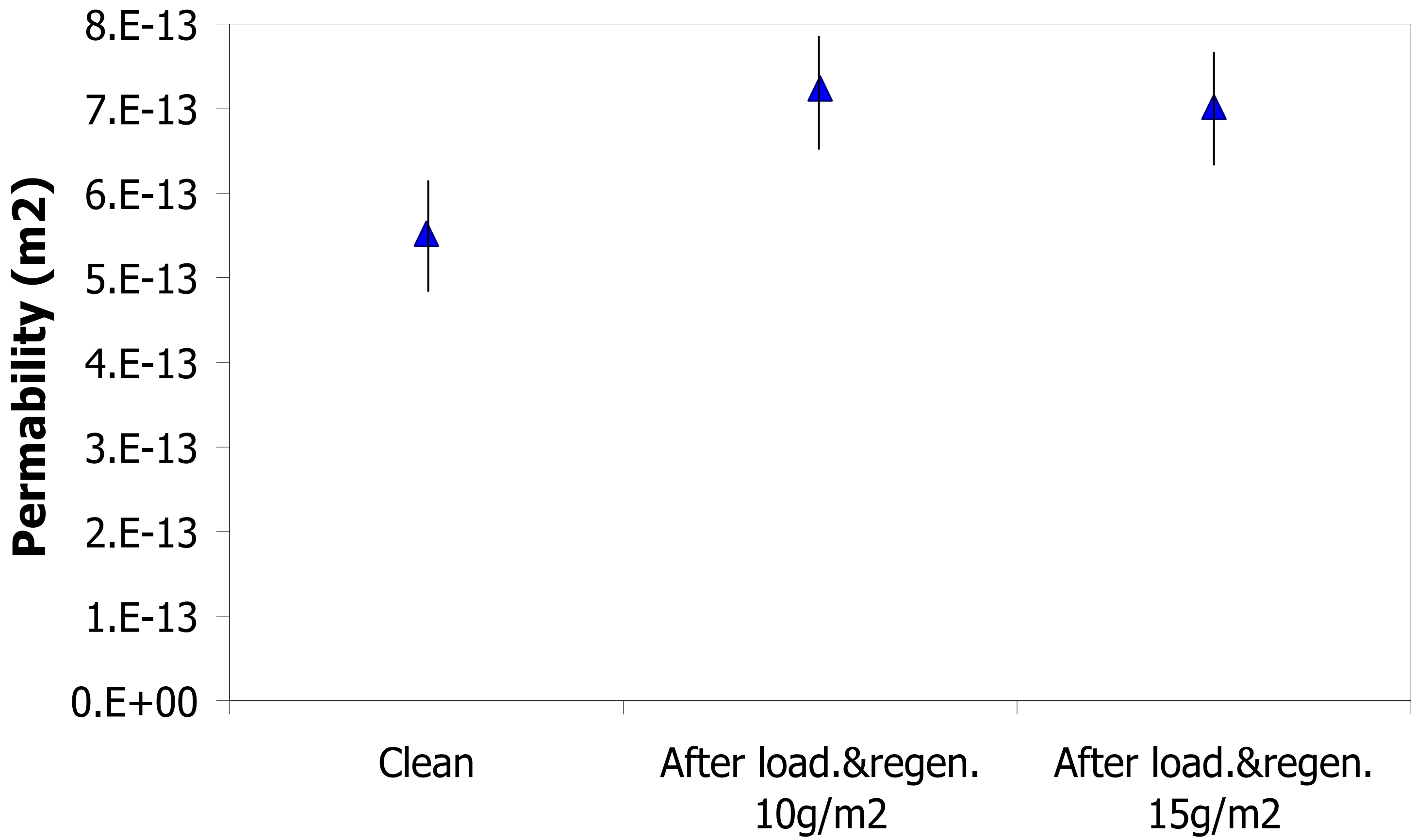


Uncontrolled Regeneration: temperature profiles at 15g/m²





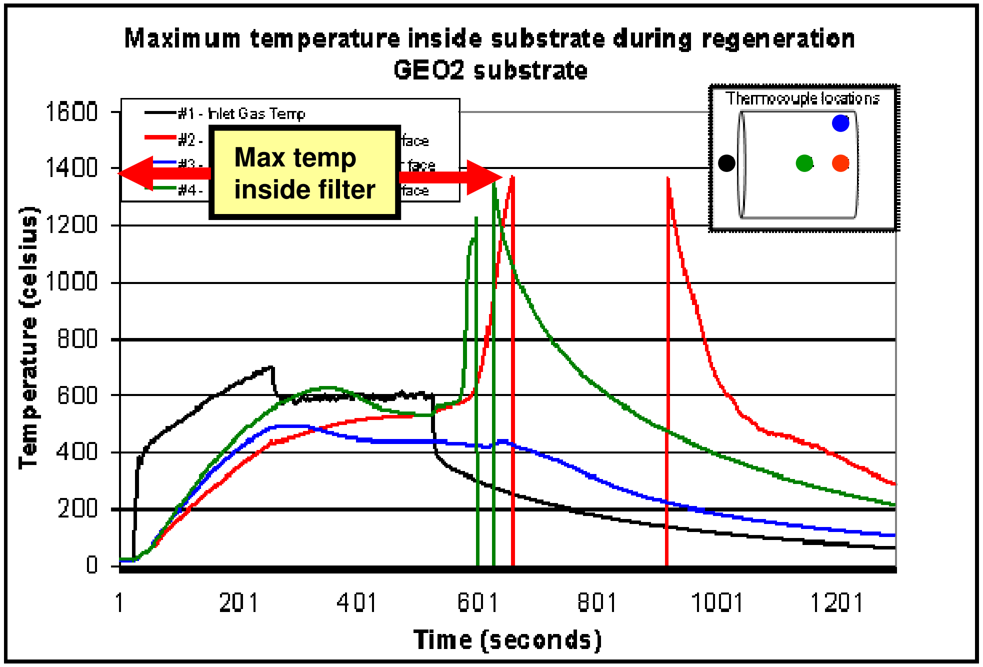
Uncontrolled regeneration – 10g/m^2 and 15 g/m^2

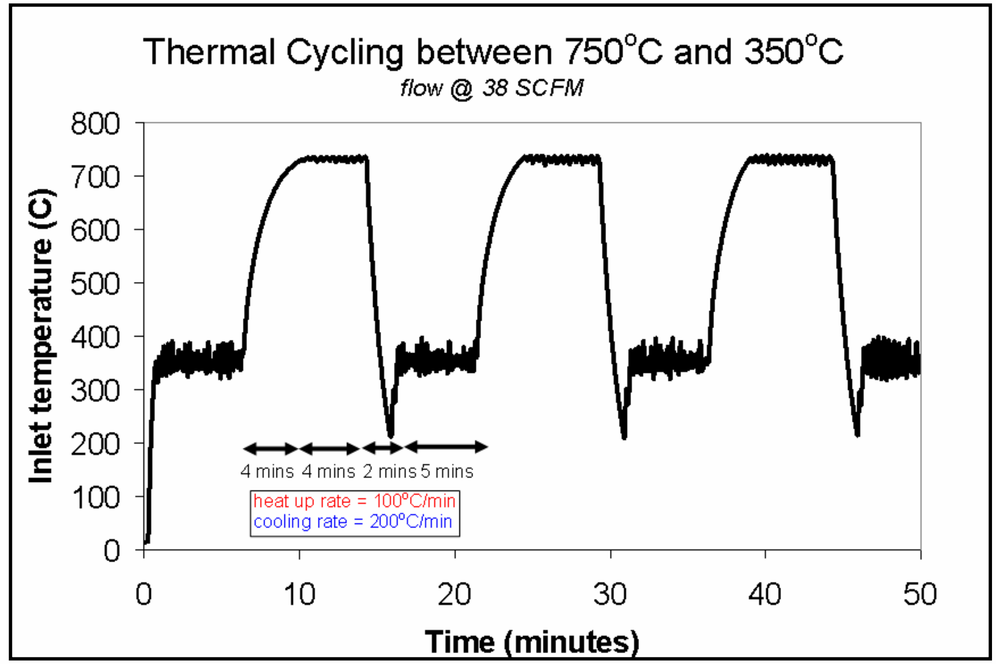


No visual defects & no change in permeability

Filters intact and survive the thermal shock

GEO_2 filters survive >1400C temperature excursions during uncontrolled regenerations





Cordierite DPF melted at 1370C

GEO2 DPF survived >1500C

Thermal Cycling, fatigue testing ongoing

1000 cycles → no visible cracks or defects

MoR, E-modulus → No change

Contents

Backpressure and soot regeneration on catalyzed filters
filter size: (∅ 25 mm x 50 mm)

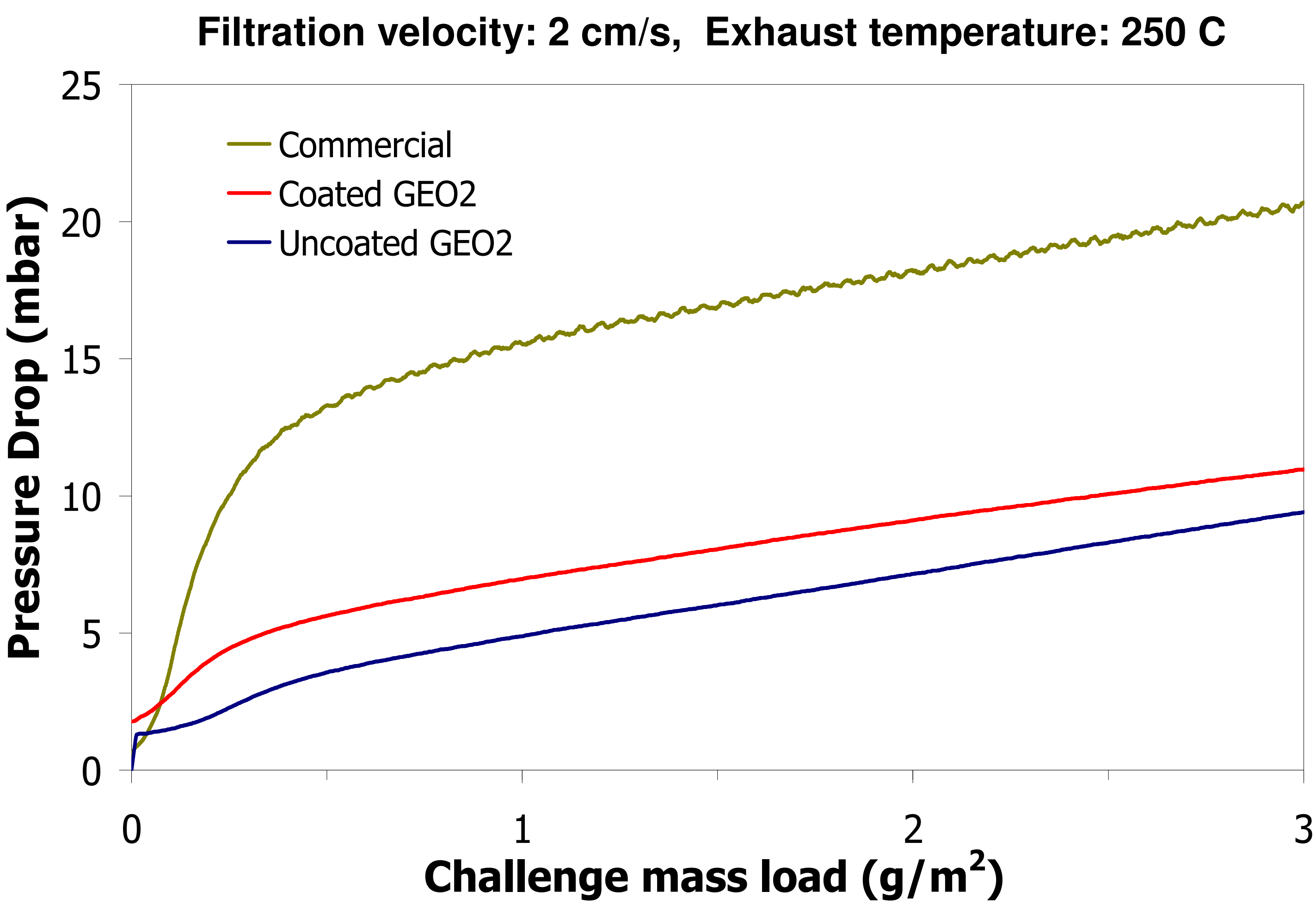
- **Commercially catalyzed sample:**
  SiC 200 cpsi, 3 g/m^2 Pt on Al_2O_3 catalyst load

- **In-house coated sample:**
  GEO_2 200 cpsi, 3 g/m^2 Pt on Al_2O_3 catalyst load

- **In-house coated sample:**
  SiC 200 cpsi, 14 g/m^2 base metal catalyst load

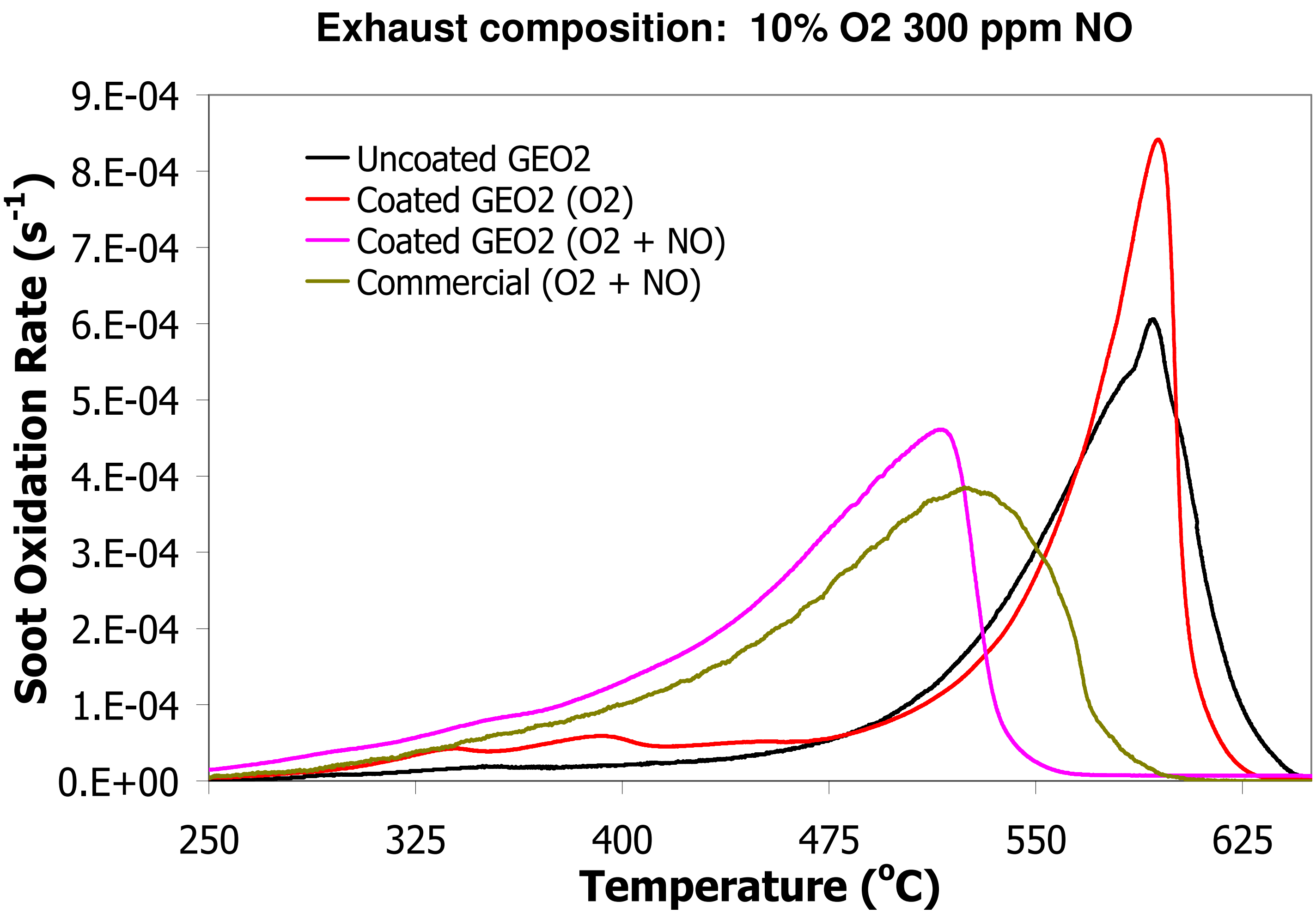
- **In-house coated sample:**
  GEO_2 200 cpsi, 14 g/m^2 base metal catalyst load

Pressure drop vs. challenge mass load: Pt coated samples



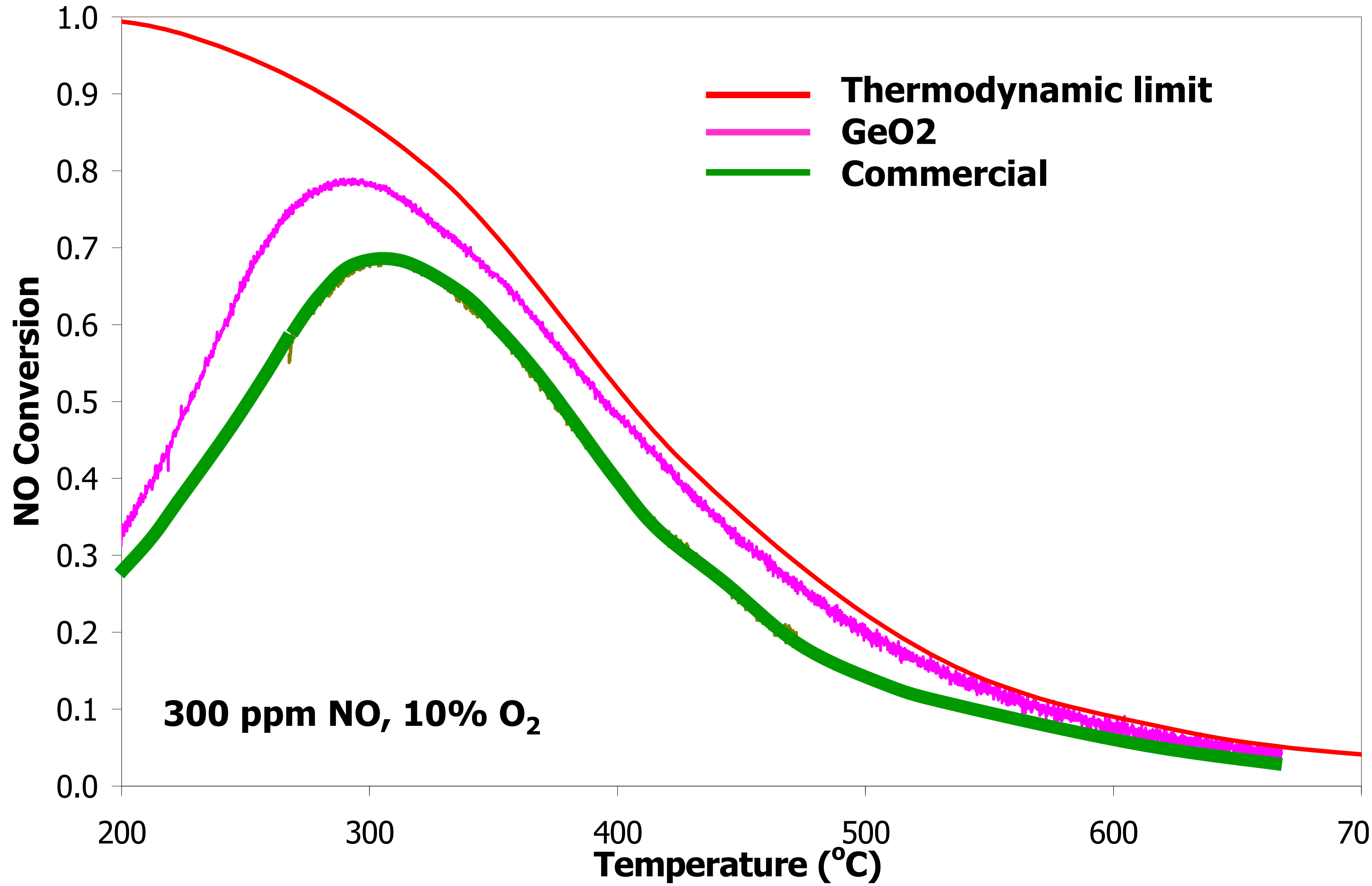
GEO_2 coated sample has significantly lower pressure drop upon loading

NO/NO_2 assisted soot oxidation rate on Pt coated samples

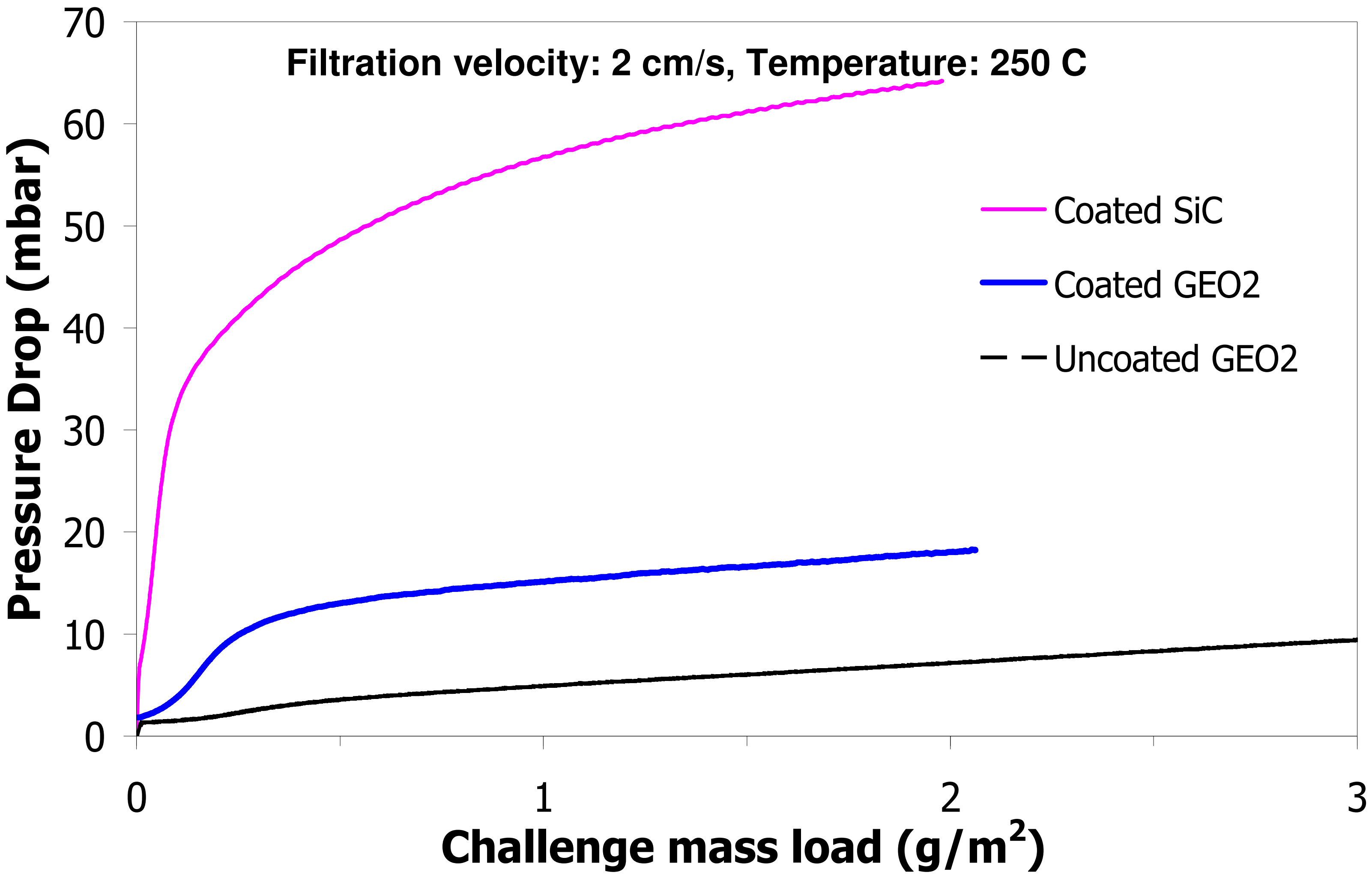


GEO_2 coated sample has higher NO/NO_2 assisted soot oxidation rate

NO Conversion on Pt coated samples

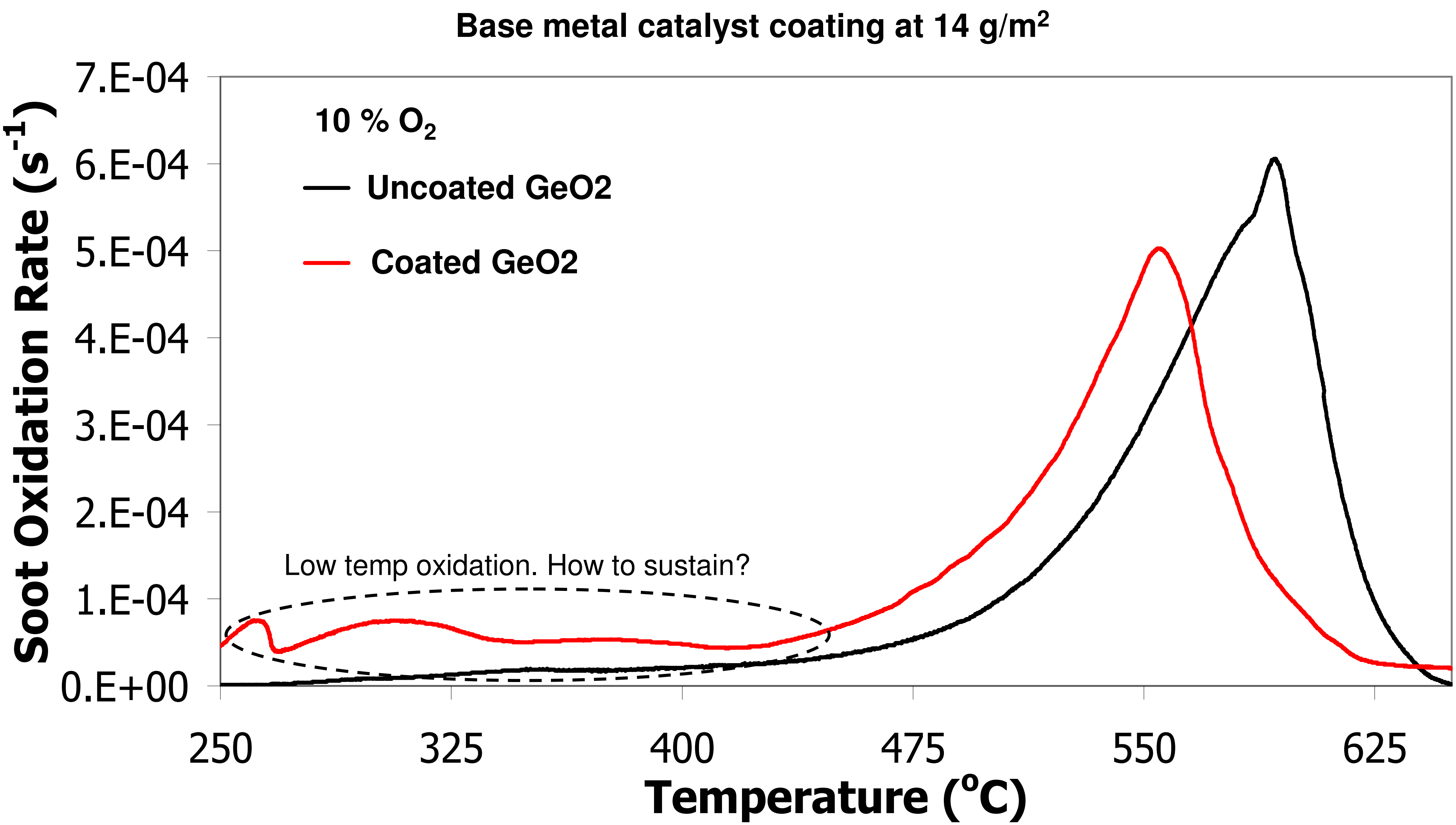


Pressure drop vs. challenge mass load
Base metal coated samples

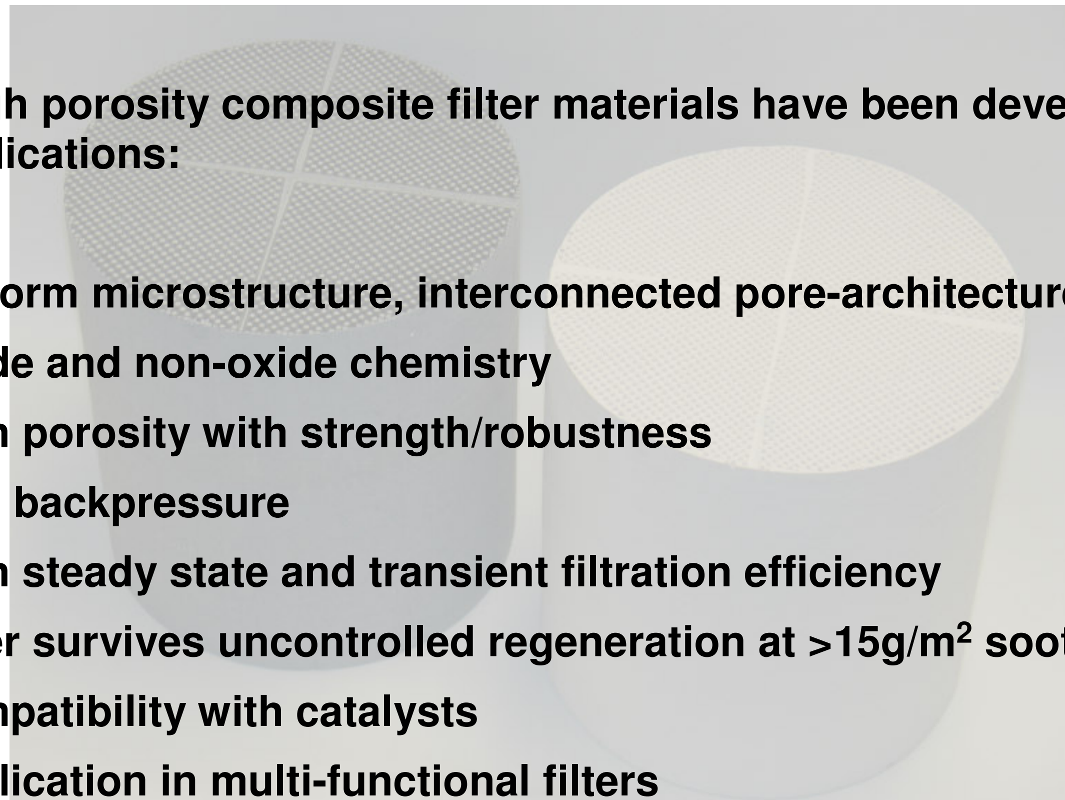


Base metal catalyst coated GEO_2 filter has lower pressure drop

Direct catalytic soot oxidation



Conclusions



Advanced high porosity composite filter materials have been developed for wall flow DPF applications:

- ☑ **Uniform microstructure, interconnected pore-architecture**
- ☑ **Oxide and non-oxide chemistry**
- ☑ **High porosity with strength/robustness**
- ☑ **Low backpressure**
- ☑ **High steady state and transient filtration efficiency**
- ☑ **Filter survives uncontrolled regeneration at >15g/m^2 soot loading**
- ☑ **Compatibility with catalysts**
- ☑ **Application in multi-functional filters**
- ☑ **Potential for filter size reduction and/or PGM reduction**

** Thank you for your time **

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