Transient Measurement of Diesel Nano-Particles by a Newly Developed DDMA

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N T S E L

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Agenda

- Experimental System and Method
  - Target of DDMA Development
  - Detail of DDMA
  - Experimental Method
- Result and Discussion
  1. after Exhaust Manifold
  2. after Full Dilution Tunnel
  3. Effect of Oxidation Catalyst
- Conclusion

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Target of DDMA Development

- Transient Measurement
- Reliability , Repeatability
- Low Price, Easy Operation

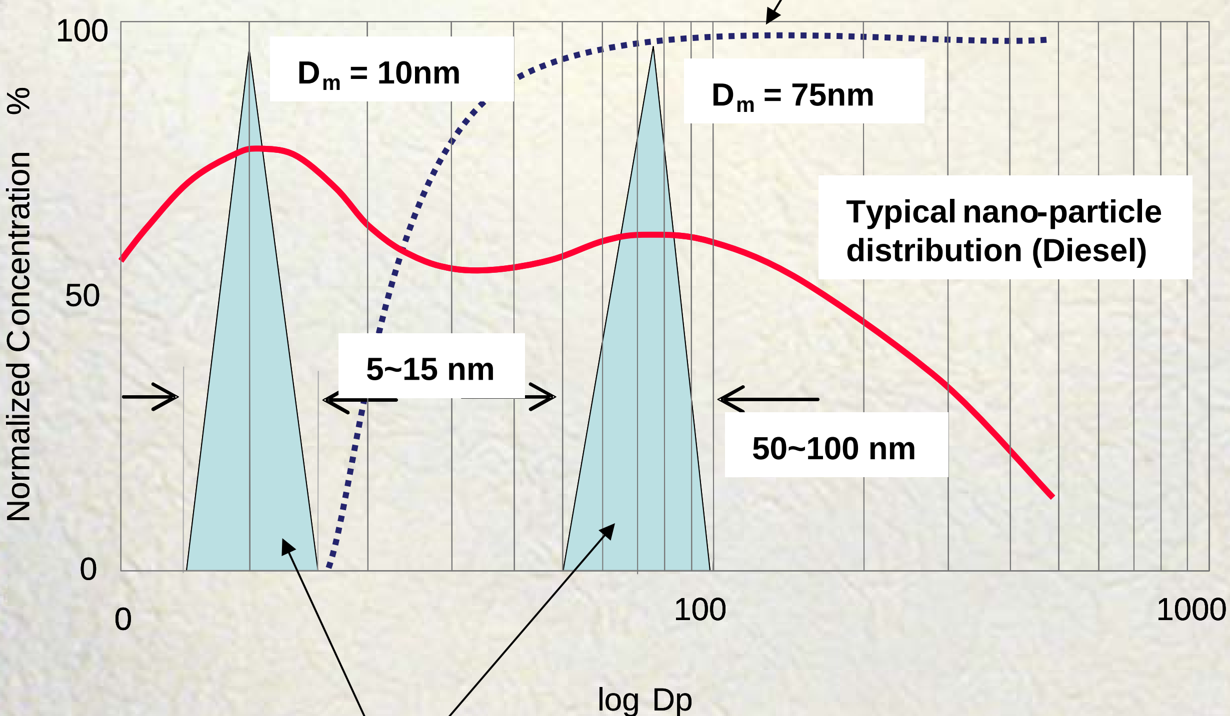
Passive defined filtering
by Sampling Method

↓

Active Theoretical Filtering

Active Theoretical Filtering

Overall Passive Filtering Function



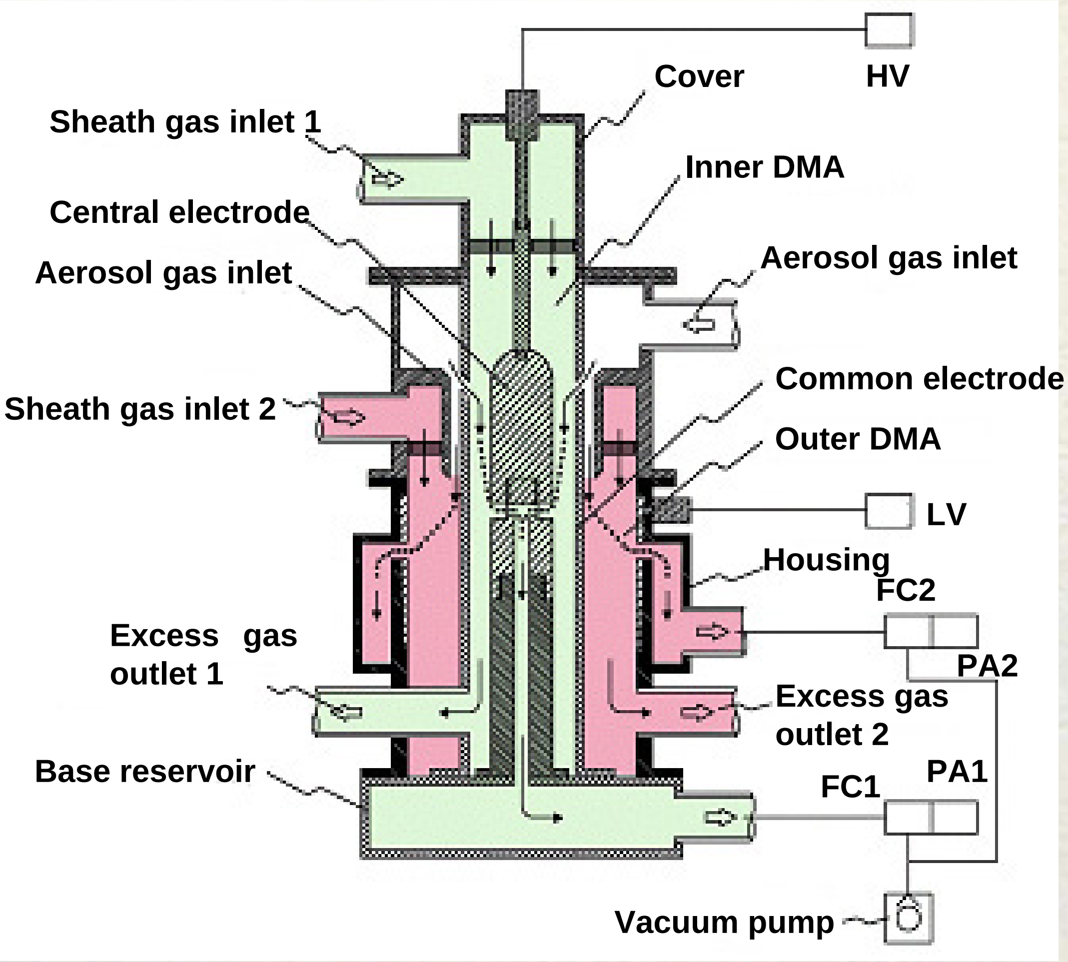
affect

- •CPC size detection range
- •Temperature condition
- •Characteristic of particle (Fraction of Volatile)

Not affect

Active Theoretical Filtering Function

Section view of DDMA



Electrical mobility of particles

$$Z^* = \frac{Q_{sh} \ln(R_2 / R_1)}{2\pi L V}$$

$$= \frac{n_p e C_c}{3\pi \mu D_p}$$

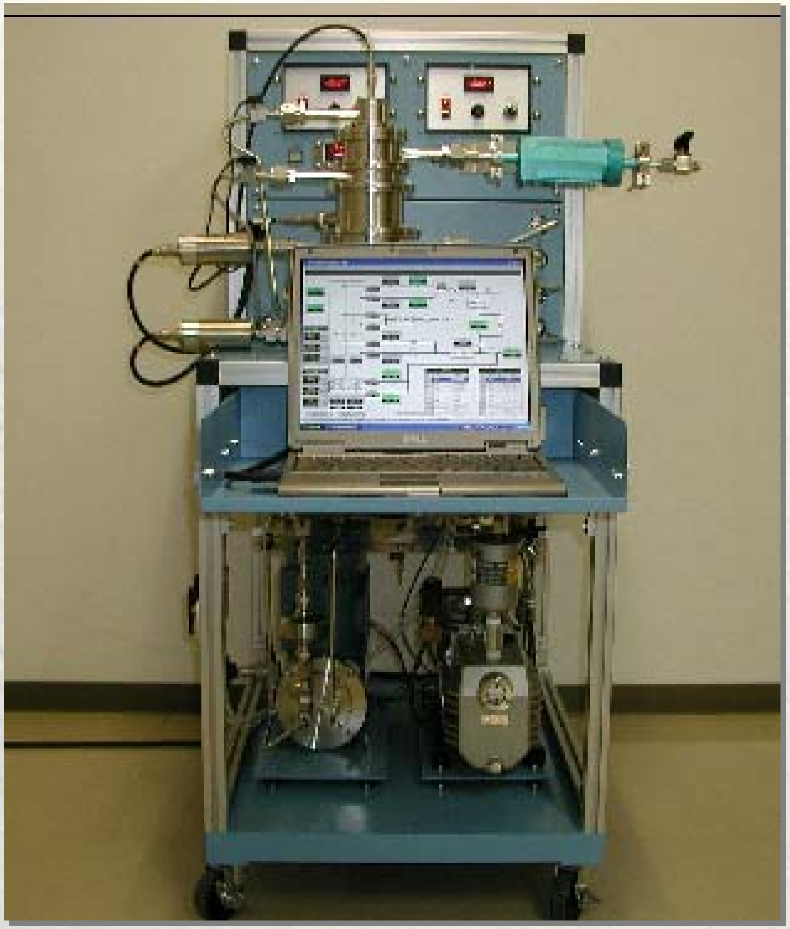
D_p: Particle diameter

C_c: Cunningham correction factor

μ: Gas viscosity

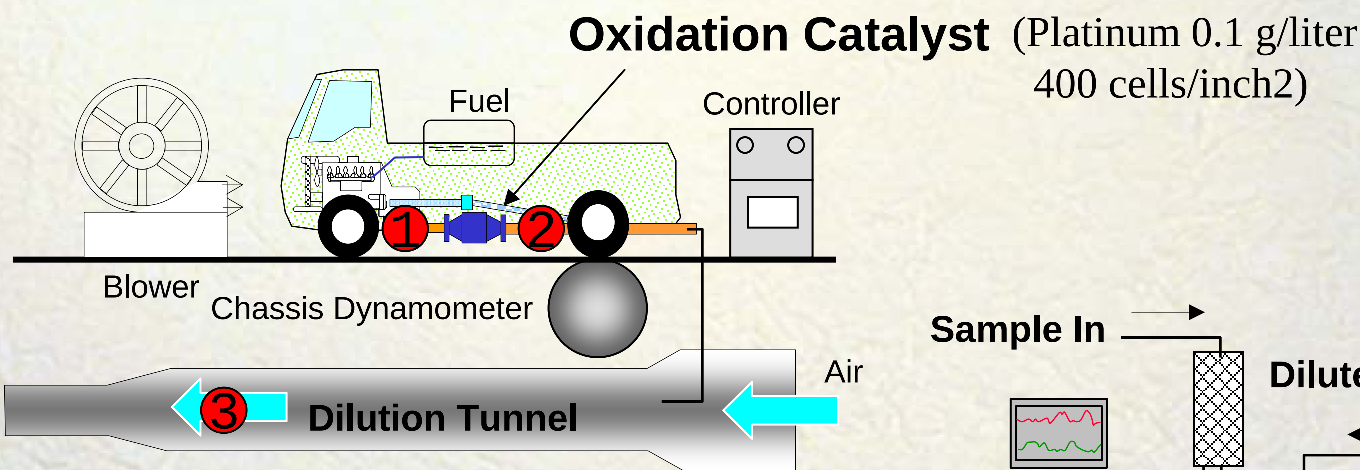
n_p: Number of elementary charges on a particle

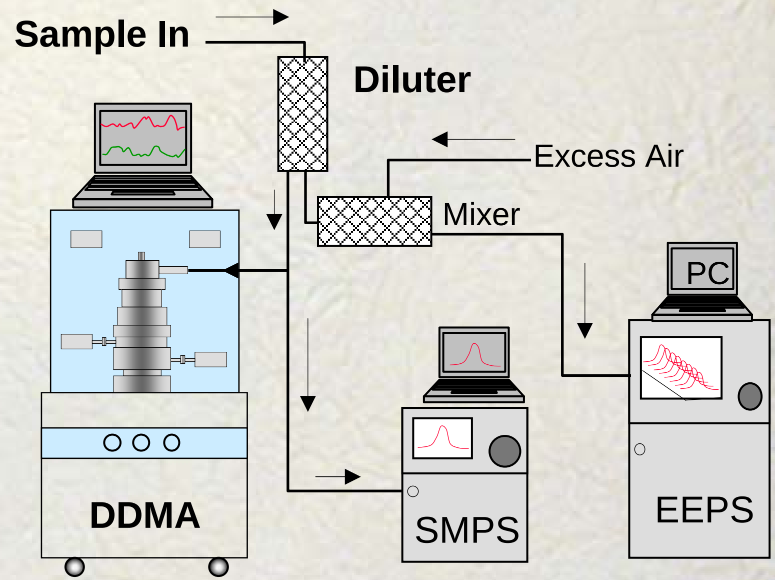
Prototype DDMA



Parameters	Outer DMA	Inner DMA
Classification length	18 mm	141.5 mm
Radius of central rod	42 mm	29 mm
Radius of outer housing	60 mm	38 mm
Particle charging	Am-241	
Sheath gas	Air	

Experimental setup





Sampling Point

1. After Exhaust manifold (before Catalyst)
2. After Catalyst
3. After Full Dilution Tunnel

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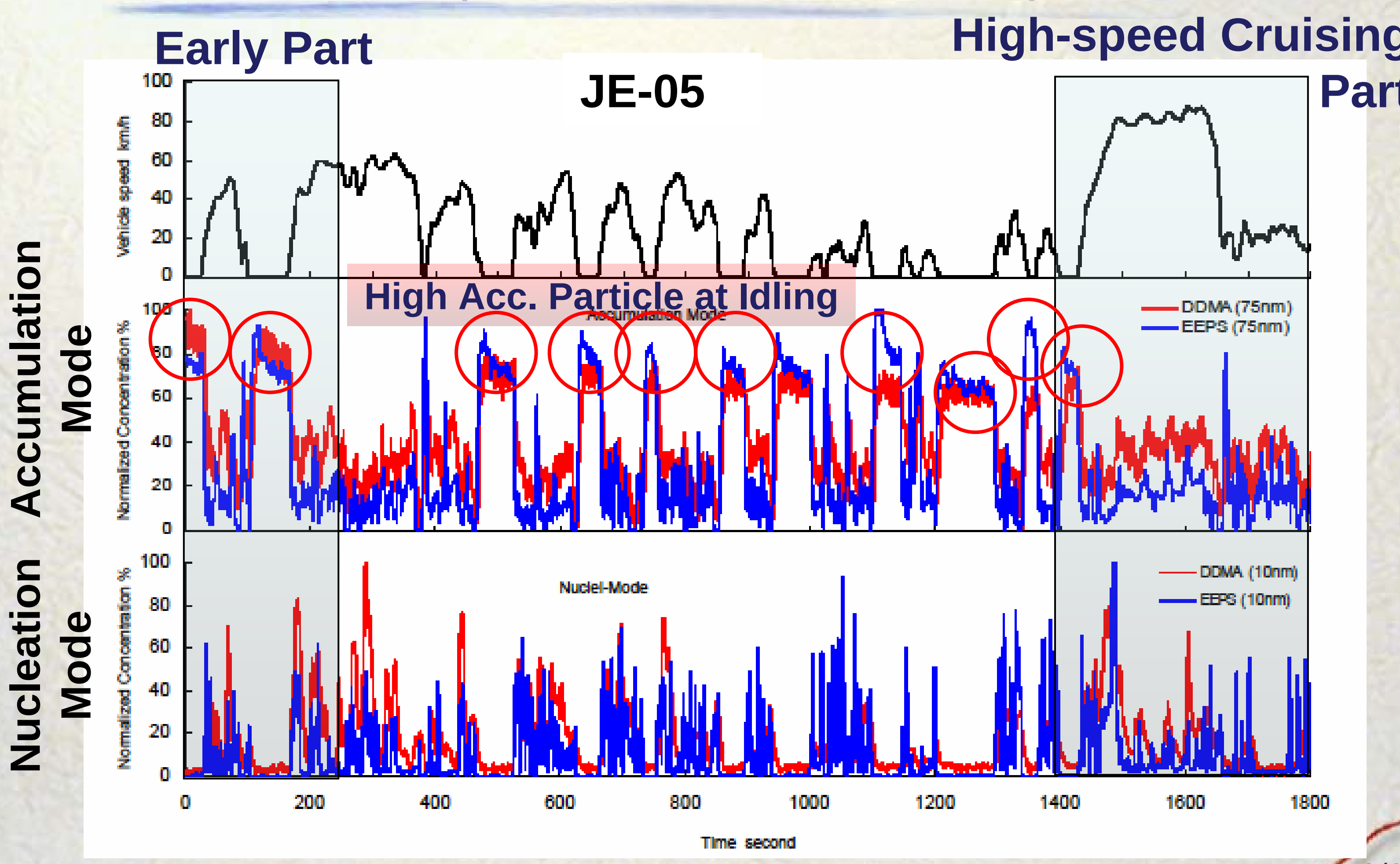
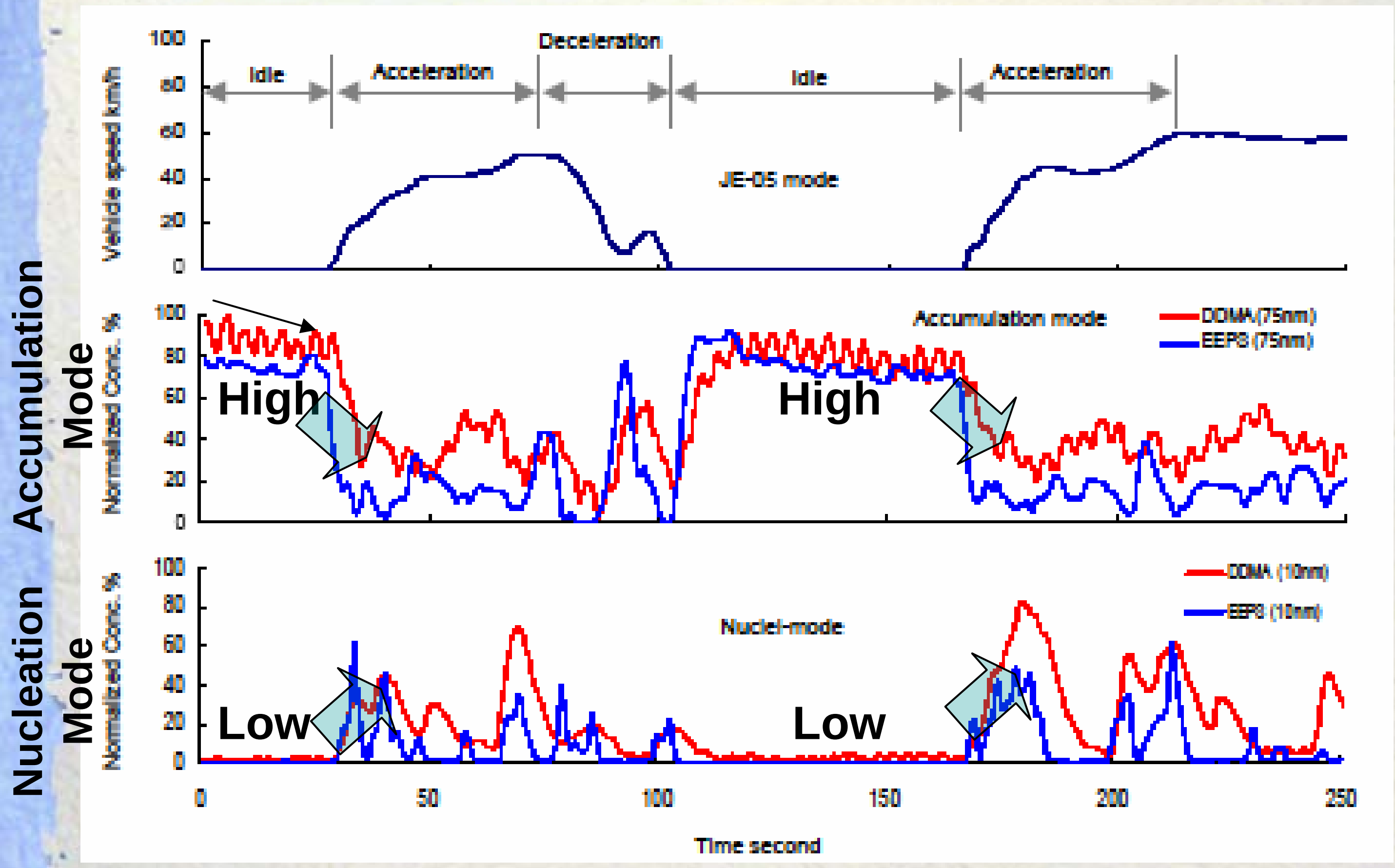
Transient behavior of Nano-Particles

(After exhaust manifold)



Low Speed Part of JE05 Mode

(After exhaust manifold)



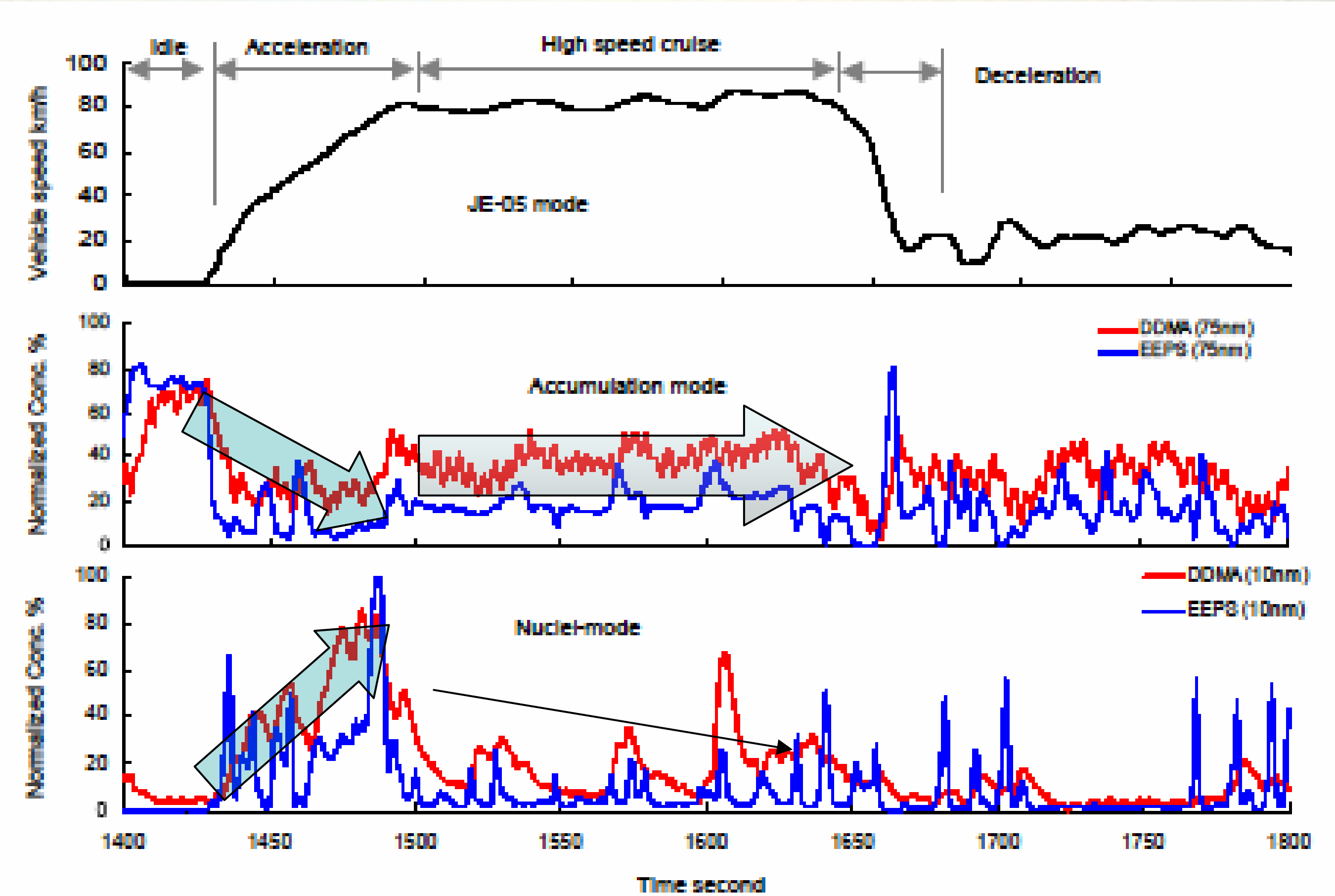
Idle: almost no Nuc, High Acc.

Acc. Decreases with time due to engine warm up.

Acceleration: Nuc. Increases, Acc. Decreases

High Speed Cruising Part

(After exhaust manifold)



High Speed Cruising: Nuc. Slight decreasing. Acc. remain constant

Spikes: due to gear change

The both mode particles are very sensitive to the acceleration, deceleration and gear change.

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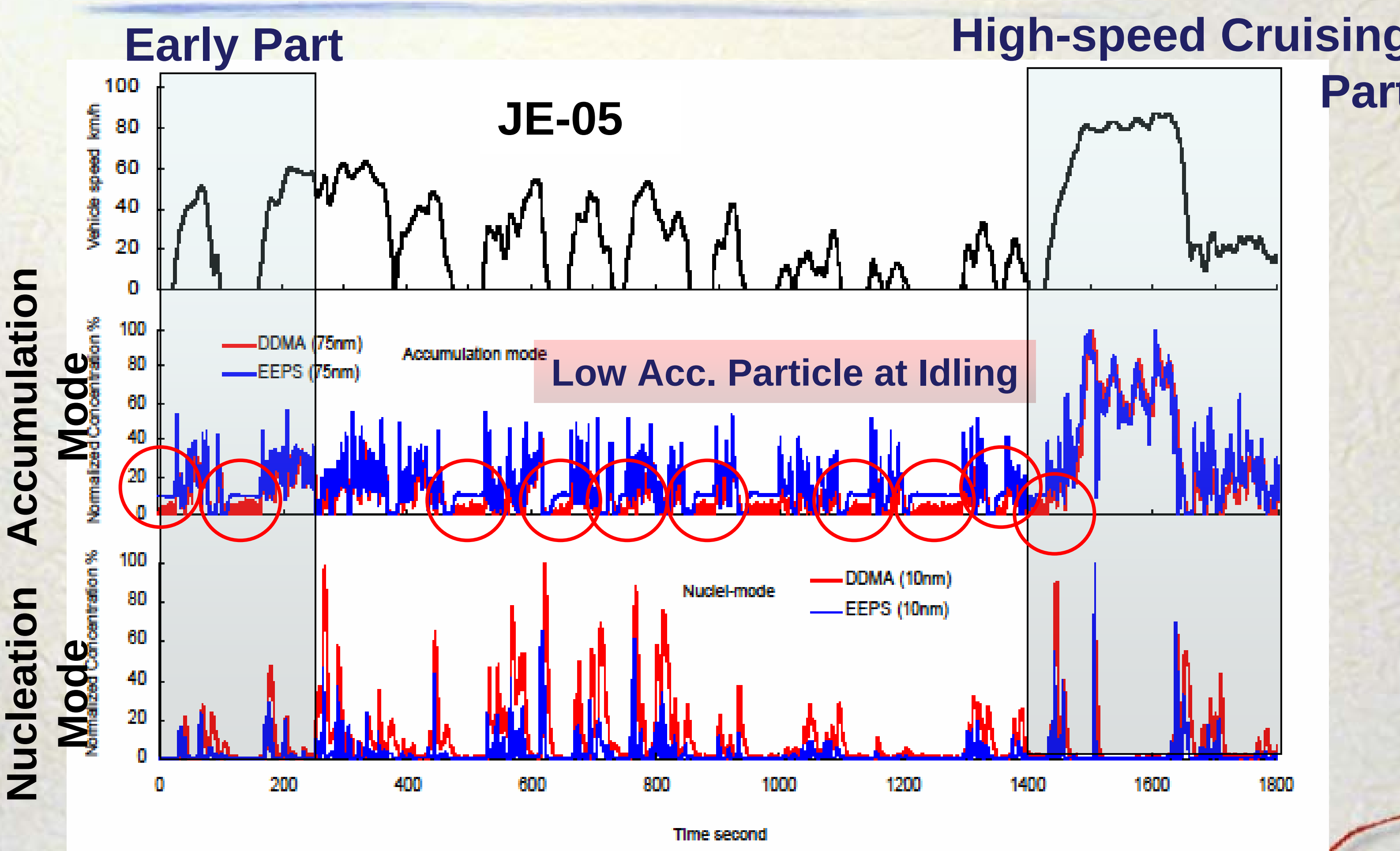
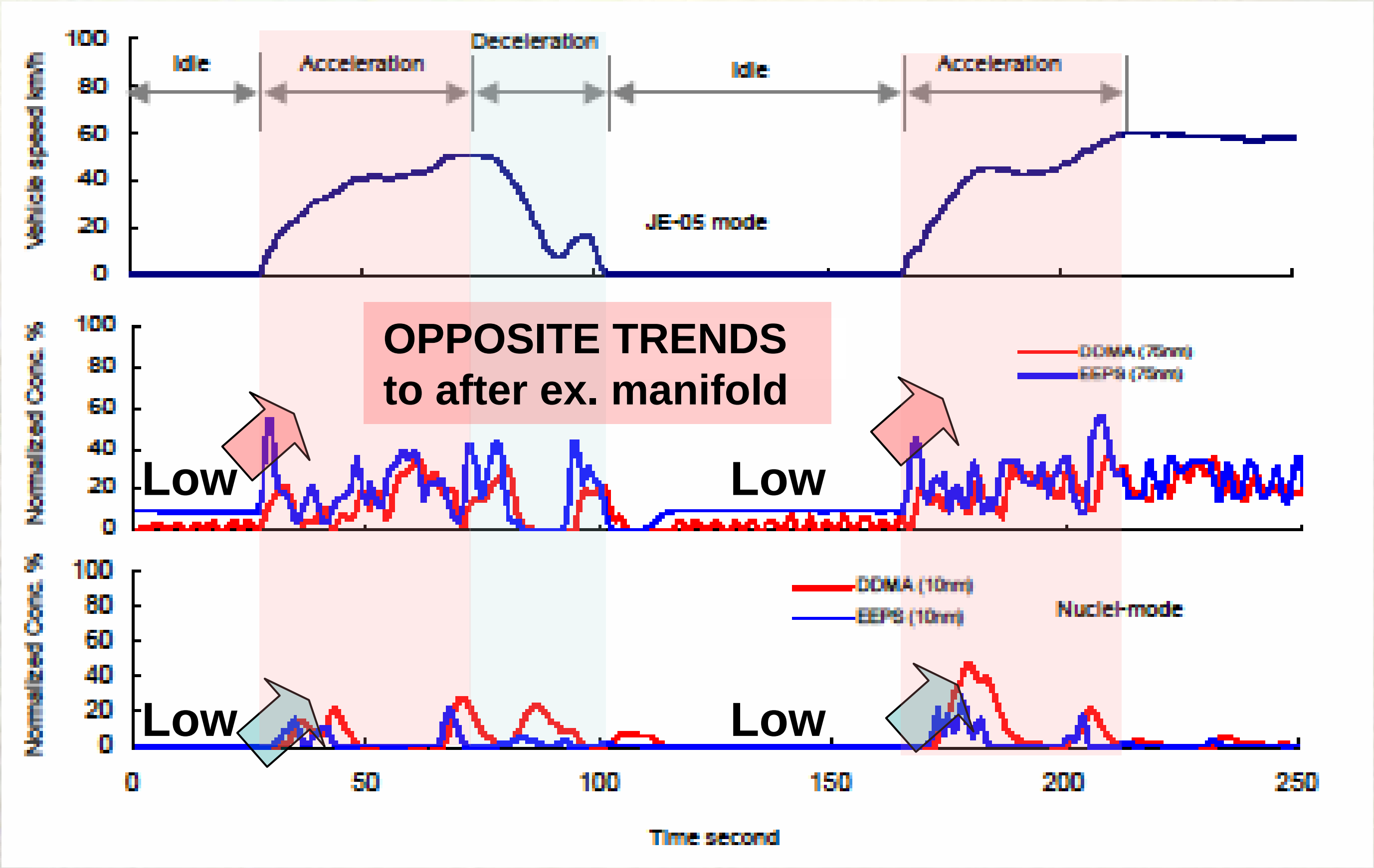
Transient behavior of Nano-Particles
(after Dilution Tunnel w/o catalyst)



Low Speed Part of JE05 Mode
(After dilution tunnel w/o Cat.)



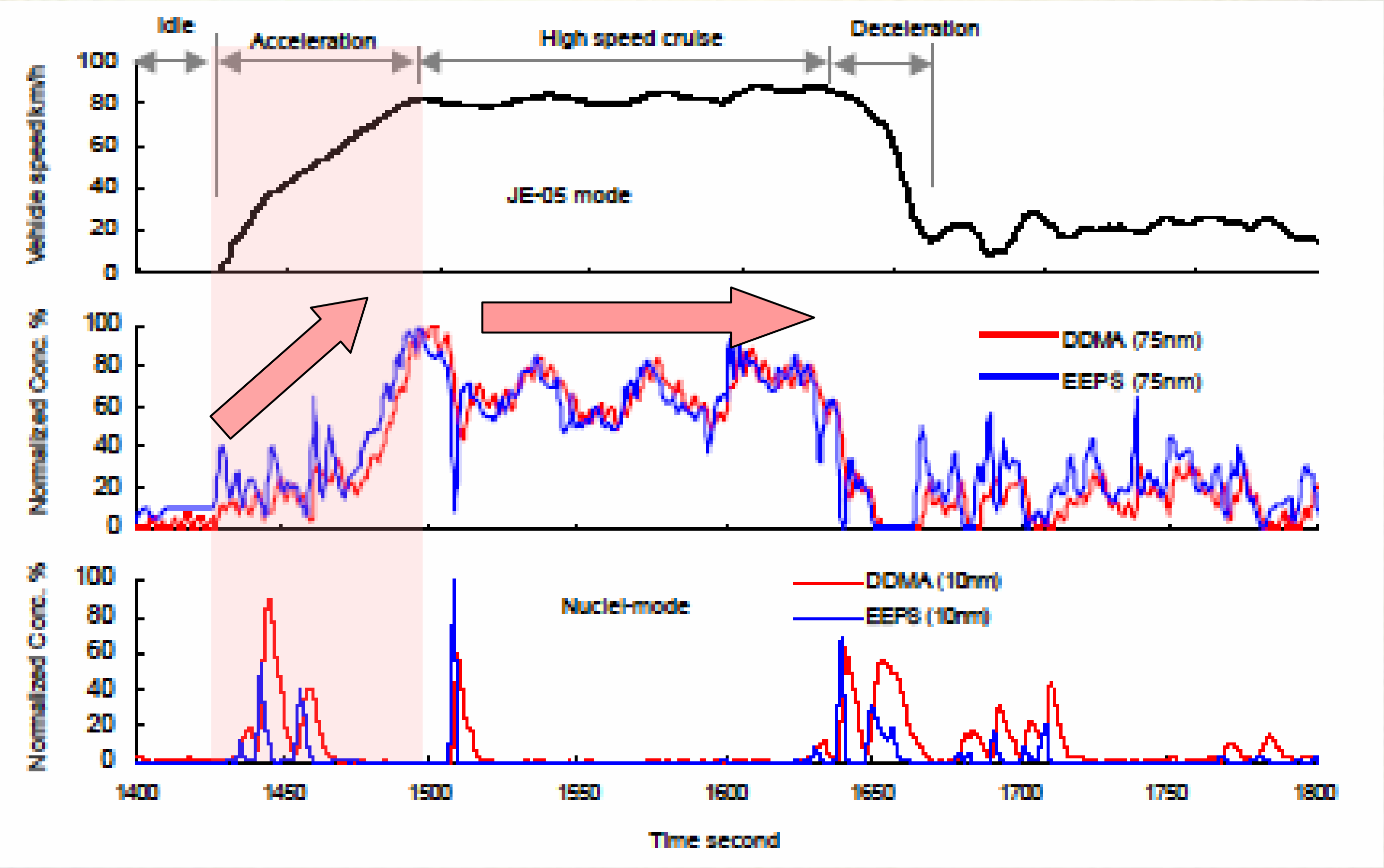
Idling: Nuc. Almost 0, Acc. Low

Nuc. Mode: Increase in Accelaration, decrease in deceleration

Acc Mode: increase in acceleration, Decrease in deceleration.

OPPOSITE TRENDS to after ex. manifold

High Speed Cruising Part of JE05 Mode
(After dilution tunnel w/o Cat)



Accelaration : ACC Gradually increase, Nuc. High → zero at maximum speed

Comparison of AEM and ADT

Driving ↓ Test point→	Nuclei		Accumulation	
	AEM	ADT	AEM	ADT
Idling	L	L	H	L
Acceleration	↑	↑	↓	↑
Deceleration	↓	↓	↑	↓
Low speed	H	H	L	H
High speed	H	L	L	H

AEM: After Exhaust Manifold, ADT: After Dilution Tunnel, H: High Concentration, L: Low Concentration, ↑: Increasing, ↓: Decreasing

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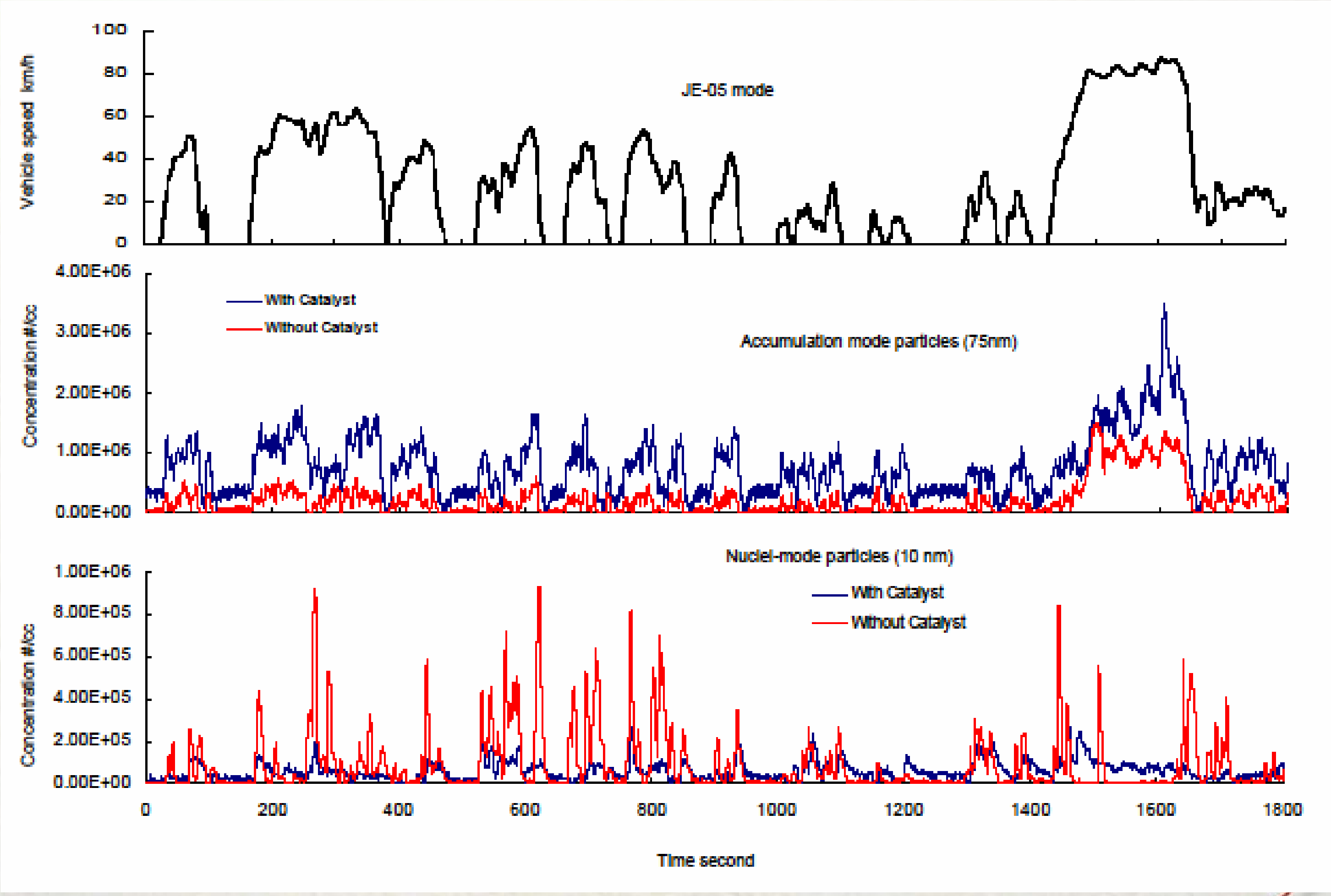
Effect of Oxidation catalyst

(After dilution tunnel)



Conclusion 1

- DDMA has enough potential for transient measurement of nano-particles from real diesel vehicle.
- Separate measurement of Nuc. and Acc. Mode particles lead a deep understanding of characteristics of nano particle behavior.

Conclusion 2

- A diesel oxidation catalyst causes increases in the concentration of the Acc. particles with decreases in the concentration of Nuc. particles depending on the sulfur content of the fuel.
- In future, If we decide that only the size range of Acc. mode is enough to regulate. The active theoretical filtering method by DMA technique shown in this study is very effective for robust measurement and regulation.

Acknowledgments

- This research work is supported by the Program for Promoting Fundamental Transport Technology Research from Japan Railway Construction, Transport and Technology Agency (JRTT).

JRTT
Japan Railway Construction, Transportation and Technology Agency

- The detail design and development of DDMA were done by Wyckoff Co., Ltd.

Thank you.

See you Next ETH-Conference on Combustion Generated Nannoparticles

He is kept waiting Lunch for a long time

Engine and Fuel Spec.
Test Conditions

Specifications of Truck Engine

Engine	4-Cylinder Diesel
Injection system	Common-rail
Bore x Stroke	115 x 115 mm
Swept volume	4777 CC
Maximum power	96 kW/3000 rpm
Maximum torque	333 N-m/2000 rpm
Emission standard	Japan 2000

Fuel Properties

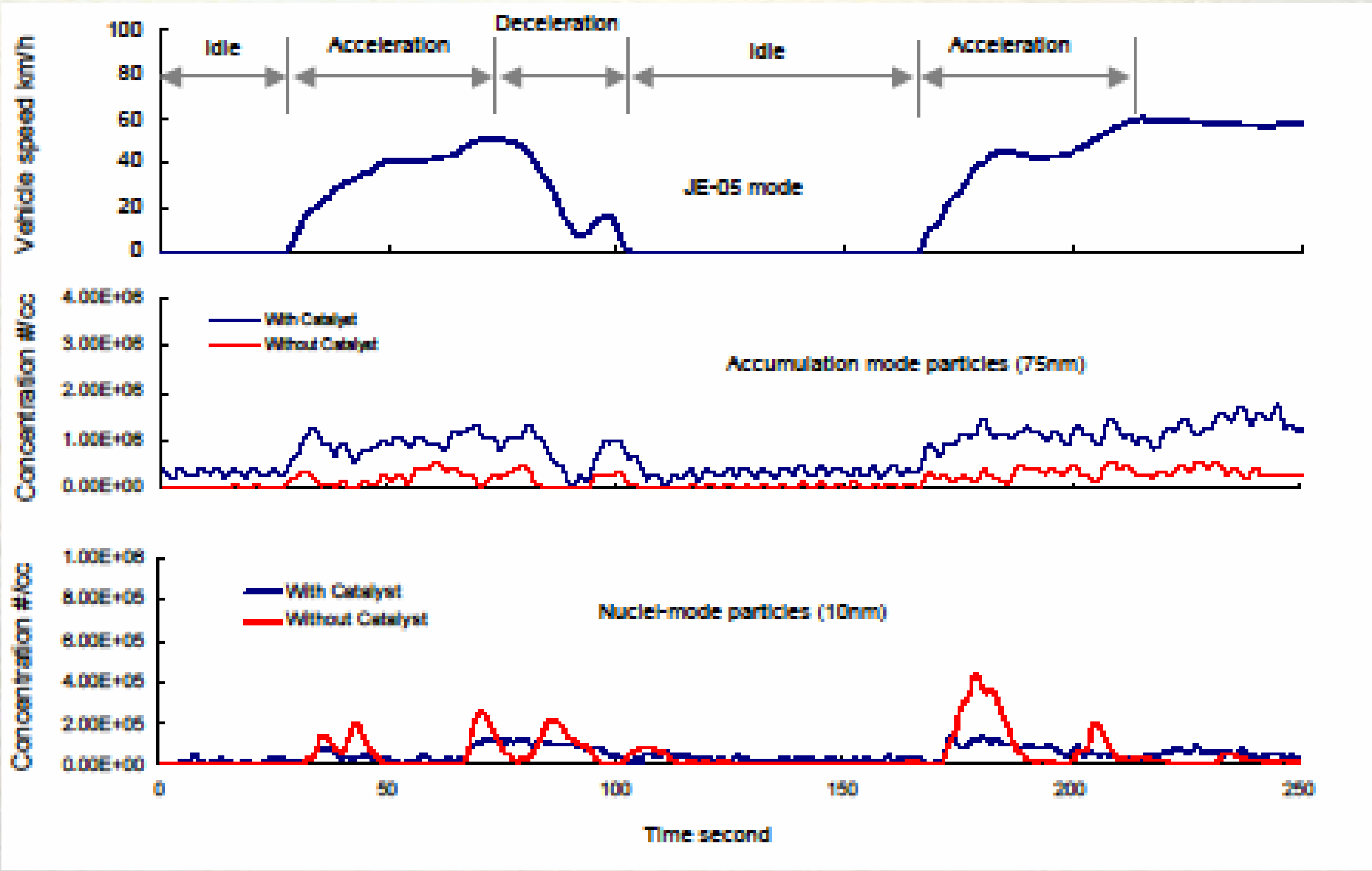
Fuel Type	Diesel
Density @25°C	0.8201 gm/cc
Viscosity @30°C	3.518 mm/s
Distillation point 90%	336.5 °C
Sulfur content	30 ppm

Test Conditions

Idling	575 rpm
Low load	1200 rpm
Medium Load	1800 rpm
Transient	JE-05

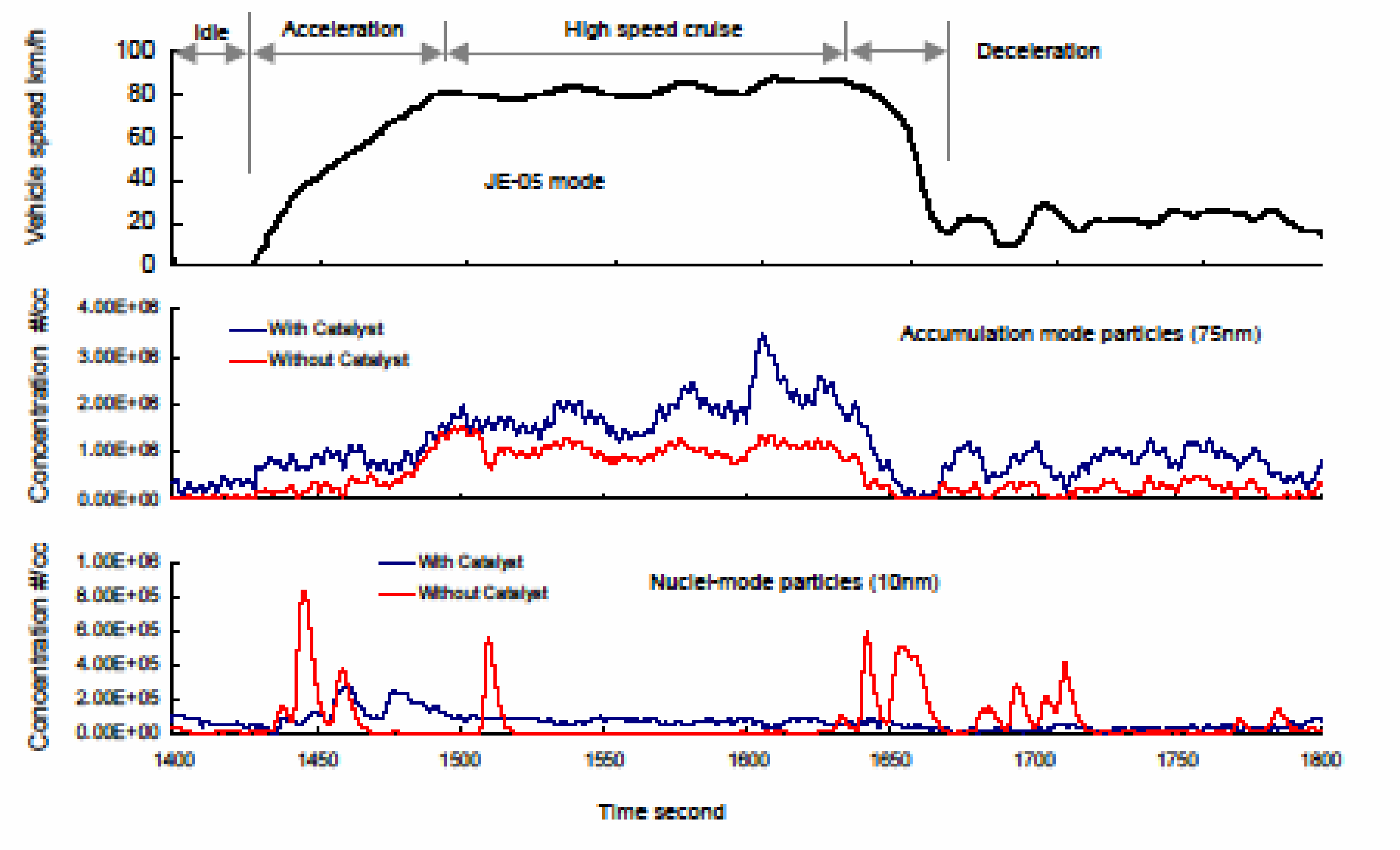
Low Speed Part of JE05 Mode

(After Dilution Tunnel with Catalyst)

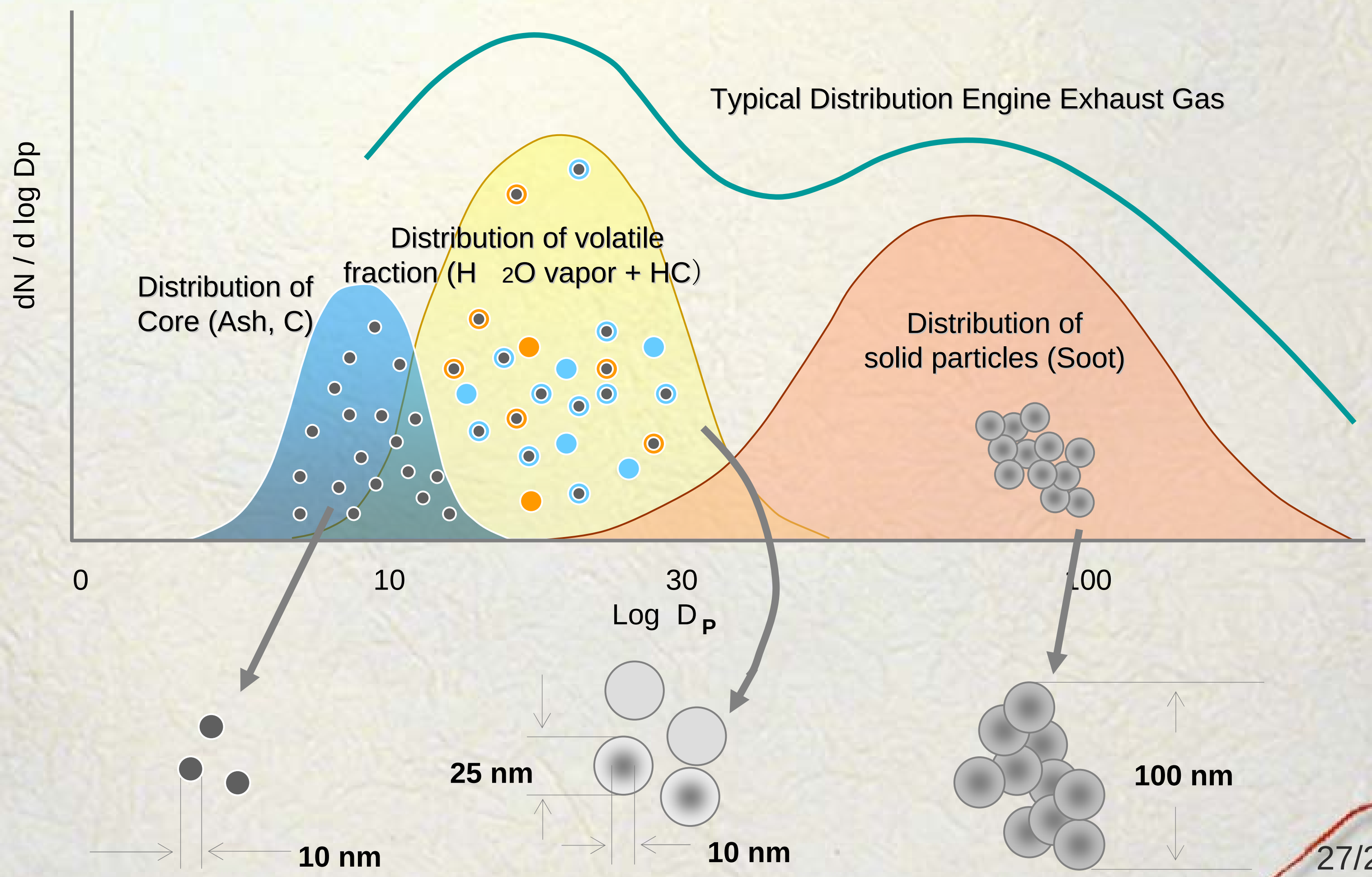


High Speed Cruising Part

(After dilution tunnel with catalyst)

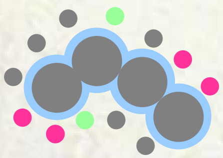


Nano-Particle Model



Types of Nano-Particles

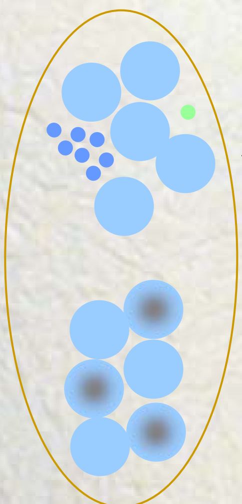
Accumulation mode particles:



±100 nm
Solid particles (soot)
Agglomerate of soot

These cannot be vaporized/desorbed significantly by thermal-conditioning.

Nuclei-mode particles:

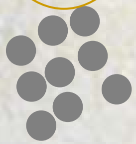


15~30 nm
Volatile particles

Nucleate due to cold dilution but vaporizes/desorbs under thermo-conditioning even at 100° C

15~30 nm
Semi-volatile particles

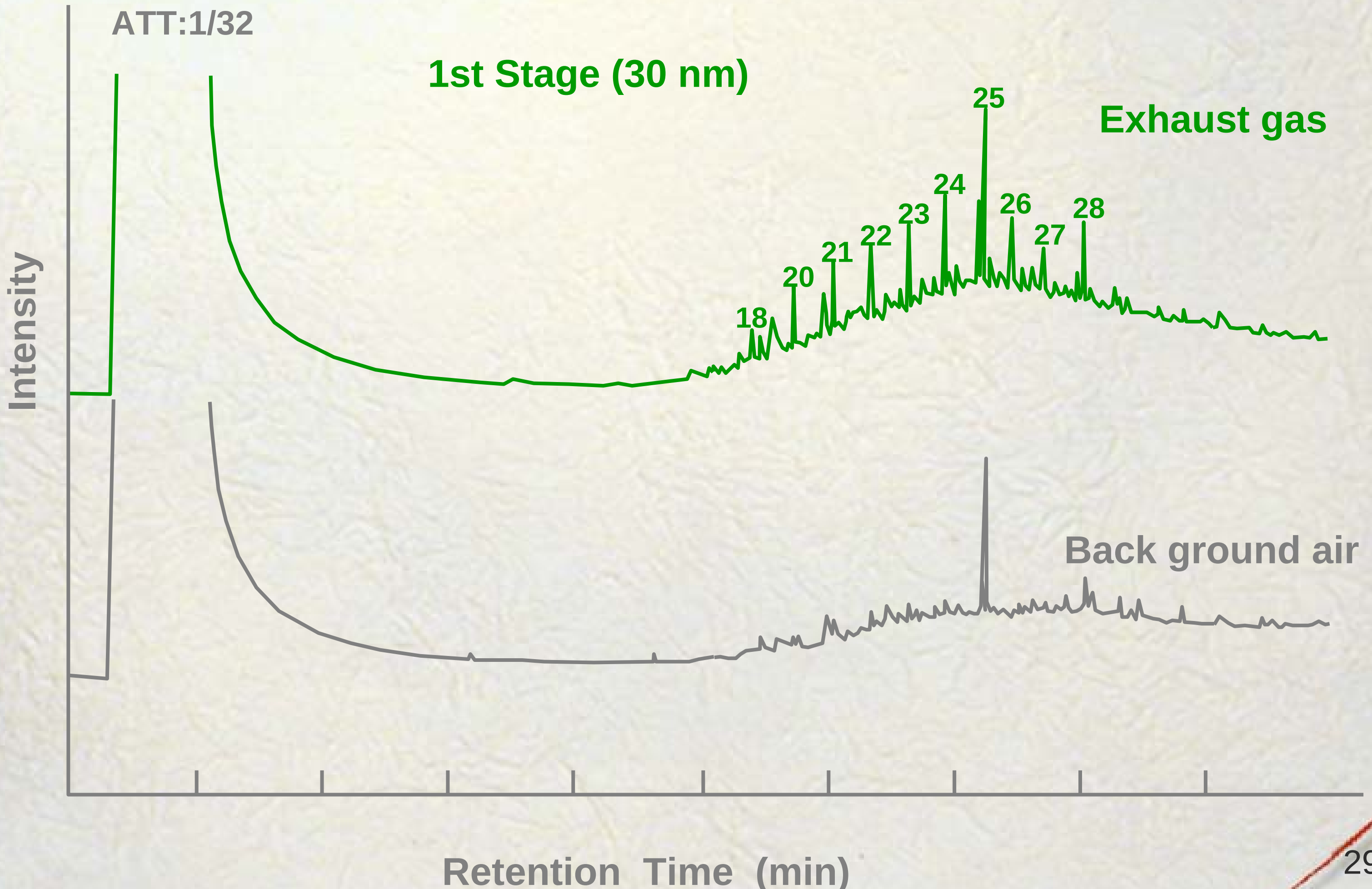
Nucleate due to cold dilution but vaporizes/desorbs slightly or becomes smaller in size under thermo-conditioning at 100~300° C



<=10 nm
Ash/Carbon/Heavy HC

Do not vaporize/disrobe or change in size under thermo-conditioning even above 400° C

GC Analysis of Nano-Particles



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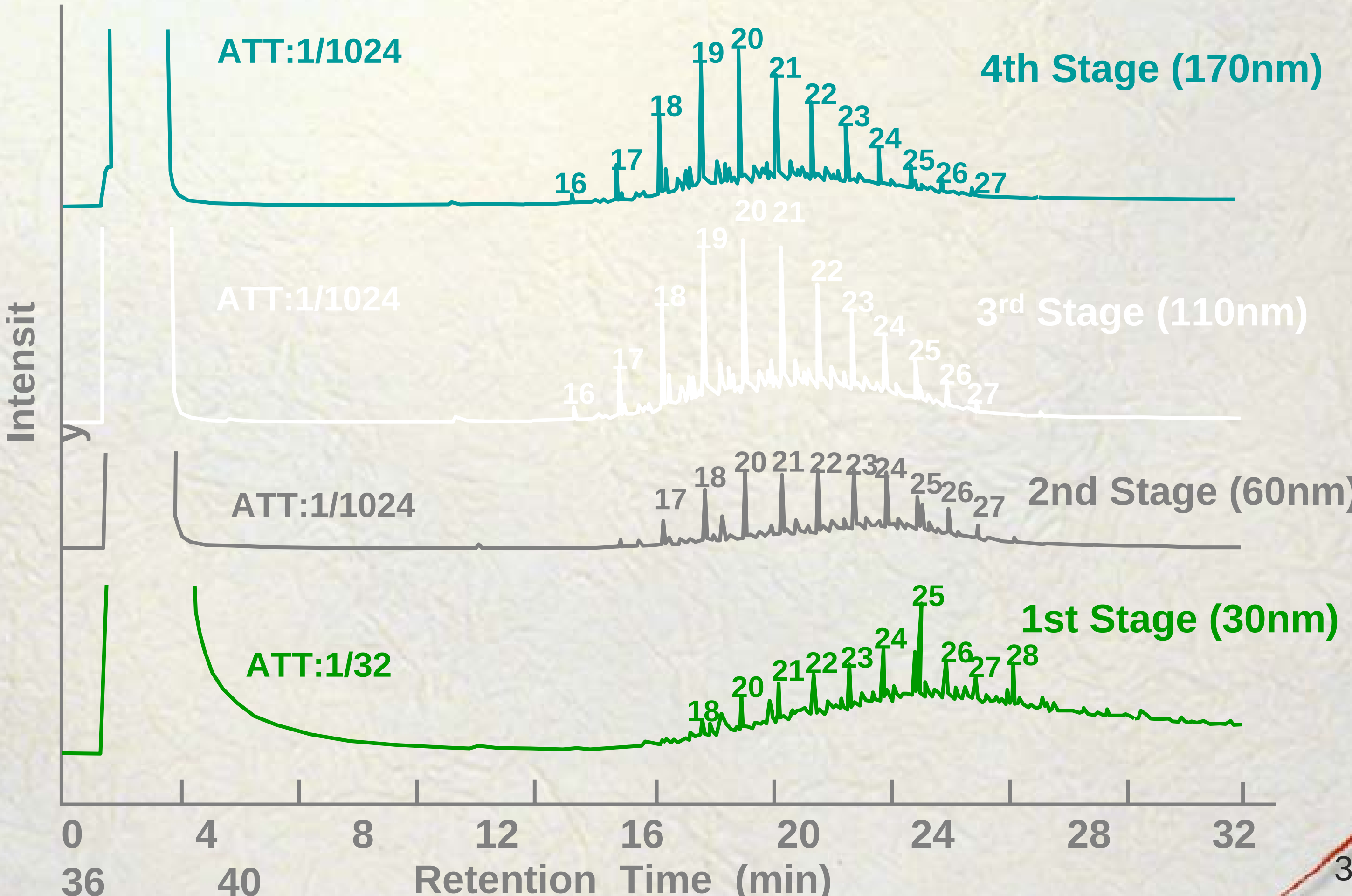

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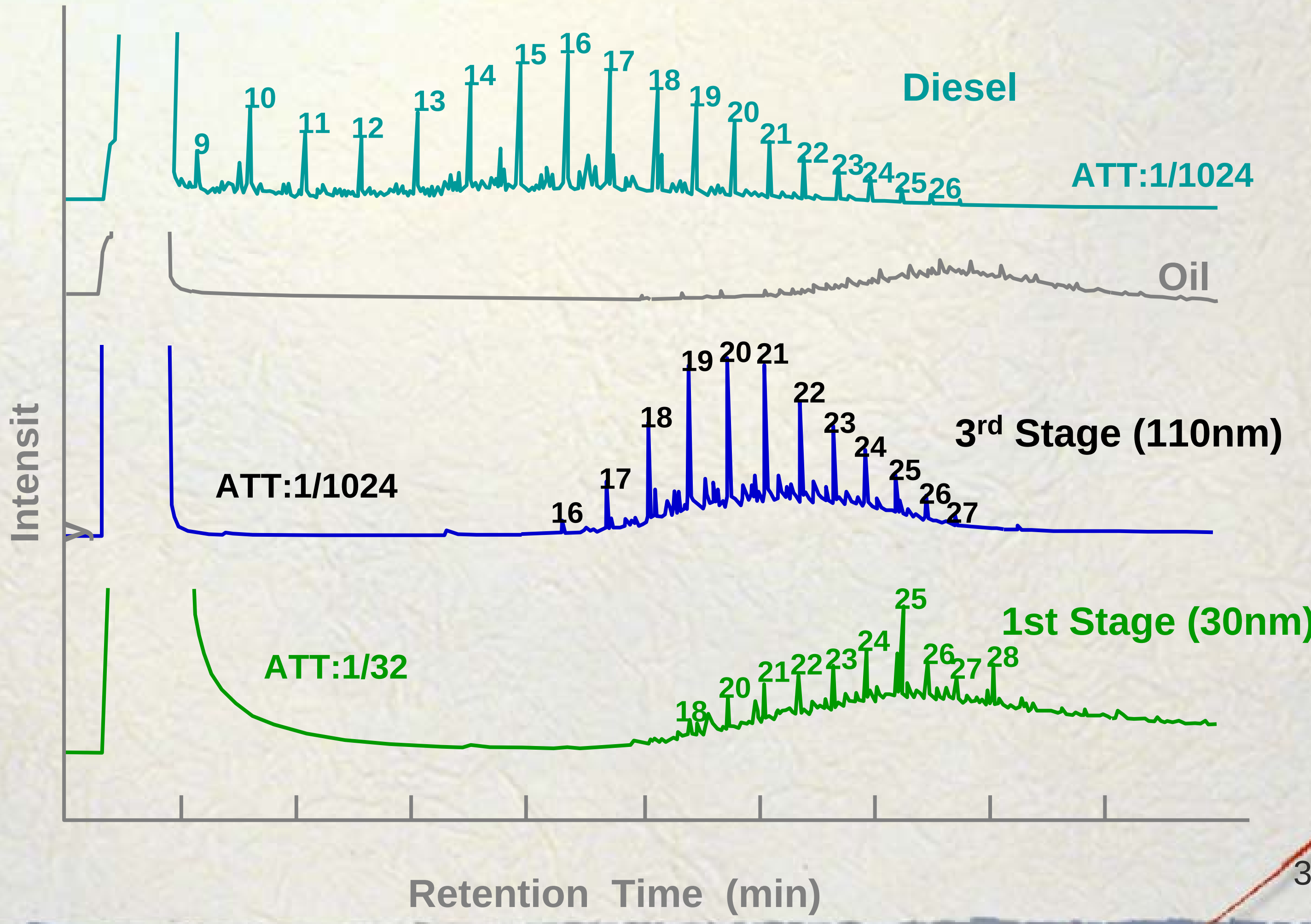

GC Analysis of Nano-Particles