

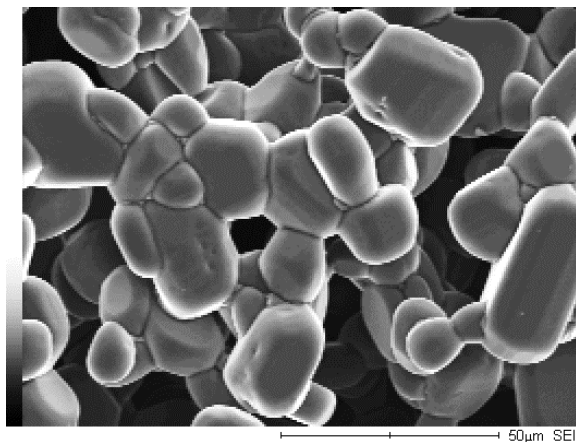
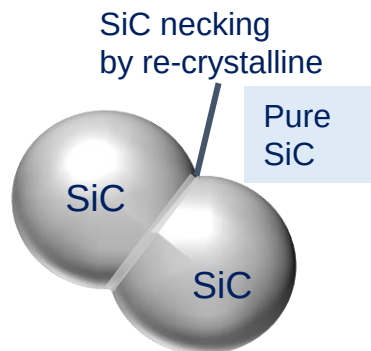
Optimized R-SiC DPF design for LD applications under evolving emission regulations in India

Naoki Kawamura, Engineering Group Manager, Ibiden Co., Ltd.
Keigo Matsunaga, Engineering Staff , Ibiden Co., Ltd.



- IBIDEN R-SiC DPF can contribute high filtration, high thermal resistance and high exhaust gas/ash resistance.

R-SiC



R-SiC Characteristic	Contribute to DPF
Narrow pore distribution	<p> — :Market cordierite — :Market Si-SiC — :Market AT — :R-SiC </p> <p>High filtration performance</p>
High thermal conductivity	<p>High Competitor SiC R-SiC Homogeneous DPF inside temperature</p> <p>Low Temp. Low High Thermal conductivity</p> <p>High thermal resistance (Soot capacity)</p>
High chemical resistance	<p>Heat treatment : 1200deg.C/3hrs</p> <p>High exhaust gas/ash resistance</p>

LD emission regulatory trends in Europe and India

Table Emission regulation trend

	'20	'21	'22	'23	'24	'25	'26	'27	'28	'29	'30	'31	'32	
EU	<div><u>Euro 6d/6e</u> WLTP+RDE PN23:6.0×10¹¹#/km NOx:80mg/km Durability Requirements: 160,000km</div>							<div><u>Euro 7</u> WLTP+RDE PN10:6.0×10¹¹#/km, NOx:80mg/km Durability Requirements/Additional requirement: 160,000km/200,000km</div>						
IND	<div><u>BS VI Phase1</u> MIDC PN23:6.0×10¹¹#/km NOx:80mg/km Durability Requirements: 160,000km</div>			<div><u>BS VI Phase2</u> MIDC+RDE PN23:6.0×10¹¹#/km NOx:80mg/km Durability Requirements: 160,000km</div>				<div><u>BS VI with WLTP</u> WLTP+RDE PN23:6.0×10¹¹#/km NOx:80mg/km Durability Requirements: 160,000km</div>			<div><u>BS VII(TBD)</u> Euro 7 equivalent?</div>			

Note: Values shown for M1 diesel vehicles

Table Regulatory changes, technical impacts and IBIDEN solutions

Regulatory change 	Impact on vehicle and ATS 	DPF requirement 	IBIDEN solution 
RDE requirements ('23~)	Diverse traffic, loading and operating conditions	Stable PN filtration under transient and high flow conditions	R-SiC sharp pore distribution
Introduction of WLTC ('27~)	Higher vehicle speed/ Higher exhaust flow/ More transient operation	Stable PN filtration under transient and high flow conditions	R-SiC sharp pore distribution <div>1 </div>
Durability requirement ('30~) CAFE III regulation ('27~)	Long-term use/ Better fuel efficiency	High ash capacity and low pressure loss Sufficient soot-regeneration margin	VPL for increased ash-storage capacity <div>2 </div>

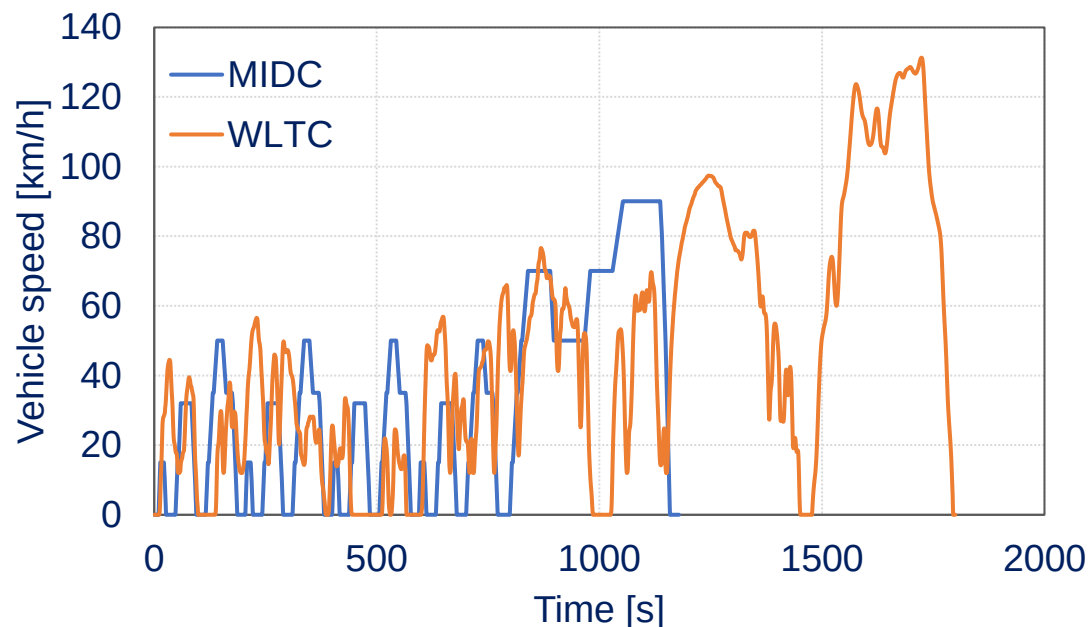


Figure MIDC vs WLTC: Vehicle speed profiles

Changes from MIDC to WLTC

- Longer duration
- Higher maximum speed
- More transient operation

Impact on PN control

- Wider exhaust flow range
- Greater engine-out PN value
- Higher demand for stable PN filtration

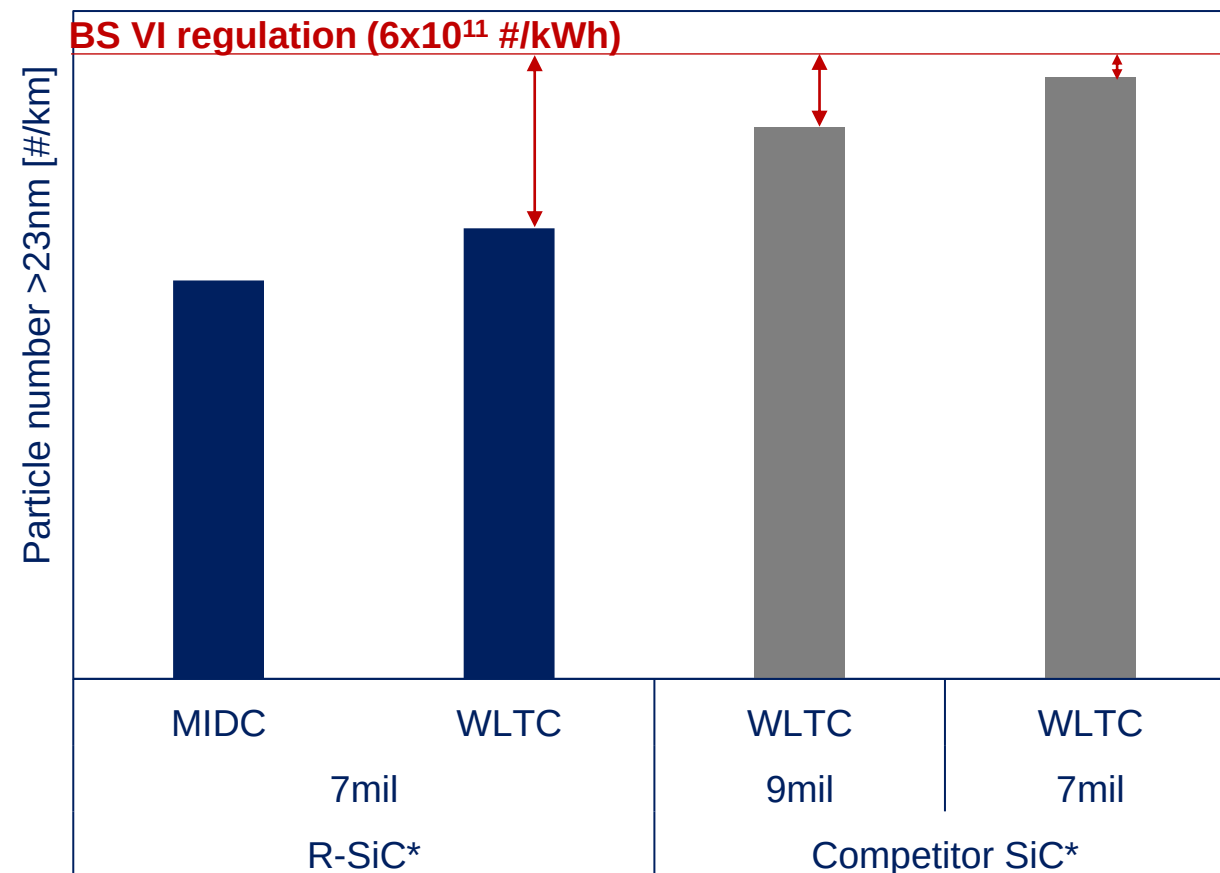


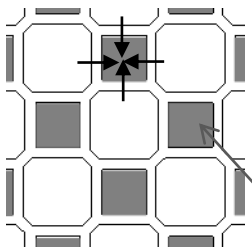
Figure PN Emission Results under MIDC and WLTC Conditions

- The PN value tends to be higher for WLTC compared to MIDC.
- Low PN emissions under both MIDC and WLTC conditions
- Sufficient margin against the BS VI PN limit

IBIDEN VPL technology

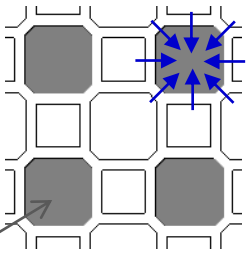
Conventional OS

(Oct square)
Inlet ch.
4 direction
Gas flow



VPL

(Valuable Plugging Layout)
Inlet ch.
8 direction
Gas flow



Outlet

- **Bigger outlet channels** to reduce friction at outlet channel(ΔP_4).
- **Increased of inlet channels** to increase inlet volume and filtration area
- ➔ **Higher filtration area** to reduce wall surface friction(ΔP_2) and wall/soot layer friction(ΔP_3)

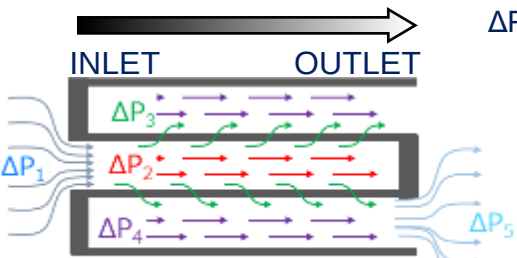


Fig. Pressure loss analysis in DPF

$$\Delta P = \Delta P_1 + \Delta P_2 + \Delta P_3 + \Delta P_4 + \Delta P_5$$

- ΔP : Total pressure loss
 ΔP_1 : DP from contraction
 ΔP_2 : DP from inlet channel friction
 ΔP_3 : DP from wall and soot layer
 ΔP_4 : DP from outlet channel friction
 ΔP_5 : DP from expansion

Tab. DPF condition

Item	Detail
Substrate	7/300 conventional 7/300 VPL
Size	5.66"x6"L

Tab. Gas condition

Item	Detail
Gas temp.	400deg.C
Gas flow rate	340kg/h

Tab. Ash soot condition

Item	Detail
Oil Consumption	0.1L/1000km
Ash Content*	1.0%
Ash density*	350kg/m ³
Ash finding rate*	30%
Ash deposition*	Bottom
Ash amount	0g(driving distance:0km) 50g(driving distance:200,000km)
Soot amount	6g/L

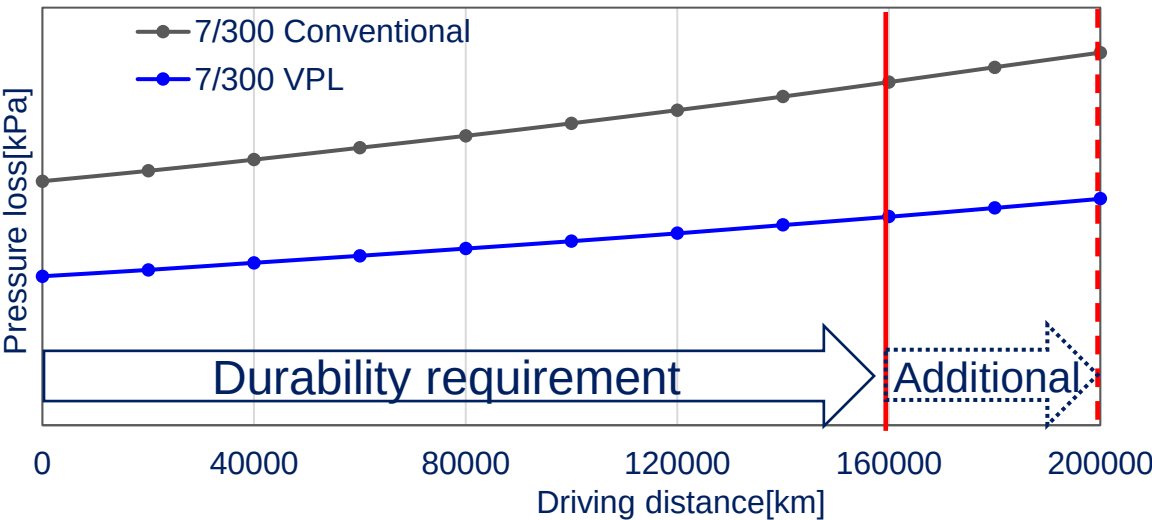


Figure Effect of VPL on pressure loss over driving distance

VPL significantly reduces pressure loss under soot- and ash-loaded conditions.
This supports long-term DPF performance and contributes to improved fuel economy.



Impact on DPF

- Higher soot accumulation
- Fewer opportunities for passive regeneration
- More severe regeneration conditions

High soot capacity
(High soot mass limit) is needed

- R-SiC showed lower DPF max temp./gradient than competitor SiC during DTI testing.
- R-SiC which has high soot capacity & can be used for higher robustness in Indian market

Tab. Test sample

Item	Detail
Substrate	R-SiC:7mil/300cpsi Competitor SiC:7mil/300cpsi
Filter size	D10.5"xL7"
Bare/Coat	Coat sample

Tab. Fixed condition

Item	Condition
Engine	EUVI
Volume	7.2L
Soot load	3.0~6.0g/L
DTI condition	Inlet DPF temp:600deg.C

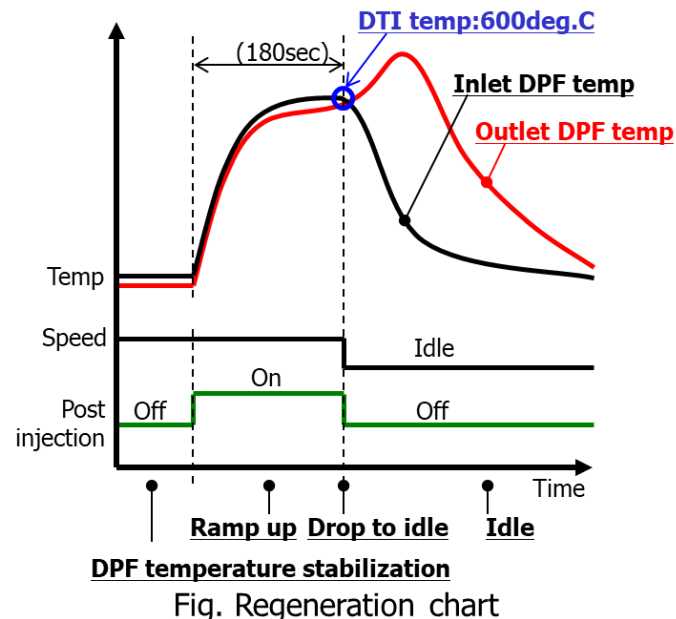
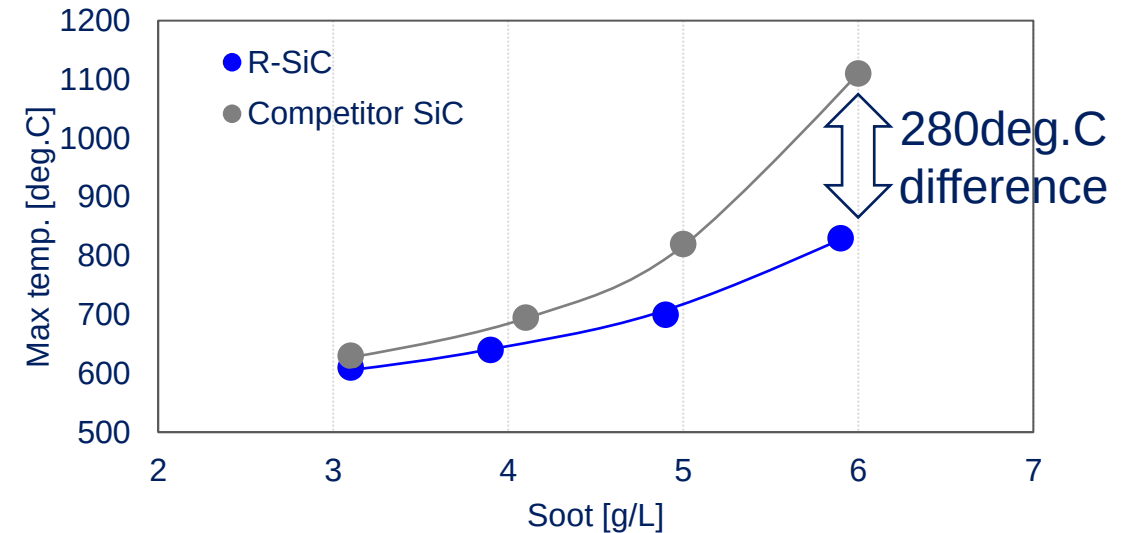
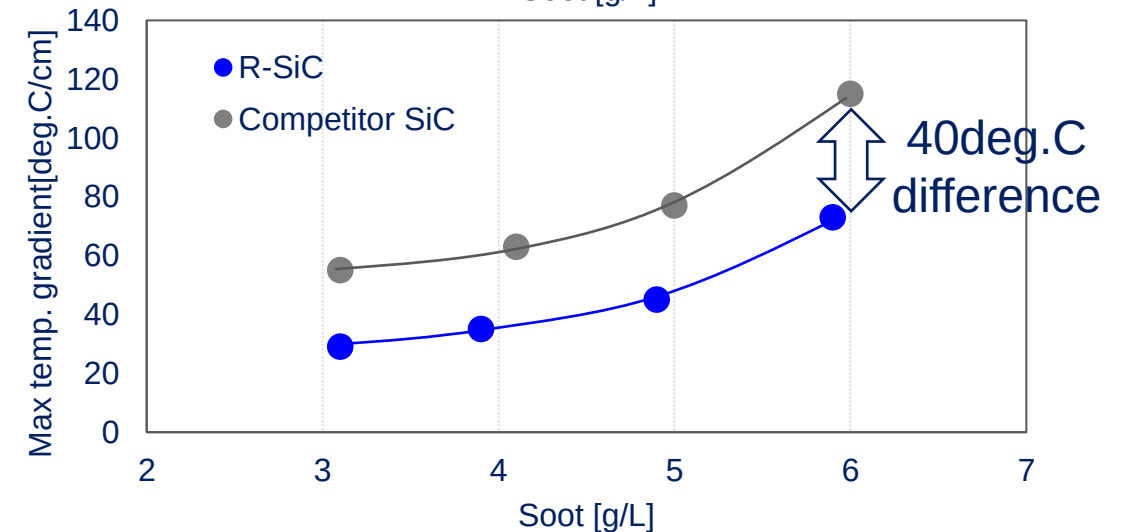
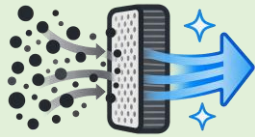


Figure Maximum temperature and maximum temperature gradient at drop-to-idle testing

Value provided by IBIDEN R-SiC DPF technology



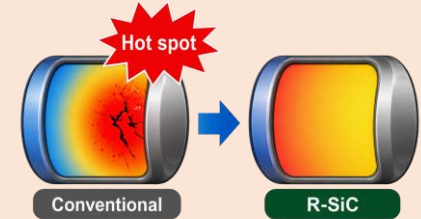
High filtration

Stable PN filtration under WLTC conditions, with sufficient compliance margin



Low pressure loss

Low pressure loss under ash loaded conditions through VPL technology



High robust

Reduces hot spots and thermal stress during regeneration



Benefits for OEM/end user

Supports reliable PN compliance under diverse operating conditions

Contributes to improved fuel economy and reduced CO₂ emissions

Reduces thermal-damage risk and increases regeneration-calibration flexibility

IBIDEN R-SiC DPF technology supports robust regulatory compliance and contributes to the efficiency, reliability and long-term value of LD vehicles in India.