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(54) **CATALYTICALLY ACTIVE PARTICULATE FILTER**

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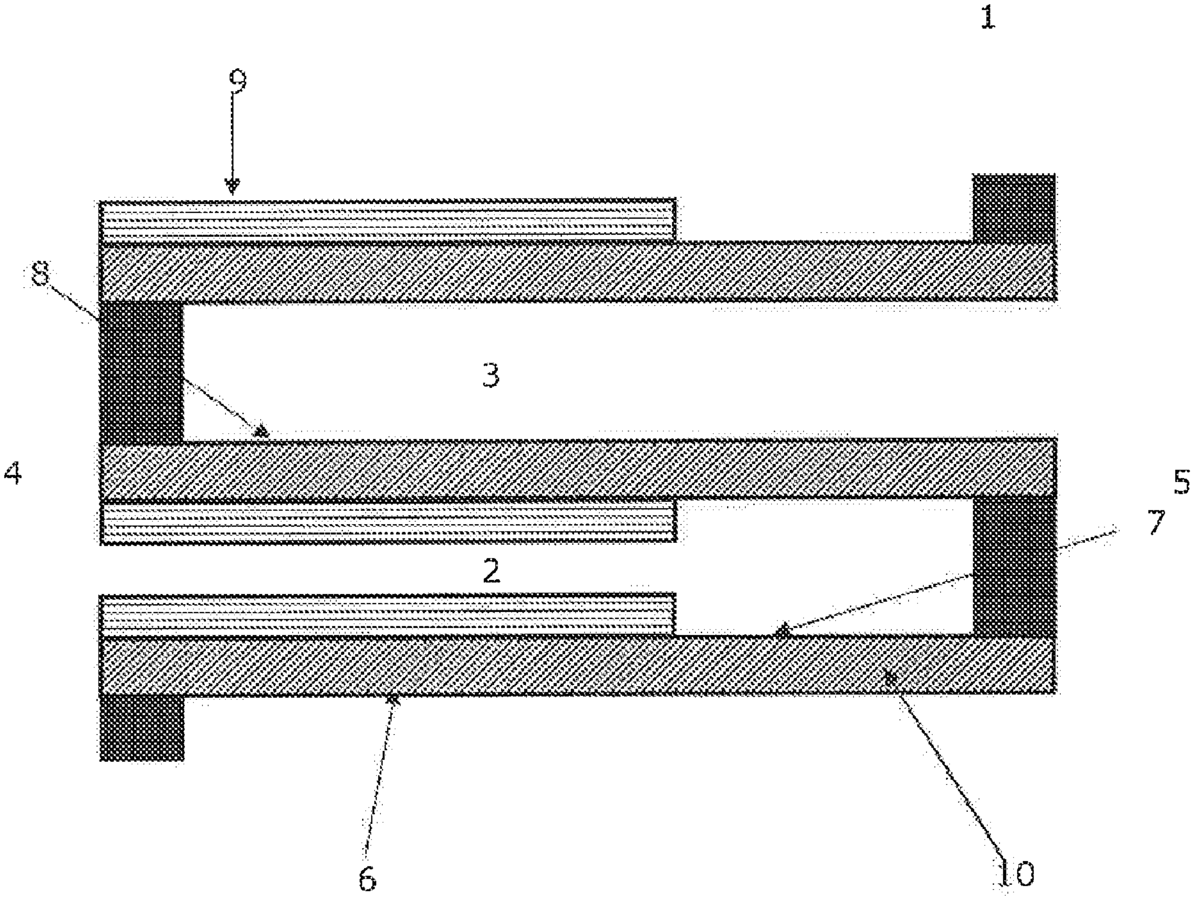
(57) **ABSTRACT**

The present invention relates to a particulate filter which comprises a wall-flow filter of length L and two different catalytically active coatings Y and Z, wherein the wall flow filter comprises channels E and A that extend in parallel between a first and a second end of the wall-flow filter and are separated by porous walls which form the surfaces O_E and O_A, respectively, and wherein the channels E are closed at the second end and the channels A are closed at the first end. The invention is characterized in that the coating Y is located in the channels E on the surfaces O_E and the coating Z is located in the porous walls.



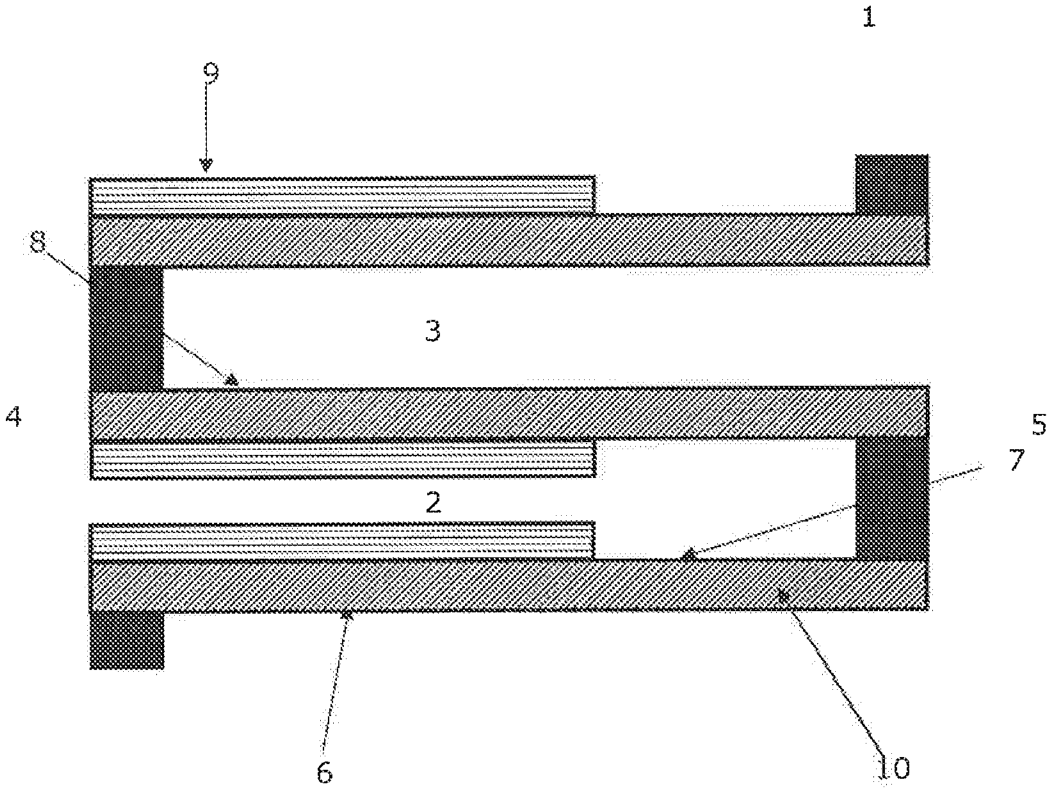


Figure 1

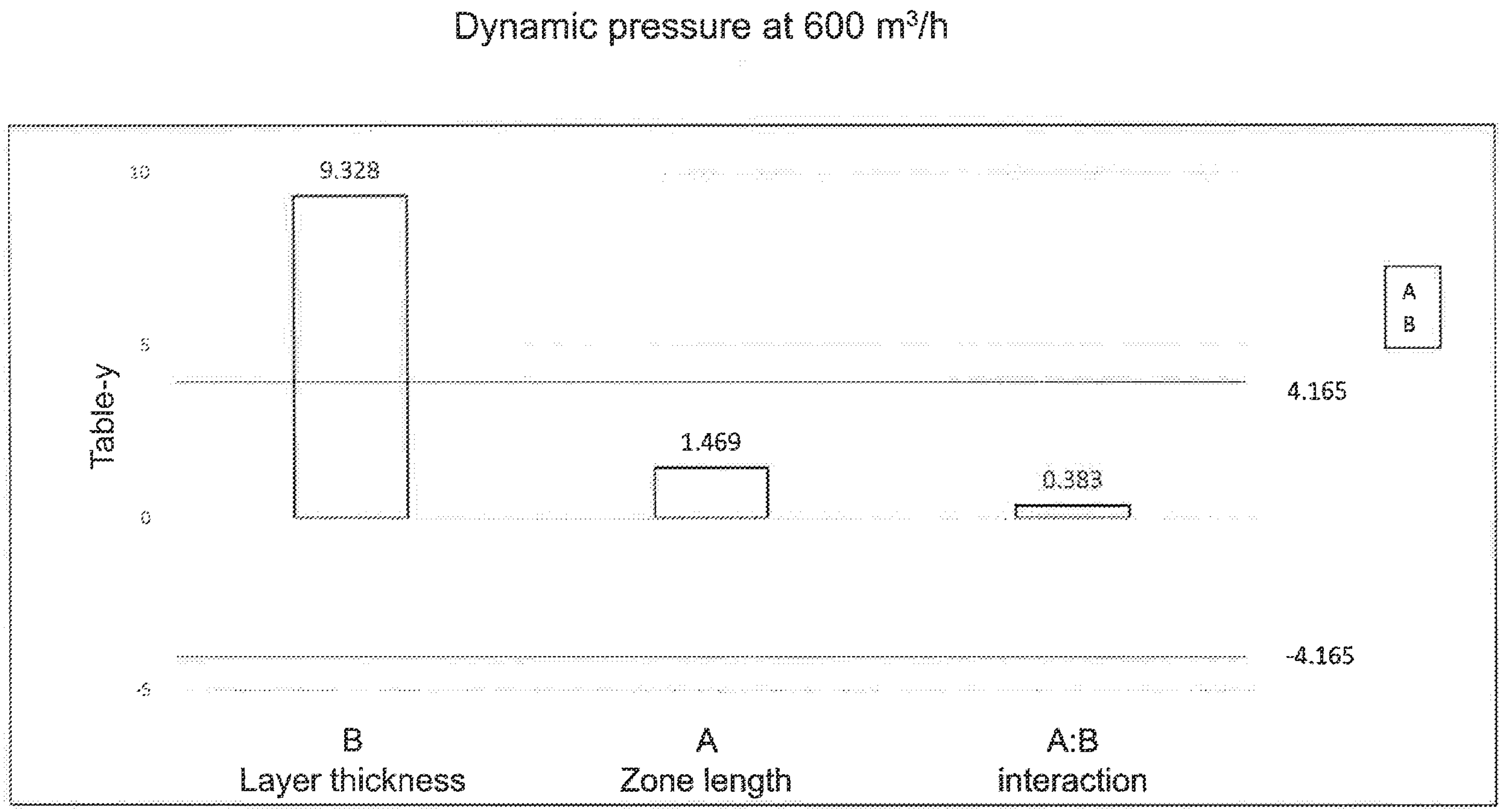

Dynamic pressure at 600 m³/h
Table-y
10
5
0
-5
9.328
1.469
0.383
4.165
-4.165
A
B
B
Layer thickness
A
Zone length
A:B
interaction

Fig. 2

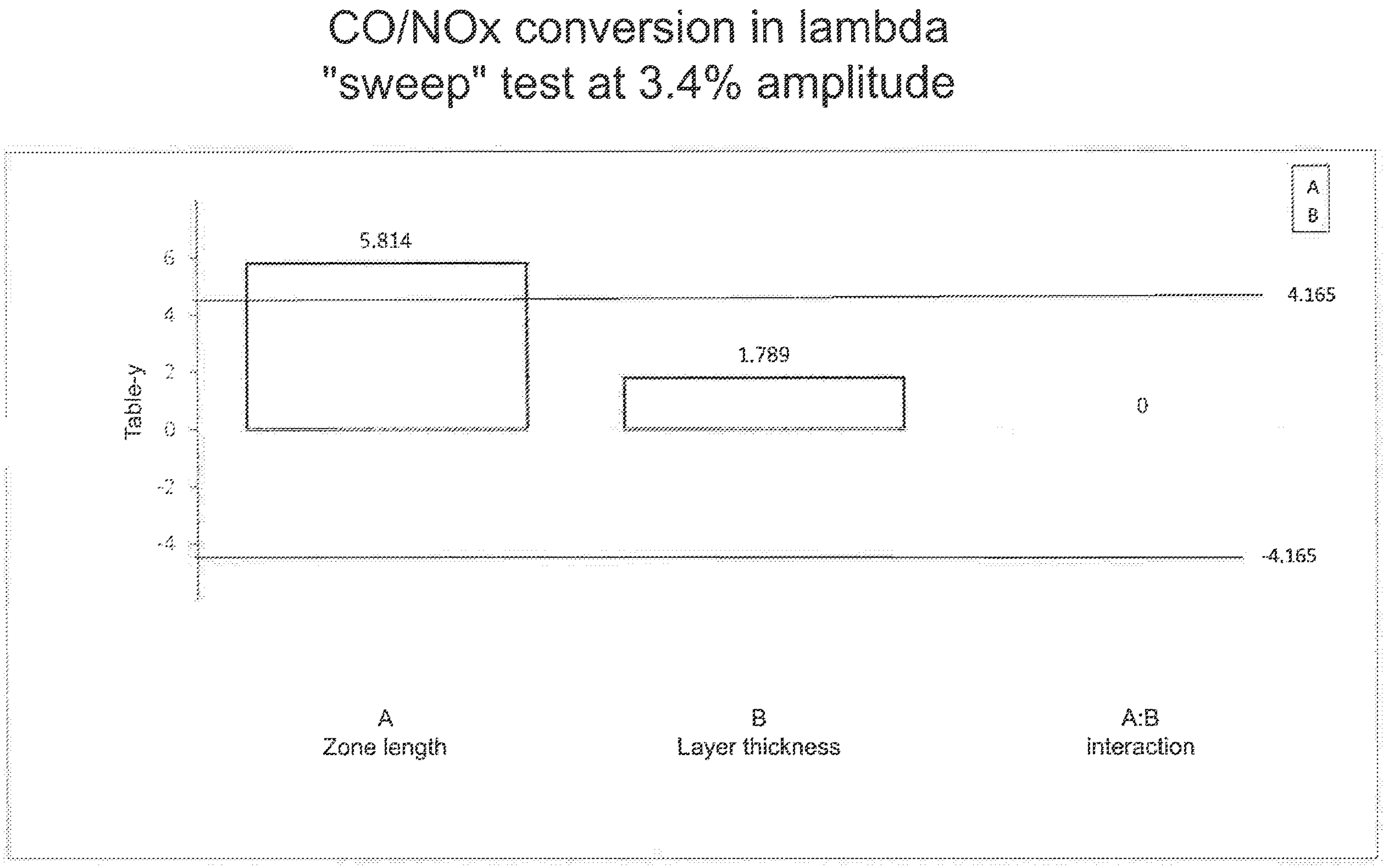

CO/NOx conversion in lambda
"sweep" test at 3.4% amplitude
A
B
Table-y
6
4
2
0
-2
-4
5.814
1.789
0
4.165
-4.165
A
Zone length
B
Layer thickness
A:B
interaction

Fig. 3

CATALYTICALLY ACTIVE PARTICULATE FILTER

[0001] The present invention relates to a catalytically active particulate filter that is particularly suitable for removing particles, carbon monoxide, hydrocarbons and nitrogen oxides from the exhaust gas of combustion engines fueled by stoichiometric air-fuel mixture.

[0002] Exhaust gases from combustion engines, i.e. gasoline engines, fueled by stoichiometric air-fuel mixtures are cleaned in conventional methods with the aid of three-way catalytic converters. Such catalytic converters are capable of simultaneously converting the three major gaseous pollutants of the engine, namely hydrocarbons, carbon monoxide and nitrogen oxides, into harmless components.

[0003] In addition to such gaseous pollutants, the exhaust gas from gasoline engines also contains extremely fine particles (PM) which result from the incomplete combustion of fuel and essentially consist of soot. In contrast to particulate emission by diesel engines, the particles in the exhaust gas of stoichiometrically operated gasoline engines are very small and have an average particle size of less than 1 μm. Typical particle sizes range from 10 to 200 nm. Furthermore, the quantity of particles emitted is very low and ranges from 2 to 4 mg/km.

[0004] The European exhaust emission standard EU-6c is associated with a conversion of the limit value for such particles from the particle mass limit value to a more critical particle number limit value of 6×10^{11}/km (in the Worldwide Harmonized Light Vehicles Test Cycle—WLTP). This creates a need for exhaust gas cleaning concepts for stoichiometrically operated combustion engines, which include effective equipment for removing particles.

[0005] Wall-flow filters made of ceramic materials, such as silicon carbide, aluminum titanate and cordierite, have proven themselves in the field of cleaning exhaust gases from lean-burn engines, i.e. in particular diesel engines. These are made up of a plurality of parallel channels formed by porous walls. The channels are alternately sealed at one of the two ends of the filter so that channels A, which are open at the first side of the filter and sealed at the second side of the filter, and channels B, which are sealed at the first side of the filter and open at the second side of the filter, are formed. Exhaust gas flowing into, for example, channels A can only leave the filter via channels B and must flow through the porous walls between channels A and B for this purpose. When the exhaust gas passes through the wall, the particles are retained and the exhaust gas is cleaned.

[0006] The particles retained in this manner must then be burnt off or oxidized in order to prevent a clogging of the filter or an unacceptable increase in the back pressure of the exhaust system.

[0007] For this purpose, the wall-flow filter is, for example, provided with catalytically active coatings that reduce the ignition temperature of soot. Applying such coatings to the porous walls between the channels (so-called "on-wall coating") or introducing them into the porous walls (so-called "in-wall coating") is already known. EP 1 657 410 A2 also already describes a combination of both coating types; that is, part of the catalytically active material is present in the porous walls and another part is present on the porous walls.

[0008] The concept of removing particles from exhaust gas using wall-flow filters has already been applied to the cleaning of exhaust gas from combustion engines operated with stoichiometric air-fuel mixtures; see, for example, EP 2042226 A2. According to its teaching, a wall-flow filter comprises two layers arranged one above the other, wherein one can be arranged in the porous wall and the other can be arranged on the porous wall.

[0009] DE 102011050788 A1 pursues a similar concept. There, the porous filter walls contain a catalyst material of a three-way catalytic converter, while in addition a catalyst material of a three-way catalytic converter is applied to partial regions of the filter walls.

[0010] Other documents that describe filter substrates provided with catalytically active coatings are EP 3205388 A1, EP 3207977 A1, EP 3207978 A1, EP 3207987 A1, EP 3207989 A1. EP 3207990 A1 and EP 3162428 A1.

[0011] There is still a need for catalytically active particulate filters that combine the functionalities of a particulate filter and a three-way catalytic converter and at the same time adhere to the limits that will apply in the future.

[0012] The present invention relates to a particulate filter for removing particles, carbon monoxide, hydrocarbons and nitrogen oxides from the exhaust gas of combustion engines operated with stoichiometric air-fuel mixtures, which filter comprises a wall-flow filter of length L and two coatings Y and Z, wherein the wall-flow filter comprises channels E and A that extend in parallel between a first and a second end of the wall-flow filter and are separated by porous walls which form surfaces O_E and O_A, respectively, and wherein the channels E are closed at the second end and the channels A are closed at the first end, characterized in that the coating Y is located in the channels E on the surfaces O_E and extends from the first end of the wall-flow filter over a length of 51 to 90% of the length L, and the coating Z is located in the porous walls and extends from the second end of the wall-flow filter over a length of 60 to 100% of the length L.

[0013] The coatings Y and Z are three-way catalytically active, especially at operating temperatures of 250 to 1100° C. They are preferably different from each other, but both usually contain one or more noble metals fixed to one or more substrate materials and one or more oxygen storage components. The coatings Y and Z may differ in the components they contain. For example, they may differ in terms of the noble metals they contain or the oxygen storage components they contain. However, they may also contain identical constituents. In the latter case, the coatings Y and Z may contain the components in equal or different amounts.

[0014] Platinum, palladium and rhodium are particularly suitable as noble metals, wherein palladium, rhodium or palladium and rhodium are preferred and palladium and rhodium are particularly preferred.

[0015] Based on the particulate filter according to the invention, the proportion of rhodium in the entire noble metal content is in particular greater than or equal to 10% by weight.

[0016] The noble metals are usually used in quantities of 0.15 to 5 g/l based on the volume of the wall-flow filter.

[0017] In the context of the invention, it may happen that some washcoat of the layers Y penetrates into the surface pores of the wall-flow filter during coating. According to the invention, however, this should be avoided as much as possible. Generally, the amount of washcoat which penetrates into the surface regions of the porous filter wall is <10%, more preferably <5% and most preferably <2%, based on the weight of washcoat used.

[0018] Since the coating Y is an on-wall coating in the present case, it has a certain elevation over the wall surface. However, the thickness of the two layers is generally between 5-250 μm, preferably 7.5-225 μm and most preferably between 10-200 μm.

[0019] All materials familiar to the person skilled in the art for this purpose can be considered as substrate materials for the noble metals. Such materials are in particular metal oxides with a BET surface area of 30 to 250 m^2/g, preferably 100 to 200 m^2/g (determined according to DIN 66132—newest version on the date of application).

[0020] Particularly suitable substrate materials for the noble metals are selected from the series consisting of aluminum oxide, doped aluminum oxide, silicon oxide, titanium dioxide and mixed oxides of one or more of these. Doped aluminum oxides are, for example, aluminum oxides doped with lanthanum oxide, zirconium oxide and/or titanium oxide. Lanthanum-stabilized aluminum oxide is advantageously used, wherein lanthanum is used in quantities of 1 to 10% by weight, preferably 3 to 6% by weight, in each case calculated as La_2O_3 and based on the weight of the stabilized aluminum oxide.

[0021] Cerium/zirconium/rare earth metal mixed oxides are particularly suitable as oxygen storage components. The term "cerium/zirconium/rare earth metal mixed oxide" within the meaning of the present invention excludes physical mixtures of cerium oxide, zirconium oxide and rare earth oxide. Rather, "cerium/zirconium/rare earth metal mixed oxides" are characterized by a largely homogeneous, three-dimensional crystal structure that is ideally free of phases of pure cerium oxide, zirconium oxide or rare earth oxide. Depending on the manufacturing process, however, not completely homogeneous products may arise which can generally be used without any disadvantage.

[0022] In all other respects, the term "rare earth metal" or "rare earth metal oxide" within the meaning of the present invention does not include cerium or cerium oxide.

[0023] Lanthanum oxide, yttrium oxide, praseodymium oxide, neodymium oxide and/or samarium oxide can, for example, be considered as rare earth metal oxides in the mixed cerium/zirconium/rare earth metal mixed oxides.

[0024] Lanthanum oxide, yttrium oxide and/or praseodymium oxide are preferred. Lanthanum oxide and/or yttrium oxide are particularly preferred, and lanthanum oxide and yttrium oxide, yttrium oxide and praseodymium oxide, and lanthanum oxide and praseodymium oxide are more particularly preferred.

[0025] In embodiments of the present invention, the oxygen storage components are free from neodymium oxide.

[0026] In accordance with the invention, the cerium oxide to zirconium oxide ratio in the cerium/zirconium/rare earth metal mixed oxides can vary within wide limits. It can be, for example, 0.1 to 1.5, preferably 0.2 to 1 or 0.3 to 0.5.

[0027] In embodiments of the present invention, the coating Y comprises an oxygen storage component with a cerium oxide content of 20 to 40% by weight, based on the weight of the oxygen storage component.

[0028] In embodiments of the present invention, the coating Z comprises an oxygen storage component with a cerium oxide content of 20 to 60% by weight, based on the weight of the oxygen storage component.

[0029] Lanthanum oxide-containing oxygen storage components have in particular a lanthanum oxide to cerium oxide mass ratio of 0.05 to 0.5.

[0030] The coatings Y and Z usually contain oxygen storage components in quantities from 15 to 120 g/l, based on the volume of the wall-flow filter.

[0031] The mass ratio of substrate materials and oxygen storage components in the coatings Y and Z is usually 0.3 to 1.5, for example 0.4 to 1.3.

[0032] In the embodiments of the present invention, one or both of the coatings Y and Z contain an alkaline earth compound, such as strontium oxide, barium oxide or barium sulfate. The amount of barium sulfate per coating is, in particular, 2 to 20 g/l volume of the wall-flow filter.

[0033] Coating Z contains, in particular, strontium oxide or barium oxide.

[0034] In further embodiments of the present invention, one or both of the coatings Y and Z contain additives, such as rare earth compounds, such as lanthanum oxide, and/or binders, such as aluminum compounds. Such additives are used in quantities that can vary within wide limits and that the person skilled in the art can determine in the specific case by simple means.

[0035] In embodiments of the present invention, the coatings Y and Z are different from each other, wherein, however, they both comprise lanthanum-stabilized aluminum oxide, along with rhodium, palladium or palladium and rhodium and an oxygen storage component comprising zirconium oxide, cerium oxide, lanthanum oxide, and yttrium oxide and/or praseodymium oxide.

[0036] In coating Z, the yttrium oxide content is in particular 5 to 15% by weight, based on the weight of the oxygen storage component. The lanthanum oxide to yttrium oxide weight ratio is in particular 0.1 to 1, preferably 0.125-0.75 and most preferably 0.15-0.5.

[0037] In embodiments of the present invention, the yttrium oxide content in the oxygen storage component of the coating Z is larger than or equal to the yttrium oxide content in the oxygen storage component of the coating Y, based in each case on the weight of the respective oxygen storage component.

[0038] In particular, the coating Z may comprise an additional oxygen storage component containing zirconium oxide, cerium oxide, praseodymium oxide and lanthanum oxide.

[0039] In this case, the praseodymium oxide content in particular is 2 to 10% by weight, based on the weight of the oxygen storage component. The lanthanum oxide to praseodymium oxide weight ratio is in particular 0.1 to 2, preferably 0.125-1.7 and most preferably 0.15-1.5.

[0040] In embodiments of the present invention, in coating Z the zirconium oxide content of the yttrium oxide-containing oxygen storage component is greater than the zirconium oxide content of the praseodymium oxide-containing oxygen storage component, in each case based on the respective oxygen storage component. In this embodiment in particular, it is advantageous if the weight ratio of Ce:Zr in the yttrium oxide-containing oxygen storage component (CeZr1) is smaller than the Ce:Zr ratio in the praseodymium oxide-containing oxygen storage component (CeZr2). In this case, the value of Ce:Zr1 is 0.1-1.0, preferably 0.15-0.75 and most preferably 0.2-0.6. By contrast, for Ce:Zr2, values of 0.2-1.5, preferably 0.25-1.3 and most preferably 0.3-1.1 are found.

[0041] In embodiments, the coatings Y and Z each comprise lanthanum-stabilized aluminum oxide in quantities from 20 to 70% by weight, particularly preferably 25 to 60%

by weight, and the oxygen storage component in quantities from 25 to 80% by weight, particularly preferably 40 to 70% by weight, in each case based on the total weight of the coating Y or Z.

[0042] In embodiments of the present invention, in coating Y, the weight ratio of aluminum oxide to the oxygen storage component is at least 0.7.

[0043] In embodiments of the present invention, in coating Z, the weight ratio of aluminum oxide to the oxygen storage component is at least 0.3.

[0044] In embodiments of the present invention, the coating Y extends from the first end of the wall-flow filter over 51 to 90%, in particular 57 to 85%, of the length L of the wall-flow filter. The load of the wall-flow filter with coating Y preferably amounts to 33 to 125 g/l, based on the volume of the wall-flow filter.

[0045] In embodiments of the present invention, the coating Z extends from the second end of the wall-flow filter over 51 to 100%, preferably over 57 to 100%, more preferably over 90 to 100% of the length L of the wall-flow filter. The load of the wall-flow filter with coating Z preferably amounts to 33 to 125 g/l, based on the volume of the wall-flow filter.

[0046] The total washcoat load of the particulate filter in accordance with the invention is in particular 40 to 150 g/l, based on the volume of wall-flow filter.

[0047] In embodiments of the present invention, the sum of the lengths of coating Y and coating Z is 110 to 180% of length L.

[0048] In embodiments of the present invention, neither coating Y nor coating Z contains a zeolite or a molecular sieve.

[0049] In one embodiment of the present invention, the present invention relates to a particulate filter which comprises a wall-flow filter of length L and two different coatings Y and Z, wherein the wall-flow filter comprises channels E and A that extend in parallel between a first and a second end of the wall-flow filter and are separated by porous walls forming surfaces O_E and O_A, respectively, wherein the channels E are closed at the second end and the channels A are closed at the first end, wherein

[0050] Coating Y is located in the channels E on the surfaces O_E and extends from the first end of the wall-flow filter over 57 to 65% of the length L and contains aluminum oxide in an amount of 35 to 60% by weight, based on the total weight of the coating Y, palladium, rhodium or palladium and rhodium and an oxygen storage component in an amount of 40 to 50% by weight, based on the total weight of the coating Y, wherein the oxygen storage component comprises zirconium oxide, cerium oxide, lanthanum oxide and yttrium oxide or zirconium oxide, cerium oxide, lanthanum oxide and praseodymium oxide, and

[0051] Coating Z is located in the porous walls and extends from the second end of the wall-flow filter over 60 to 100% of the length L and contains aluminum oxide in an amount of 25 to 50% by weight, based on the total weight of the coating, palladium, rhodium or palladium and rhodium and two oxygen storage components in a total amount of 50 to 80% by weight, based on the total weight of the coating Z, wherein one oxygen storage component contains zirconium oxide, cerium oxide, lanthanum oxide and yttrium oxide and the other contains zirconium oxide, cerium oxide, lanthanum oxide and praseodymium oxide.

[0052] Wall-flow filters that can be used in accordance with the present invention are well-known and available on the market. They consist of, for example, silicon carbide, aluminum titanate or cordierite, and have, for example, a cell density of 200 to 400 cells per inch and usually a wall thickness between 6 and 12 mil, or 0.1524 and 0.305 millimeters.

[0053] In the uncoated state, they have porosities of 50 to 80, in particular 55 to 75%, for example. In the uncoated state, their average pore size is, for example, 10 to 25 micrometers.

[0054] Generally, the pores of the wall-flow filter are so-called open pores, that is, they have a connection to the channels. Furthermore, the pores are normally interconnected with one another. This enables, on the one hand, the easy coating of the inner pore surfaces and, on the other hand, the easy passage of the exhaust gas through the porous walls of the wall-flow filter.

[0055] The particulate filter in accordance with the invention can be produced according to methods known to the person skilled in the art, for example by applying a coating suspension, which is usually called a washcoat, to the wall-flow filter by means of one of the usual dip coating methods or pump and suction coating methods. Thermal post-treatment or calcination usually follow.

[0056] The coatings Y and Z are obtained in separate and successive coating steps.

[0057] The person skilled in the art knows that the average pore size of the wall-flow filter and the average particle size of the catalytically active materials must be matched to each other in order to achieve an on-wall coating or an in-wall coating. In the case of an in-wall coating, the average particle size of the catalytically active materials must be small enough to penetrate the pores of the wall-flow filter. In contrast, in the case of an on-wall coating, the average particle size of the catalytically active materials must be large enough not to penetrate the pores of the wall-flow filter.

[0058] In embodiments of the present invention, the coating suspensions for the production of the coatings Y are ground up to a particle size distribution of d_{50}=4 to 8 μm and d_{99}=22 to 16 μm.

[0059] In embodiments of the present invention, the coating suspensions for the production of coating Z are ground up to a particle size distribution of d_{50}=1 to 2 μm and d_{99}=6 to 7 μm.

[0060] The particulate filter according to the invention is perfectly suited for removing particles, carbon monoxide, hydrocarbons and nitrogen oxides out of the exhaust gas of combustion engines operated with stoichiometric air/fuel mixture.

[0061] The present invention thus also relates to a method for removing particles, carbon monoxide, hydrocarbons and nitrogen oxides from the exhaust gas of combustion engines operated with stoichiometric air/fuel mixture, characterized in that the exhaust gas is conducted through a particulate filter according to the invention.

[0062] The exhaust gas can be conducted through a particulate filter according to the invention in such a way that it enters the particulate filter through channels E and leaves it again through channels A.

[0063] However, it is also possible for the exhaust gas to enter the particulate filter through channels A and to leave it again through channels E.

[0064] FIG. **1** shows a particulate filter in accordance with the invention, comprising a wall-flow filter of length L (**1**) with channels E (**2**) and channels A (**3**), which extend in parallel between a first end (**4**) and a second end (**5**) of the wall-flow filter and are separated by porous walls (**6**) forming surfaces O_E (**7**) and O_A (**8**), respectively, and wherein channels E (**2**) are closed at the second end (**5**) and channels A (**3**) are closed at the first end (**4**). Coating Y (**9**) is located in the channels E (**2**) on the surfaces O_E (**7**) and coating Z (**10**) is located in the porous walls (**6**).

[0065] The invention is explained in more detail in the following examples.

COMPARATIVE EXAMPLE 1

[0066] Aluminum oxide stabilized with lanthanum oxide was suspended in water with a first oxygen storage component which comprised 40% by weight cerium oxide, zirconium oxide, lanthanum oxide and praseodymium oxide and a second oxygen storage component which comprised 24% by weight cerium oxide, zirconium oxide, lanthanum oxide and yttrium oxide. Both oxygen storage components were used in equal parts. The weight ratio of aluminum oxide and oxygen storage component was 30:70. The suspension thus obtained was then mixed with a palladium nitrate solution and a rhodium nitrate solution under constant stirring. The resulting coating suspension was used directly for coating a commercially available wall-flow filter substrate, wherein the coating was introduced into the porous filter wall over 100% of the substrate length. The total load of this filter amounted to 100 g/l; the total noble metal load amounted to 0.44 g/l with a ratio of palladium to rhodium of 8:3. The coated filter thus obtained was dried and then calcined. It is hereinafter referred to as VGPF 1.

EXAMPLE 1

[0067] a) Application of the in-Wall Coating:

[0068] Aluminum oxide stabilized with lanthanum oxide was suspended in water with a first oxygen storage component which comprised 40% by weight cerium oxide, zirconium oxide, lanthanum oxide and praseodymium oxide and a second oxygen storage component which comprised 24% by weight cerium oxide, zirconium oxide, lanthanum oxide and yttrium oxide. Both oxygen storage components were used in equal parts. The weight ratio of aluminum oxide and oxygen storage component was 30:70. The suspension thus obtained was then mixed with a palladium nitrate solution and a rhodium nitrate solution under constant stirring. The resulting coating suspension was used directly for coating a commercially available wall-flow filter substrate, wherein the coating was introduced into the porous filter wall over 100% of the substrate length. The load of this filter amounted to 100 g/l; the noble metal load amounted to 0.34 g/l with a ratio of palladium to rhodium of 16:3. The coated filter thus obtained was dried and then calcined.

[0069] b) Coating the Input Channels

[0070] Aluminum oxide stabilized with lanthanum oxide was suspended in water with an oxygen storage component which comprised 24% by weight cerium oxide, zirconium oxide, lanthanum oxide and yttrium oxide. The weight ratio of aluminum oxide and oxygen storage component was 56:44. The suspension thus obtained was then mixed with a palladium nitrate solution and a rhodium nitrate solution under constant stirring. The resulting coating suspension was used directly to coat the wall-flow filter substrate obtained under a). wherein the filter walls of the substrate were coated in the input channels to a length of 38% of the filter length. The load of the input channel amounted to 54 g/l; the noble metal load amounted to 0.27 g/l with a ratio of palladium to rhodium of 2.6:5. The coated filter thus obtained was dried and then calcined. The total load of this filter thus amounted to 121 g/l; the total noble metal load amounted to 0.44 g/with a ratio of palladium to rhodium of 8:3. It is hereinafter referred to as GPF 1.

[0071] Catalytic Characterization

[0072] The particulate filters VGPF1 and GPF1 were aged together in an engine test bench aging process. This aging process consists of an overrun fuel cut-off aging process with an exhaust gas temperature of 950° C. before the catalyst inlet (maximum bed temperature of 1030° C.). The aging time was 9.5 hours (see Motortechnische Zeitschrift, 1994, 55, 214-218).

[0073] The catalytically active particulate filters were then tested in the aged state at an engine test bench in the so-called "light-off test" and in the "lambda sweep test." In the light-off test, the light-off performance is determined in the case of a stoichiometric exhaust gas composition with a constant average air ratio λ (λ=0.999 with 3.4% amplitude).

[0074] Table 1 below contains the temperatures T_{50} at which 50% of each of the considered components is converted.

TABLE 1

	T_{50} HC stoichiometric	T_{50} CO stoichiometric	T_{50} NOx stoichiometric
VGPF1	418	430	432
GPF1	377	384	387

[0075] The dynamic conversion behavior of the particulate filters was determined in a lambda sweep test in a range from λ=0.99-1.01 at a constant temperature of 510° C. The amplitude of λ in this case amounted to ±6.8%. Table 2 shows the conversion at the intersection of the CO and NOx conversion curves, along with the associated HC conversion of the aged particulate filters.

TABLE 2

	CO/NOx conversion at the point of intersection	HC conversion at λ of the CO/NOx point of intersection
VGPF1	79%	94%
GPF1	83%	95%

[0076] The particulate filter GPF1 according to the invention shows a marked improvement in light-off performance and dynamic CO/NOx conversion in the aged state compared with VGPF1.

COMPARATIVE EXAMPLE 2

[0077] a) Application of the in-Wall Coating:

[0078] Aluminum oxide stabilized with lanthanum oxide was suspended in water with a first oxygen storage component which comprised 40% by weight cerium oxide, zirconium oxide, lanthanum oxide and praseodymium oxide and a second oxygen storage component which comprised 24% by weight cerium oxide, zirconium oxide, lanthanum oxide and yttrium oxide. Both oxygen storage components were used in equal parts. The weight ratio of aluminum oxide and oxygen storage component was 30:70. The suspension thus obtained was then mixed with a palladium nitrate solution and a rhodium nitrate solution under constant stirring. The resulting coating suspension was used directly for coating a commercially available wall-flow filter substrate, wherein the coating was introduced into the porous filter wall over 100% of the substrate length. The total load of this filter amounted to 75 g/l; the noble metal load amounted to 0.71 g/l with a palladium to rhodium ratio of 3:1. The coated filter thus obtained was dried and then calcined.

[0079] b) Coating the Input Channels

[0080] Aluminum oxide stabilized with lanthanum oxide was suspended in water with an oxygen storage component which comprised 24% by weight cerium oxide, zirconium oxide, lanthanum oxide and yttrium oxide. The weight ratio of aluminum oxide and oxygen storage component was 56:44. The suspension thus obtained was then mixed with a palladium nitrate solution and a rhodium nitrate solution under constant stirring. The resulting coating suspension was used directly to coat the wall-flow filter substrate obtained under a), wherein the filter walls of the substrate were coated in the input channels to a length of 25% of the filter length. The load of the input channel amounted to 50 g/l; the noble metal load amounted to 2.12 g/l with a ratio of palladium to rhodium of 5:1. The coated filter thus obtained was dried and then calcined.

[0081] c) Coating the Output Channels

[0082] Aluminum oxide stabilized with lanthanum oxide was suspended in water with an oxygen storage component which comprised 24% by weight cerium oxide, zirconium oxide, lanthanum oxide and yttrium oxide. The weight ratio of aluminum oxide and oxygen storage component was 56:44. The suspension thus obtained was then mixed with a palladium nitrate solution and a rhodium nitrate solution under constant stirring. The resulting coating suspension was used directly to coat the wall-flow filter substrate obtained under b), wherein the filter walls of the substrate were coated in the output channels to a length of 25% of the filter length. The load of the output channel amounted to 50 g/l; the noble metal load amounted to 2.12 g/l with a ratio of palladium to rhodium of 5:1. The coated filter thus obtained was dried and then calcined. The total load of this filter thus amounted to 100 g/l; the total noble metal load amounted to 1.77 g/l with a ratio of palladium to rhodium of 4:1. It is hereinafter referred to as VGPF2.

EXAMPLE 2

[0083] a) Application of the in-Wall Coating:

[0084] Aluminum oxide stabilized with lanthanum oxide was suspended in water with a first oxygen storage component which comprised 40% by weight cerium oxide, zirconium oxide, lanthanum oxide and praseodymium oxide and a second oxygen storage component which comprised 24% by weight cerium oxide, zirconium oxide, lanthanum oxide and yttrium oxide. Both oxygen storage components were used in equal parts. The weight ratio of aluminum oxide and oxygen storage component was 30:70. The suspension thus obtained was then mixed with a palladium nitrate solution and a rhodium nitrate solution under constant stirring. The resulting coating suspension was used directly for coating a commercially available wall-flow filter substrate, wherein the coating is introduced into the porous filter wall over 100% of the substrate length. The load of this filter amounted to 50 g/l; the noble metal load amounted to 0.71 g/l with a ratio of palladium to rhodium of 3:1. The coated filter thus obtained was dried and then calcined.

[0085] b) Coating the Input Channels

[0086] Aluminum oxide stabilized with lanthanum oxide was suspended in water with an oxygen storage component which comprised 24% by weight cerium oxide, zirconium oxide, lanthanum oxide and yttrium oxide. The weight ratio of aluminum oxide and oxygen storage component was 56:44. The suspension thus obtained was then mixed with a palladium nitrate solution and a rhodium nitrate solution under constant stirring. The resulting coating suspension was used directly to coat the wall-flow filter substrate obtained under a), wherein the filter walls of the substrate were coated in the input channels to a length of 60% of the filter length. The load of the input channel amounted to 83.3 g/l; the noble metal load amounted to 1.77 g/l with a ratio of palladium to rhodium of 42:8. The coated filter thus obtained was dried and then calcined. The total load of this filter thus amounted to 100 g/l; the total noble metal load amounted to 1.77 g/l with a ratio of palladium to rhodium of 4:1. It is hereinafter referred to as GPF2

[0087] Catalytic Characterization

[0088] The particulate filters VGPF2 and GPF2 were aged together in an engine test bench aging process. This aging process consists of an overrun fuel cut-off aging process with an exhaust gas temperature of 950° C. before the catalyst inlet (maximum bed temperature of 1030° C.). The aging time was 58 hours (see Motortechnische Zeitschrift, 1994, 55, 214-218).

[0089] The catalytically active particulate filters were then tested in the aged state at an engine test bench in the so-called "light-off test" and in the "lambda sweep test." In the light-off test, the light-off performance is determined in the case of a stoichiometric exhaust gas composition with a constant average air ratio λ (λ=0.999 with 3.4% amplitude).

[0090] Table 3 below contains the temperatures T_{50} at which 50% of each of the considered components is converted.

TABLE 3

	T_{50} HC stoichiometric	T_{50} CO stoichiometric	T_{50} NOx stoichiometric
VGPF2	356	360	365
GPF2	351	356	359

[0091] The dynamic conversion behavior of the particulate filters was determined in a lambda sweep test in a range from λ=0.99-1.01 at a constant temperature of 510° C. The amplitude of λ in this case amounted to ±6.8%. Table 4 shows the conversion at the intersection of the CO and NOx conversion curves, along with the associated HC conversion of the aged particulate filters.

TABLE 4

	CO/NOx conversion at the point of intersection	HC conversion at λ of the CO/NOx point of intersection
VGPF2	79%	96%
GPF2	86%	97%

[0092] The particulate filter GPF2 according to the invention shows a marked improvement in light-off performance and dynamic CO/NOx conversion in the aged state compared with VGPF2.

COMPARATIVE EXAMPLE 3

[0093] a) Application of the in-Wall Coating:

[0094] Aluminum oxide stabilized with lanthanum oxide was suspended in water with a first oxygen storage component which comprised 40% by weight cerium oxide, zirconium oxide, lanthanum oxide and praseodymium oxide and a second oxygen storage component which comprised 24% by weight cerium oxide, zirconium oxide, lanthanum oxide and yttrium oxide. Both oxygen storage components were used in equal parts. The weight ratio of aluminum oxide and oxygen storage component was 30:70. The suspension thus obtained was then mixed with a palladium nitrate solution and a rhodium nitrate solution under constant stirring. The resulting coating suspension was used directly for coating a commercially available wall-flow filter substrate, wherein the coating was introduced into the porous filter wall over 100% of the substrate length. The total load of this filter amounted to 100 g/l; the noble metal load amounted to 2.60 g/l with a palladium to rhodium ratio of 60:13.75. The coated filter thus obtained was dried and then calcined.

[0095] b) Coating the Input Channels

[0096] Aluminum oxide stabilized with lanthanum oxide was suspended in water with an oxygen storage component which comprised 40% by weight cerium oxide, zirconium oxide, lanthanum oxide and praseodymium oxide. The weight ratio of aluminum oxide and oxygen storage component was 50:50. The suspension thus obtained was then mixed with a palladium nitrate solution and a rhodium nitrate solution under constant stirring. The resulting coating suspension was used directly to coat the wall-flow filter substrate obtained under a), wherein the filter walls of the substrate were coated in the input channels to a length of 25% of the filter length. The load of the input channel amounted to 58 g/l; the noble metal load amounted to 2.30 g/l with a ratio of palladium to rhodium of 10:3. The coated filter thus obtained was dried and then calcined.

[0097] c) Coating the Output Channels

[0098] Aluminum oxide stabilized with lanthanum oxide was suspended in water with an oxygen storage component which comprised 24% by weight cerium oxide, zirconium oxide, lanthanum oxide and yttrium oxide. The weight ratio of aluminum oxide and oxygen storage component was 56:44. The suspension thus obtained was then mixed with a palladium nitrate solution and a rhodium nitrate solution under constant stirring. The resulting coating suspension was used directly to coat the wall-flow filter substrate obtained under b), wherein the filter walls of the substrate were coated in the output channels to a length of 25% of the filter length. The load of the outlet channel amounted to 59 g/l; the noble metal load amounted to 1.06 g/l with a ratio of palladium to rhodium of 1:2. The coated filter thus obtained was dried and then calcined. The total load of this filter thus amounted to 130 g/l; the total noble metal load amounted to 3.44 g/l with a ratio of palladium to rhodium of 10:3. It is hereinafter referred to as VGPF3.

EXAMPLE 3

[0099] a) Application of the in-Wall Coating:

[0100] Aluminum oxide stabilized with lanthanum oxide was suspended in water with a first oxygen storage component which comprised 40% by weight cerium oxide, zirconium oxide, lanthanum oxide and praseodymium oxide and a second oxygen storage component which comprised 24% by weight cerium oxide, zirconium oxide, lanthanum oxide and yttrium oxide. Both oxygen storage components were used in equal parts. The weight ratio of aluminum oxide and oxygen storage component was 30:70. The suspension thus obtained was then mixed with a palladium nitrate solution and a rhodium nitrate solution under constant stirring. The resulting coating suspension was used directly for coating a commercially available wall-flow filter substrate, wherein the coating was introduced into the porous filter wall over 100% of the substrate length. The load of this filter amounted to 100 g/l; the noble metal load amounted to 2.07 g/l with a ratio of palladium to rhodium of 45:13.5. The coated filter thus obtained was dried and then calcined.

[0101] b) Coating the Input Channels

[0102] Aluminum oxide stabilized with lanthanum oxide was suspended in water with an oxygen storage component which comprised 24% by weight cerium oxide, zirconium oxide, lanthanum oxide and yttrium oxide. The weight ratio of aluminum oxide and oxygen storage component was 56:44. The suspension thus obtained was then mixed with a palladium nitrate solution and a rhodium nitrate solution under constant stirring. The resulting coating suspension was used directly to coat the wall-flow filter substrate obtained under a), wherein the filter walls of the substrate were coated in the input channels to a length of 60% of the filter length. The load of the input channel amounted to 80 g/l; the noble metal load amounted to 2.30 g/l with a ratio of palladium to rhodium of 10:3. The coated filter thus obtained was dried and then calcined. The total load of this filter thus amounted to 148 g/l; the total noble metal load amounted to 3.44 g/with a ratio of palladium to rhodium of 10:3. It is hereinafter referred to as GPF3.

[0103] Catalytic Characterization

[0104] The particulate filters VGPF3 and GPF3 were aged together in an engine test bench aging process. This aging process consists of an overrun fuel cut-off aging process with an exhaust gas temperature of 950° C. before the catalyst inlet (maximum bed temperature of 1030° C.). The aging time was 76 hours (see Motortechnische Zeitschrift, 1994, 55, 214-218).

[0105] The catalytically active particulate filters were then tested in the aged state at an engine test bench in the so-called "light-off test" and in the "lambda sweep test." In the light-off test, the light-off performance is determined in the case of a stoichiometric exhaust gas composition with a constant average air ratio λ (λ=0.999 with ±3.4% amplitude).

[0106] Table 5 below contains the temperatures T_{50} at which 50% of each of the considered components is converted.

TABLE 5

	T_{50} HC stoichiometric	T_{50} CO stoichiometric	T_{50} NOx stoichiometric
VGPF3	363	374	371
GPF3	341	345	340

[0107] The dynamic conversion behavior of the particulate filters was determined in a lambda sweep test in a range from λ=0.99-1.01 at a constant temperature of 510° C. The amplitude of λ in this case amounted to ±6.8%. Table 6 shows the conversion at the intersection of the CO and NOx conversion curves, along with the associated HC conversion of the aged particulate filters.

TABLE 6

	CO/NOx conversion at the point of intersection	HC conversion at λ of the CO/NOx point of intersection
VGPF3	83%	97%
GPF3	90%	98%

[0108] The particulate filter GPF3 according to the invention shows a marked improvement in light-off performance and dynamic CO/NOx conversion in the aged state compared with VGPF3.

[0109] It was furthermore systematically investigated what the main effects responsible for the lowest possible exhaust back pressure are. In doing so, various filters with different zone lengths (factor A) and washcoat layer thicknesses (factor B) were prepared and compared with one another. All filters had the same total washcoat load and the same noble metal content.

TABLE 7

Factor	Name	Unit	Min	Max
A	Zone length	%	30	60
B	Washcoat thickness	g/l	50	80

[0110] The statistical evaluation shows that it is particularly advantageous to distribute the washcoat on as large a surface as possible on the filter walls with a resultant low layer thickness instead of covering only a small surface with a high layer thickness, since a high layer thickness is to be regarded as the main cause of a high exhaust back pressure (FIG. **2**). In addition, the particulate filters were aged together in an engine test bench aging process. This aging process consists of an overrun fuel cut-off aging process with an exhaust gas temperature of 950° C. before the catalyst inlet (maximum bed temperature of 1030° C.). The aging time was 19 hours (see Motortechnische Zeitschrift, 1994, 55, 214-218).

[0111] The catalytically active particulate filters were then tested in the aged state at an engine test bench in the so-called “lambda sweep test.” Surprisingly, the statistical evaluation of the test results also shows a significant advantage in the lambda sweep test if the catalytic coating is applied with a low layer thickness to as large a surface as possible (FIG. **3**).

1. A particulate filter for removing particles, carbon monoxide, hydrocarbons and nitrogen oxides from the exhaust gas of combustion engines fueled by stoichiometric air-fuel mixtures, which filter comprises a wall-flow filter of length L and two different coatings Y and Z, wherein the wall-flow filter comprises channels E and A that extend in parallel between a first and a second end of the wall-flow filter and are separated by porous walls which form the surfaces O_E and O_A, respectively, and wherein the channels E are closed at the second end and the channels A are closed at the first end, characterized in that coating Y is located in the channels E on the surfaces O_E and extends from the first end of the wall-flow filter over a length of 51 to 90% of the length L, and coating Z is located in the porous walls and extends from the second end of the wall-flow filter over a length of 60 to 100% of the length L.

2. The particulate filter in accordance with claim **1**, characterized in that the coating Y extends from the first end of the wall-flow filter over 51 to 80% of the length L of the wall-flow filter.

3. The particulate filter in accordance with claim **2**, characterized in that the coating Y extends from the first end of the wall-flow filter over 57 to 65% of the length L of the wall-flow filter.

4. The particulate filter in accordance with claim **1**, characterized in that the coatings Y and Z have a thickness between 5-250 μm.

5. The particulate filter in accordance with claim **1**, characterized in that each of the coatings Y and Z contains one or more noble metals fixed to one or more substrate materials, and one or more oxygen storage components.

6. The particulate filter in accordance with claim **5**, characterized in that each of the coatings Y and Z contains the noble metals platinum, palladium and/or rhodium.

7. The particulate filter in accordance with claim **5**, characterized in that each of the coatings Y and Z contains the noble metals palladium, rhodium or palladium and rhodium.

8. The particulate filter in accordance with claim **4**, characterized in that the substrate materials for the noble metals are metal oxides with a BET surface area of 30 to 250 m^2/g (determined according to DIN 66132—newest version on the date of application).

9. The particulate filter in accordance with claim **5**, characterized in that the substrate materials for the noble metals are selected from the series consisting of aluminum oxide, doped aluminum oxide, silicon oxide, titanium dioxide and mixed oxides of one or more of these.

10. The particulate filter in accordance with claim **5**, characterized in that the coatings Y and Z contain a cerium/zirconium/rare earth metal mixed oxide as oxygen storage component.

11. The particulate filter in accordance with claim **10**, characterized in that the cerium/zirconium/rare earth metal mixed oxides contain lanthanum oxide, yttrium oxide, praseodymium oxide, neodymium oxide and/or samarium oxide as rare earth metal oxide.

12. The particulate filter in accordance with claim **10**, characterized in that the cerium/zirconium/rare earth metal mixed oxides contain lanthanum oxide and yttrium oxide, yttrium oxide and praseodymium oxide or lanthanum oxide and praseodymium oxide as rare earth metal oxide.

13. The particulate filter in accordance with claim **5**, characterized in that the coatings Y and Z both comprise lanthanum-stabilized aluminum oxide, palladium, rhodium or palladium and rhodium and an oxygen storage component comprising a zirconium oxide, cerium oxide, yttrium oxide and lanthanum oxide and/or a zirconium oxide, cerium oxide, praseodymium oxide and lanthanum oxide.

14. The particulate filter in accordance with claim **1** comprising a wall-flow filter of length L and two different coatings Y and Z, wherein the wall-flow filter comprises channels E and A that extend in parallel between a first and a second end of the wall-flow filter and are separated by porous walls which form the surfaces O_E and O_A, respectively, and wherein the channels E are closed at the second end and the channels A are closed at the first end, characterized in that

Coating Y is located in the channels E on the surfaces O_E and extends from the first end of the wall-flow filter over 57 to 65% of the length L and contains aluminum oxide in an amount of 35 to 60% by weight, based on the total weight of the coating Y, palladium, rhodium or palladium and rhodium and an oxygen storage component in an amount of 40 to 50% by weight, based on the total weight of the coating Y, wherein the oxygen storage component comprises zirconium oxide, cerium oxide, lanthanum oxide and yttrium oxide or zirconium oxide, cerium oxide, lanthanum oxide and praseodymium oxide, and

Coating Z is located in the porous walls and extends from the second end of the wall-flow filter over 60 to 100% of the length L and contains aluminum oxide in an amount of 25 to 50% by weight, based on the total weight of the coating, palladium, rhodium or palladium and rhodium and two oxygen storage components in a total amount of 50 to 80% by weight, based on the total weight of the coating Z, wherein one oxygen storage component contains zirconium oxide, cerium oxide, lanthanum oxide and yttrium oxide and the other contains zirconium oxide, cerium oxide, lanthanum oxide and praseodymium oxide.

15. A method for removing particles, carbon monoxide, hydrocarbons, and nitrogen oxides from the exhaust gas of combustion engines fueled by a stoichiometric air-fuel mixture, characterized in that the exhaust gas is conducted through a particulate filter in accordance with claim **1**.

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