Komori T. / Sumitomo Chemical Co.Ltd. Japan
Newly-developed Diesel Particulate Filter - Sumitomo DPF

Introduction
The usage of Diesel Particulate Filters (DPF) has contributed to decrease the particulate matter in exhaust gas of diesel cars for over 10 years since PSA started to apply it in its passenger cars, and has become a standard diesel exhaust gas after-treatment device. While the development of deNOx technology is still ongoing, also the technical requirements for DPF are becoming more demanding, e.g. smaller size, higher performance and lower price.

Silicon carbide (SiC) is currently used as the main material for DPF due to its high thermal stability. On the other hand, aluminium titanate (AT) is recognized as an alternative material to SiC and one of the best candidates for the next generation of DPF, because of its good technical performance and the more cost-effective production compared with SiC manufacturing. Sumitomo Chemical Co., Ltd. has newly developed its advanced AT material taking advantage of its proprietary technologies cultivated in manufacturing inorganic materials such as alumina products.

Latest market requirements for DPF are mainly low pressure drop in order to reduce the fuel penalty, and high ash capacity in order to increase its life time. The author, who had invented Octo-square SiC-DFP, continued challenging further innovative designs of DPF in Robert Bosch GmbH and finally reached hexagonal cell geometry with his colleagues.

In order to fulfill the above-mentioned recent requirements, Sumitomo Chemical has newly developed its innovative AT-DFP (hereinafter called “SC-AT”). The combination of improved material properties and advantageous hexagonal cell geometry makes this innovation outstanding; The newly-developed SC-AT shows 1) higher thermal shock resistance, 2) higher ash capacity, and 3) extremely lowered pressure drop.

Herein, basic performance of SC-AT is introduced as follows.

Pressure drop performance
Figure 1 shows the result of pressure-drop behavior under soot-loading condition comparing Octo-square SiC, and SC-AT with square- and hexagonal- type, called “Hex” hereafter, which were measured with cold flow bench system. The usage of Hex design leads to a remarkably lower pressure drop due to its higher effective filtration area.

![Fig.1 Pressure-drop under soot loading in cold flow bench. DPF size: D5.66×L6.](image)
Filtration efficiency

Figure 2 shows soot filtration efficiency results in Hex-designed SC-AT, and Octosquare- SiC. The efficiency was measured by counting soot particle number in cold flow bench system. Although SC-AT shows lower pressure drop, both efficiency was comparable.

Soot Mass Limit (SML)

Drop-to-idle test was demonstrated for Octo-square-SiC and Hex-SC-AT with engine test bench. After soot was loaded onto DPF (8 ->10 ->…. g/L), Drop-to-Idle condition was performed for loaded DPF. In order to check several defects in DPF after the test, soot leak was detected by smoke-meter. Figure 3 shows the results of SML. Smoke meter indicates that its higher value corresponds to more defects in DPF. SC-AT shows higher SML than SiC, revealing high thermal shock resistance.

Conclusion

SC-AT shows

✓ High thermal shock resistance.
✓ High ash capacity.
✓ Remarkably lower pressure drop.
✓ Comparable Filtration efficiency.
✓ Higher SML.
Newly-developed Diesel Particulate Filter
- Sumitomo DPF “SC-AT” -

Sumitomo Chemical Co. Ltd.
DPF Advisor
Teruo KOMORI
Contents

1. History of DPF Development
2. DPF Market Requirement
3. Feature of “SC-AT”
4. Conclusions
# 1. History of DPF Development

<table>
<thead>
<tr>
<th>Year</th>
<th>1980</th>
<th>1990</th>
<th>2000</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Application</strong></td>
<td></td>
<td>PC</td>
<td>OHW, Retro-Fit</td>
<td>CV</td>
</tr>
<tr>
<td><strong>Material</strong></td>
<td>Cordierite</td>
<td>SiC</td>
<td>AT</td>
<td></td>
</tr>
<tr>
<td><strong>Regeneration</strong></td>
<td>Forced, CRT</td>
<td>FBC</td>
<td>C-DPF</td>
<td>C-DPF + DeNOx</td>
</tr>
</tbody>
</table>

- **Cordierite**: Used from 1980 to 2010.
- **Silicon Carbide (SiC)**: Introduced in 1990 and used until 2010.
- **AT**: Application in 2000 and continued to 2010.
- **FBC**: Forced regeneration technique.
- **C-DPF + DeNOx**: Combination used from 2000 to 2010.
1. History of DPF Development

1-1. Basic Development

1986  Start Basic Research of SiC-DPF
      Feasibility Study in Comparison with Cordierite DPF
1987  Start Joint Development for PC-DPF
1991  Start Joint Development of CV-DPF
      (burner regeneration)
1993  Complete basic technology of
      Segmented SiC-DPF
      Success in Field Test
      in Tokyo-metropolitan bus
1. History of DPF Development

1-2. Market Development

1994  Start marketing in JP       OHW, CV, Retro-fit
1996  Start marketing world-wide   OHW, CV, Retro-fit + PC
1998  Start Joint Development with PSA
      Establish Pilot Plant
1999  PSA Decision to Use SiC-DPF
1. History of DPF Development

1-3. Mass production & Market expansion

2000  
Start Mass Production for PSA  
Launch First Series Vehicle with DPF

2000-2001  
Install Mass Production Line in France

2002  
Start of Production in IDFS  
Invention of Octo-Square design*

2003  
Start of other OEM application (C-DPF)

*Cell design
Square
Octo-Square
## 2. DPF Market Requirements

<table>
<thead>
<tr>
<th>Requirements</th>
<th>SC-AT</th>
<th>SiC</th>
<th>Cordierite</th>
</tr>
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<tbody>
<tr>
<td>Cost</td>
<td>+++</td>
<td>+</td>
<td>+++</td>
</tr>
<tr>
<td>Material</td>
<td>Mid</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>DPF Structure</td>
<td>Monolith</td>
<td>Segmented</td>
<td>Monolith</td>
</tr>
<tr>
<td>Performance</td>
<td>+++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Filtration efficiency</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Pressure drop</td>
<td>Very low</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Ash capacity</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Soot mass limit</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>
3. Features of “SC-AT”
3-1. Process Comparison

<table>
<thead>
<tr>
<th>SC-AT</th>
<th>SiC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mixing</td>
<td>1. Mixing</td>
</tr>
<tr>
<td>2. Kneading</td>
<td>2. Kneading</td>
</tr>
<tr>
<td>3. Extruding</td>
<td>3. Extruding</td>
</tr>
<tr>
<td>4. Plugging</td>
<td>4. Plugging</td>
</tr>
<tr>
<td>5. Sintering</td>
<td>5. Debinding</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>7. Segment Inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8. Assembling</td>
</tr>
<tr>
<td></td>
<td>9. Grinding</td>
</tr>
<tr>
<td></td>
<td>10. Skinning</td>
</tr>
<tr>
<td></td>
<td>11. Calcination</td>
</tr>
<tr>
<td></td>
<td>12. Final Inspection</td>
</tr>
</tbody>
</table>

Simple Process, High Yield, High Productivity
### 3. Features of “SC-AT”
#### 3-2. Material Comparison

<table>
<thead>
<tr>
<th>Substrate</th>
<th>AT</th>
<th>SiC</th>
<th>Cordierite</th>
<th>Effect on SML</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier</td>
<td><strong>Sumitomo</strong>&lt;br&gt;Corning</td>
<td>Ibiden, NGK</td>
<td>NGK, Corning</td>
<td></td>
</tr>
<tr>
<td>Theoretical density [g/cm³]</td>
<td>3.7</td>
<td>3.2</td>
<td>2.6</td>
<td><strong>High</strong></td>
</tr>
<tr>
<td>Heat Capacity [J/L·K]</td>
<td>2000</td>
<td>1900</td>
<td>1300</td>
<td><strong>High</strong></td>
</tr>
<tr>
<td>Thermal Conductivity [W/m·K]</td>
<td>2</td>
<td>50</td>
<td>2</td>
<td><strong>Low</strong></td>
</tr>
<tr>
<td>CTE / *10⁻⁶ [1/K]</td>
<td>1</td>
<td>4</td>
<td>&lt;1</td>
<td><strong>High</strong></td>
</tr>
</tbody>
</table>
3. Features of “SC-AT”

3-3. Cell Design Advantage

<table>
<thead>
<tr>
<th>Cell design</th>
<th>Square</th>
<th>Octo-square</th>
<th>Hexagonal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash capacity</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>dp initial</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>dp w soot</td>
<td>High</td>
<td>Medium</td>
<td>Very low</td>
</tr>
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</table>
### 3. Features of “SC-AT”
#### 3-4. Filter specification

<table>
<thead>
<tr>
<th>DPF</th>
<th>SC-AT</th>
<th>SiC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell design</td>
<td>Square</td>
<td>Hex</td>
</tr>
<tr>
<td>Weight [g L⁻¹] as of size 5.66”D / 6”L</td>
<td>800</td>
<td>770</td>
</tr>
<tr>
<td>dh* in/out [mm]</td>
<td>1.2/ 1.2</td>
<td>1.1/ 1.2</td>
</tr>
<tr>
<td>Cell density [cpsi]</td>
<td>290</td>
<td>350</td>
</tr>
<tr>
<td>Wall thickness [mil]</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>Segment binding area [%]</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Open frontal area [%]</td>
<td>33</td>
<td>41</td>
</tr>
<tr>
<td>Filtration area [m² L⁻¹]</td>
<td>1.0</td>
<td>1.3</td>
</tr>
</tbody>
</table>

** Including frontal area loss by segment binding layer.
3. Features of “SC-AT”

3-5. Pressure drop (dp) at cold flow bench

dp under soot-loading

Flow rate: 200Nm$^3$/h

Hex design shows the lowest dP with soot.
3. Features of “SC-AT”

3-6. Filtration efficiency at cold flow bench

<table>
<thead>
<tr>
<th>DPF</th>
<th>Filtration Efficiency** (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC-AT (Hex)</td>
<td>96</td>
</tr>
<tr>
<td>R-SiC (Octo-square)</td>
<td>94</td>
</tr>
</tbody>
</table>

**After 10 min. soot generation

Filtration efficiency ; SC-AT is comparable w/ R-SiC.
3. Features of “SC-AT”

3-7. SML test at engine bench

Test procedure

- Soot load
- Drop to Idle
- Blow-off test

Thermocouple position

Regeneration profile

(SC-AT(He) w/ 10gL⁻¹ soot)

- upstream DPF
- TDPF1
- TDPF3
- TDPF6
- TDPF9
- downstream DPF
- Speed
3. Features of “SC-AT”

3-7. SML test at engine bench

Blow-off test after thermal shock

Blow off test after cyclic regeneration

Smoke limit

Filtration efficiency > 99%

Smoke number / -

Soot load / g L⁻¹

Regeneration cycles / time

w/ 8 gL⁻¹ soot load

w/ 10 gL⁻¹ soot load
3. Features of “SC-AT”

3-7. SML test at engine bench

Distribution at Maximum temperature

(soot-load 12 g/L)

SC-AT(Hex)  

R-SiC(Octo-square)
3. Features of “SC-AT”

3-7. SML test at engine bench

Maximum temperature

Regeneration efficiency

![Graphs showing maximum temperature and regeneration efficiency for SC-AT (Hex) and R-SiC (Octo-square).]
4. Conclusion

Feature of Sumitomo DPF “SC-AT”

✓ Highly cost competitive.
✓ High thermal shock resistance.
✓ High ash capacity.
✓ Higher SML.
✓ Remarkably lower pressure drop.
✓ Comparable Filtration efficiency.
Sumitomo DPF - Exhibition
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Thank you very much for your attention.