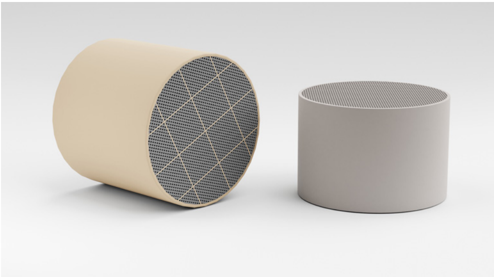
APPLICATION **NOTE**

Ceramics – Thermophysical Properties

Why Is Knowledge about the Thermal Characteristics of Cordierite Honeycomb Ceramics Important?

Jinyan Li and Shenjun Sheng, Applications Laboratory Shanghai, and Dorothea Stobitzer, Applications Laboratory Selb



1 Cordierite ceramics

Introduction

In the field of automobile exhaust gas purification, honeycomb ceramics are very important as catalyst carriers. By combining the catalyst carrier with catalysts (such as precious metals like platinum, rhodium, palladium, etc.), i.e., creating an exhaust gas catalytic purification device, and mounting it on the exhaust emission system, the harmful components in the exhaust gas (such as carbon monoxide CO, hydrocarbon HC, nitrogen oxides NOx, etc.) can be activated and chemically reacted, and transformed into harmless carbon dioxide, water and nitrogen, thus eliminating the harmful exhaust gas.

Due to their good refractoriness, low thermal expansion rate and other properties, cordierite honeycomb ceramics become core components of exhaust gas purification devices for diesel, gasoline and natural gas, serving as both the catalyst carrier and the exhaust emission channel for automobiles.

Cordierite ceramics (figure 1) as catalyst carriers have the following advantages:

- With a honeycomb structure and large specific surface area, they are conducive to the attachment and dispersion of catalyst active substances, which greatly improves the activity of the catalyst.
- Good thermal stability: The exhaust temperature of automobile engines generally ranges from 250-800°C, or even more than 800°C. Cordierite does not decompose or undergo phase change under high temperatures, which ensures the activity and service life of the catalyst.
- The coefficient of thermal expansion is small. The automobile engine starts and stops frequently; the low coefficient of thermal expansion for cordierite is favorable for preventing the rupture of the purification device over the long term in a repeated fast-cooling and fast-heating working environment, which helps ensure the effect of the catalyst and the safety of the exhaust pipeline.
- Cordierite ceramics feature low specific heat capacity. The engine is prone to producing more CO and HC during a cold start; cordierite as a carrier can make the catalyst reach the working temperature and play the catalytic role in a shorter period of time because of its lower specific heat.
- The thermal conductivity is suitable. Containers, large trucks and other diesel vehicles often need to travel long distances and for a long time, so the thermal conductivity and heat dissipation properties of the catalyst carrier are very important.

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Wittelsbacherstraße 42 · 95100 Selb · Germany
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at@netzsch.com · www.netzsch.com

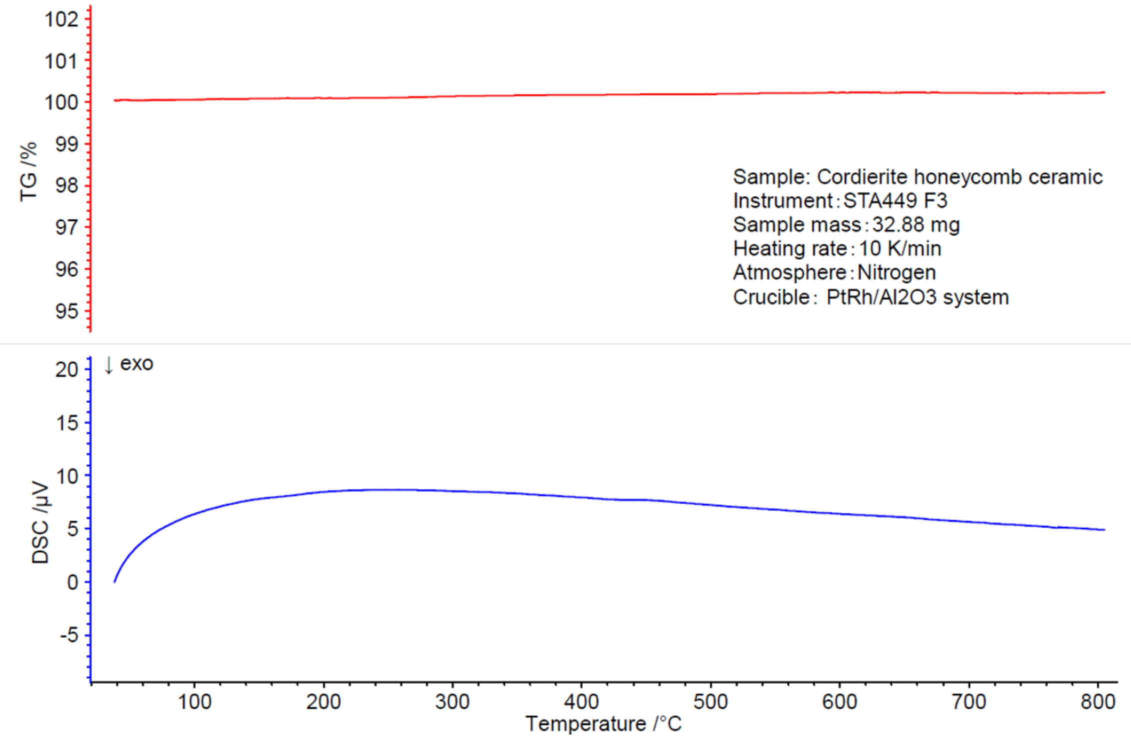
Measurement Conditions

In this application example, a cordierite sample was tested for thermal stability and specific heat capacity using the STA 449 ***F3*** Simultaneous Thermal Analyzer. The thermal expansion coefficient and thermal conductivity of this sample were also characterized using the DIL 402 *Classic* Thermal Expansion Instrument and the LFA 467 *HT HyperFlash®* Thermal Conductivity Instrument. The test temperature was from room temperature to 800°C, the engine exhaust temperature range.

Test Results and Discussion

Thermal Stability and Specific Heat Test

The test results of the STA measurements are as follows. Firstly, from the thermogravimetric (TGA) curve (figure 2), it can be seen that the sample undergoes no weight loss in the test temperature range.



2 TGA (red) and DSC results (blue) of cordierite honeycomb ceramic

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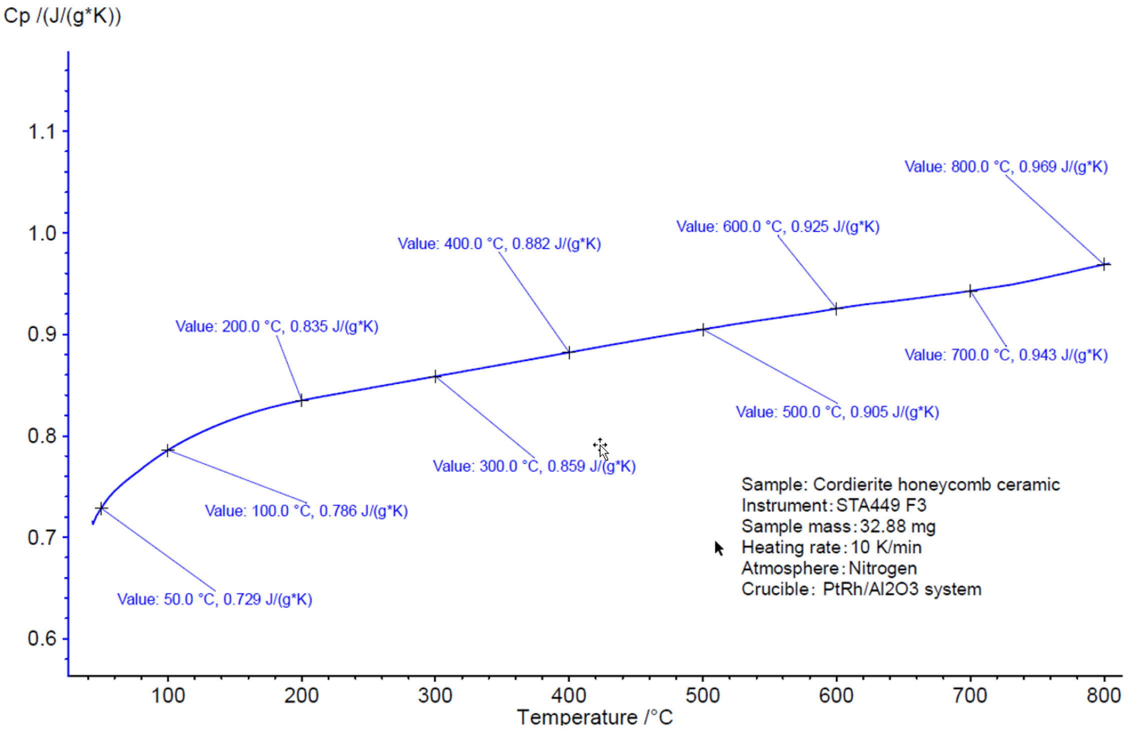
From the DSC curve (figure 3), it can be seen that it exhibits no obvious absorption or exothermic peaks in the test temperature range, i.e., there is no decomposition or phase change occurring. This indicates that the sample features good thermal stability in the engine exhaust temperature range. During the test, sapphire was used as the standard sample, and it was possible to simultaneously obtain the specific heat capacity of the sample by the ratio method. From the results in the figure, it can be seen that the specific heat capacity of the sample increases with increasing temperature, and the specific heat capacity at 50°C and 800°C is 0.729 J/(g*K) and 0.969 J/(g*K), respectively. Compared with the conventional α-Al_2O_3 ceramics (specific heat values of 0.823 J/(g*K) and 1.237 J/(g*K) at 50°C and 800°C, respectively), the specific heat of this sample is lower. To ensure the effectiveness of the specific heat test, 190-µl PtRh crucibles with Al_2O_3 liner were used for the test.



3 Specific heat capacity of cordierite honeycomb ceramic

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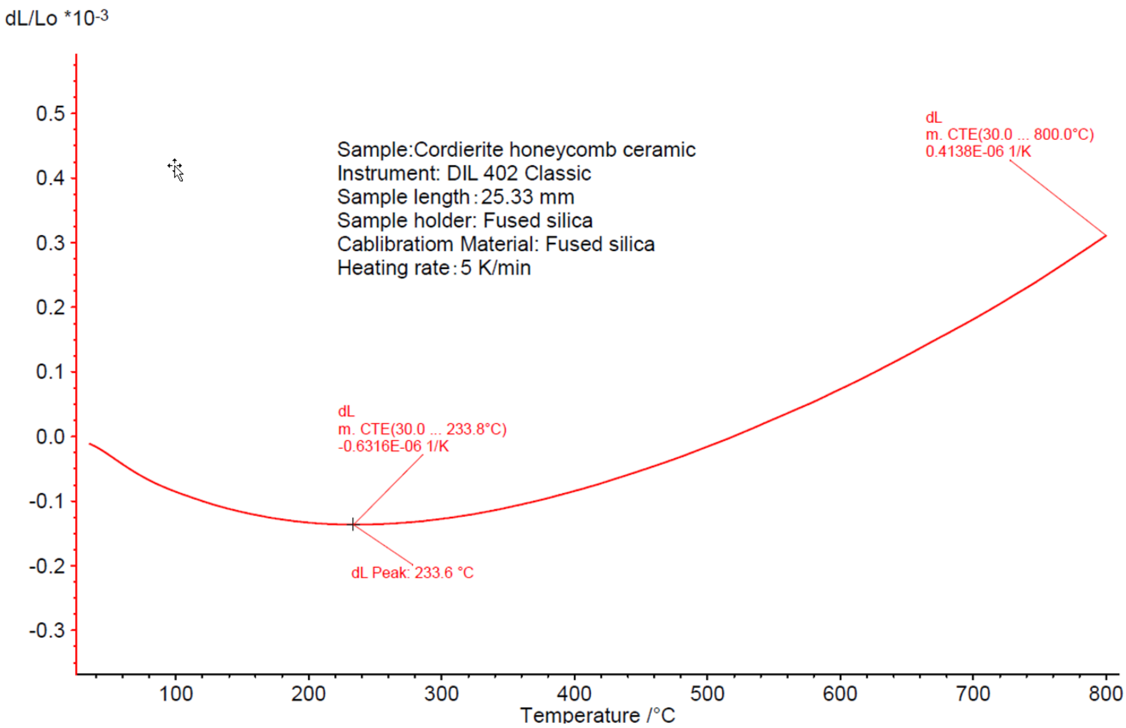
Coefficient of the Thermal Expansion Test

The dilatometer test results are shown in figure 4. It can be seen that the cordierite sample shrinks and then expands with increasing temperature in the temperature range from room temperature to 800°C, with a peak temperature of 233.6°C. The coefficient of thermal expansion (i.e., the engineering coefficient of expansion) in the range from 30°C-233.8°C is -0.6316E-06 1/K. The coefficient of thermal expansion in the range from 30°C-800°C is 0.4138E-06 1/K, which indicates that the sample's coefficient of thermal expansion is indeed small in the engine exhaust temperature range (α-Al_2O_3 ceramic has a coefficient of thermal expansion of 8.03E-06 1/K in the range from 25°C to 900°C). It is worth mentioning that because of the small coefficient of thermal expansion of the samples, both the sample holder and the specimen were made of fused silica for the tests.



4 Thermal expansion of cordierite honeycomb ceramic

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Thermal Conductivity Test

The LFA test results (figure 5) are as follows. LFA can directly measure the thermal diffusivity of the sample. The thermal conductivity of the sample can be obtained by multiplying the thermal diffusivity, density and specific heat capacity. The temperature range of the LFA test is 25°C-800°C, the temperature interval is 100 K, and three flash points are tested at each temperature point. From the information in the table, it can be seen that the results for the three flash points at the same temperature point are very close to each other, which indicates that the instrument has good test repeatability. From the trend graph below, it can be seen that both the thermal diffusivity and the thermal conductivity of the sample decrease with increasing temperature.

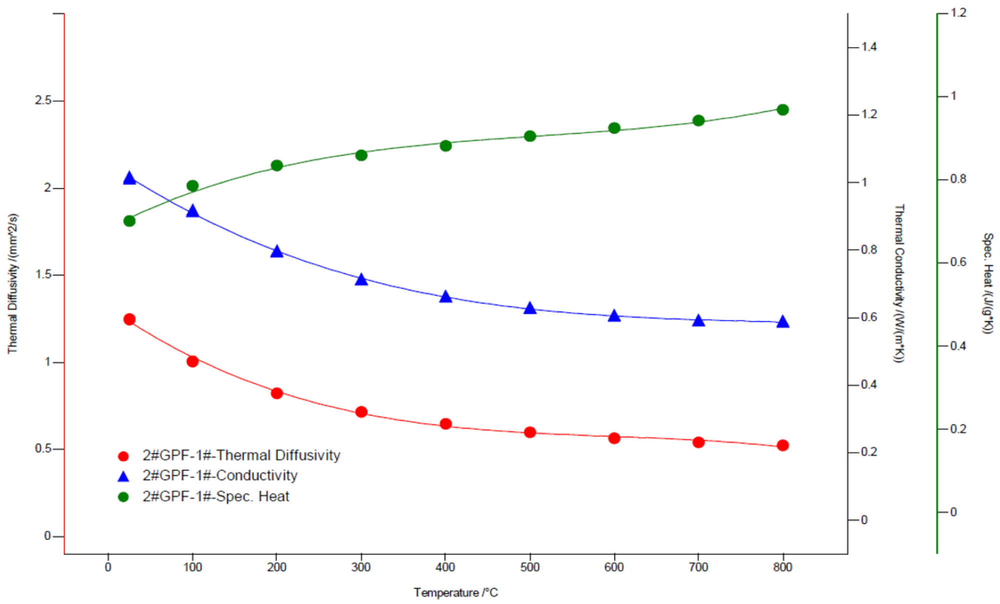
Thermal Diffusivity (Avg.) - NETZSCH LFA Analysis

General information

Database :	cordierite honeycomb ceramic.mc	**Remark(mment) :**	---
Instrument :	LFA 467	**Cp table :**	DPF1#
Identity :	c3631	**Expansion table :**	dL_const
Date :	2022/8/17	**Furnace :**	LFA 467 HighTemp S
Material :	2#GPF-1# - B	**Sample holder :**	Single round/12.7mm
Ref. density (20.0 °C) /(g/cm^3)	1.159	**Lamp :**	LFA 467 Flash Lamp
Sample :	2#GPF-1#	**Furnace TC :**	S
Type :	Single layer	**Sample TC :**	S
Sample position :	B	**Sample Xp / Tn :**	4.00 / 4.00
Detection Area (Diameter)/mm	2.8	**Furnace Xp / Tn :**	4.00 / 4.00
Filter/% :	0	**Calculation code**	Standard + p.c./l/1-0-l
Thickness (RT) /mm :	1.4770	**Purge 2 MFC**	ARGON
Diameter /mm :	12.500	**Protective MFC**	ARGON
Sensor :	InSb (HT)		
Operator :	ljy		

Results

Shot number	Temperature °C	Diffusivity mm^2/s	Std. Dev. mm^2/s	Uncertainty %	Conductivity W/(m*K)	Cp-table J/(g*K)
1, 2, 3	25.0	1.247	0.003	0.2	1.013	0.701
4, 5, 6	100.0	1.005	0.002	0.2	0.916	0.786
7, 8, 9	200.0	0.823	0.002	0.2	0.796	0.835
10, 11, 12	300.0	0.716	0.001	0.2	0.713	0.859
13, 14, 15	400.0	0.648	0.000	0.2	0.662	0.882
16, 17, 18	500.0	0.599	0.001	0.2	0.628	0.905
19, 20, 21	600.0	0.565	0.001	0.2	0.605	0.925
22, 23, 24	700.0	0.541	0.001	0.2	0.591	0.943
25, 26, 27	800.0	0.524	0.001	0.2	0.588	0.969



5 LFA test results

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Conclusion

In the industry, cordierite porous ceramics are prepared by various methods such as particle stacking, foaming and extrusion molding. The properties of cordierite ceramics obtained by different preparation methods and formulations each have their own advantages and disadvantages.

In this work, a cordierite sample was tested by means of STA, DIL and LFA methods in order to characterize the thermal stability, specific heat, thermal expansion properties and thermal conductivity of the sample.

NETZSCH has a full range of thermal analysis and physical property testing equipment, and can provide a full range of thermal analysis and testing solutions for cordierite honeycomb ceramics and other exhaust gas catalyst carrier ceramics.

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