DEVICE AND METHOD FOR TREATING EXHAUST GAS CONTAINING SOOT PARTICLES

Abstract of the Invention

The invention relates to a method for converting soot particles (2) of an exhaust gas, comprising at least the following steps: (a) providing at least nitrogen dioxide or oxygen in the exhaust gas; (b) ionizing soot particles (2) by means of an electric field (16); (c) depositing electrically charged soot particles (4) on inner duct walls (17) of at least one surface collector (6); (d) bringing at least nitrogen dioxide or oxygen into contact with the deposited soot particles (2) on the inner duct walls (7) of the at least one surface collector (6). The invention further relates to a device suitable for carrying out the method, wherein at least one surface collector (6) is provided that has a plurality of ducts (7), through which the exhaust gas can flow and which extend between an inlet region (8) and an outlet region (9), wherein at least one deposit preventer (10) for electrically charged soot particles (2) is provided in at least part of the inlet region (8), thus especially allowing the soot particles to be evenly deposited and the surface collector to be continuously regenerated.

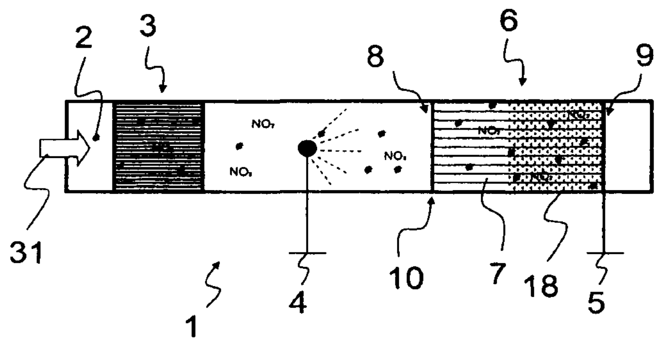

FIG. 1

We Claim:

1. A device (1) for treating exhaust gas containing soot particles (2), comprising at least
   - at least one nitrogen dioxide source (3) or an oxygen source (32),
   - at least one ionization element (4) for ionizing soot particles (2),
   - at least one neutralization element (5) for neutralizing electrically charged soot particles (2),
   - at least one surface precipitator (6) which has a multiplicity of ducts (7) through which the exhaust gas can flow and which extend between an inlet region (8) and an outlet region (9), wherein at least one deposition inhibitor (10) for electrically charged soot particles (2) is provided at least partially at the inlet region (8).

2. The device (1) as claimed in claim 1, in which the at least one neutralization element (5) is formed in the region of the outlet region (9) of the at least one surface precipitator (6).

3. The device (1) as claimed in claim 1 or 2, in which the at least one surface precipitator (6) is embodied as a honeycomb element (11).

4. The device (1) as claimed in one of the preceding claims, in which various refinements of the at least one deposition inhibitor (10) can be assigned to the ducts (7).

5. The device (1) as claimed in one of the preceding claims, in which the at least one deposition inhibitor (10) extends in various axial zones (12) of the ducts (7).

6. The device (1) as claimed in one of the preceding patent claims, in which the at least one deposition inhibitor (10) is formed by various duct shapes (13).

7. The device (1) as claimed in claim 6, in which ducts (7) in which there is a central flow are made at least larger or more structured than ducts (7) in which there is an off-center flow.

8. The device (1) as claimed in one of the preceding claims, in which the at least one deposition inhibitor (10) is formed by at least one electrical insulator (15).

9. The device (1) as claimed in one of the preceding claims, in which the at least one surface precipitator (6) has, as a basic material, an electrical insulator (15) which forms a deposition inhibitor (10).

10. The device (1) as claimed in claim 9, in which the surface precipitator (6) has at least one neutralization element (5), wherein the at least one neutralization element (5) is embodied differently in the ducts (7).

11. A method for converting soot particles (2) of an exhaust gas, comprising at least the following steps:
    a) provision of at least nitrogen dioxide or oxygen in the exhaust gas,
    b) ionization of soot particles (2) by means of an electrical field (16),
    c) depositing of electrically charged soot particles (4) on inner duct walls (7) of at least one surface precipitator (6), and
    d) placing of at least nitrogen dioxide or oxygen in contact with the deposited soot particles (2) on inner duct walls (7) of the at least one surface precipitator (6).

12. The method as claimed in claim 11, wherein the flow behavior of the exhaust gas through the ducts (7) of the at least one surface precipitator (6) or the configuration of the electrical field (16) is varied as a function of an exhaust gas parameter.

13. The method as claimed in claim 11 or 12, wherein continuous regeneration of the at least one surface precipitator (6) takes place.

14. The method as claimed in one of claims 11 to 13, wherein the electrically charged soot particles (4) are deposited uniformly on all the ducts (7) of the at least one surface precipitator (6).

Dated this the 5th Day of March, 2012

Manisha Singh Nair

MANISHA SINGH NAIR
Agent for the Applicant [IN/PA-740]
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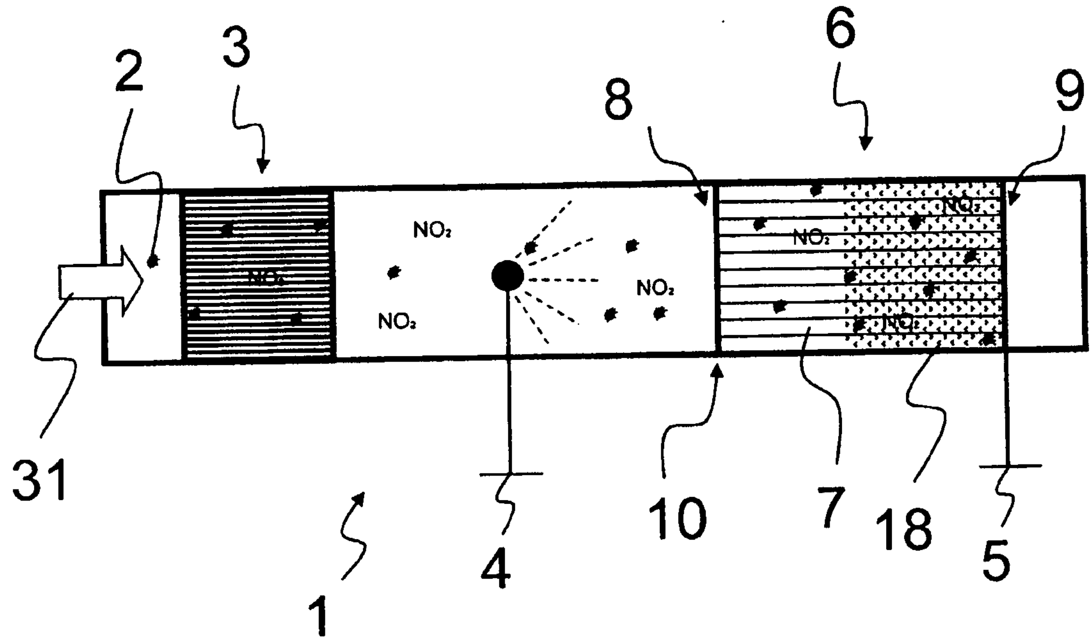

FIG. 1

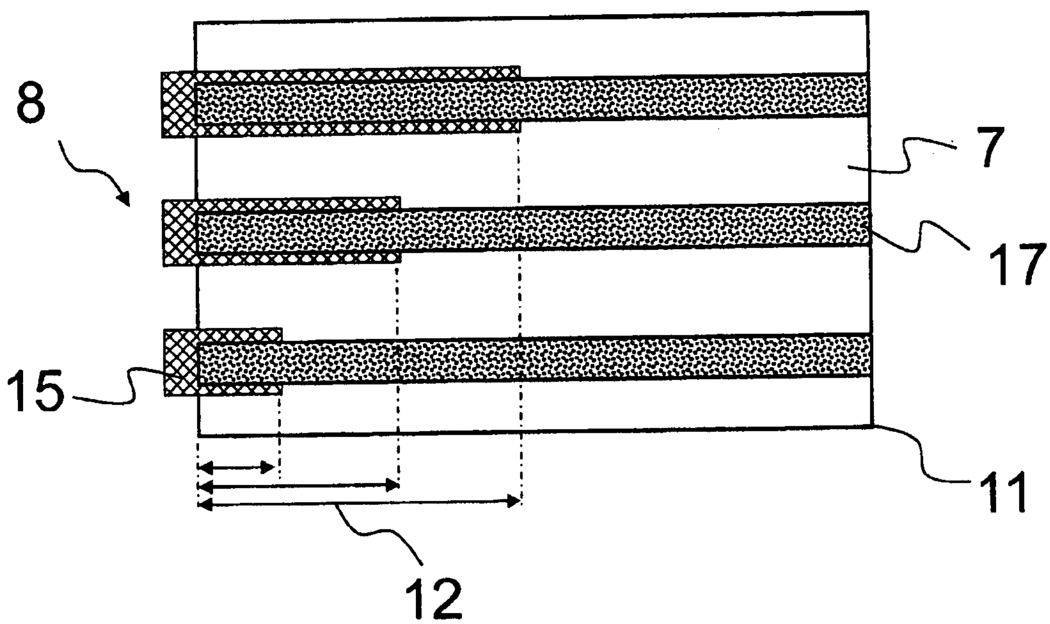

FIG. 2

Manisha Singh Nair
MANISHA SINGH NAIR
Agent for the Applicant [IN/PA-740]
LEX ORBIS IP PRACTICE

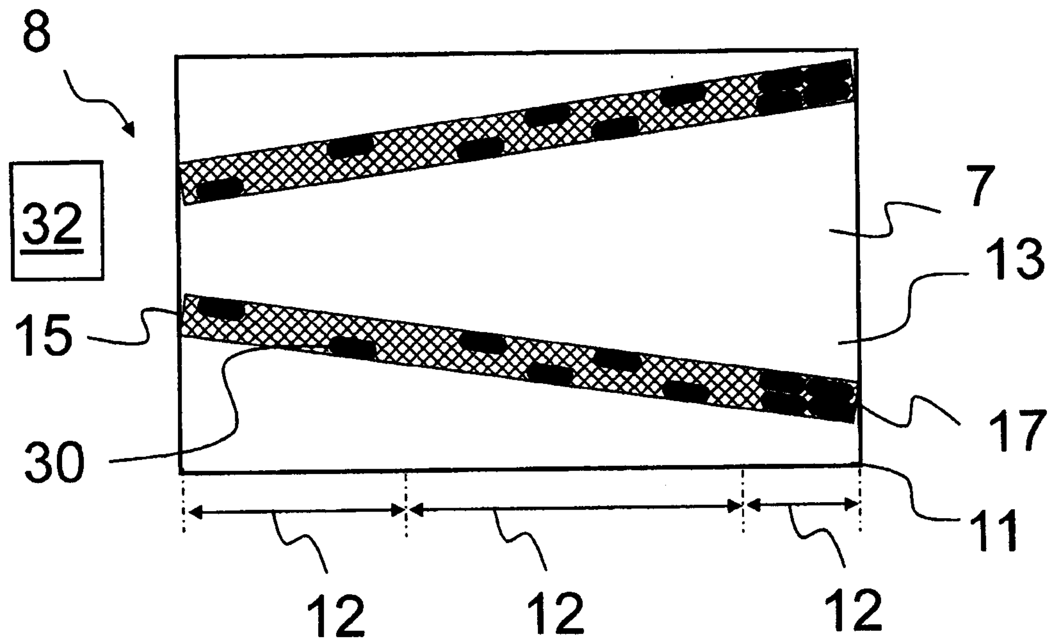

FIG. 3

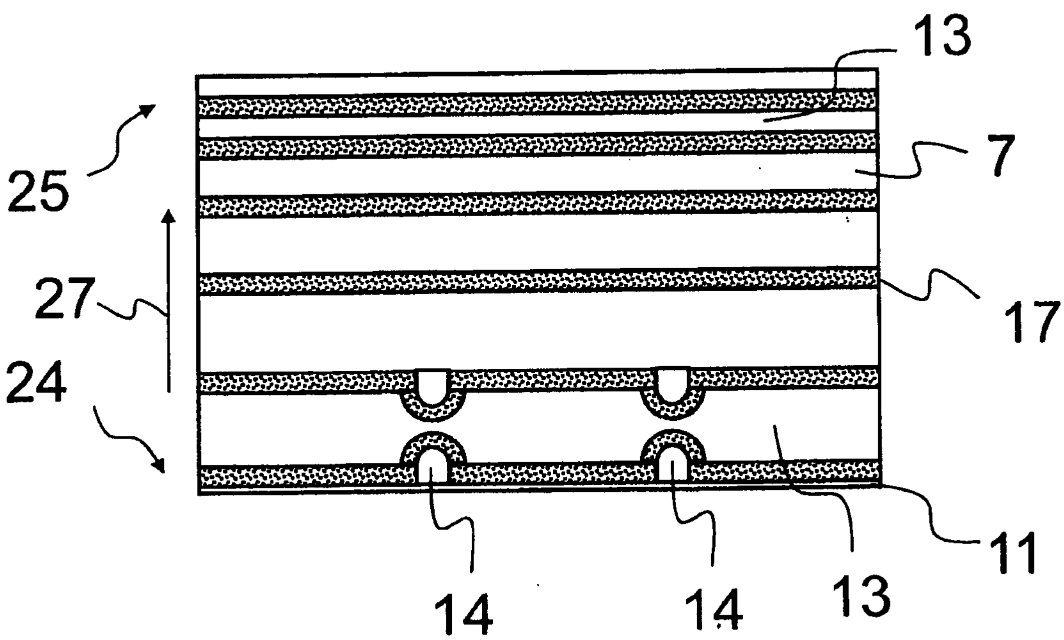

FIG. 4

Manisha Singh Nair
MANISHA SINGH NAIR
Agent for the Applicant [IN/PA-740]
LEX ORBIS IP PRACTICE

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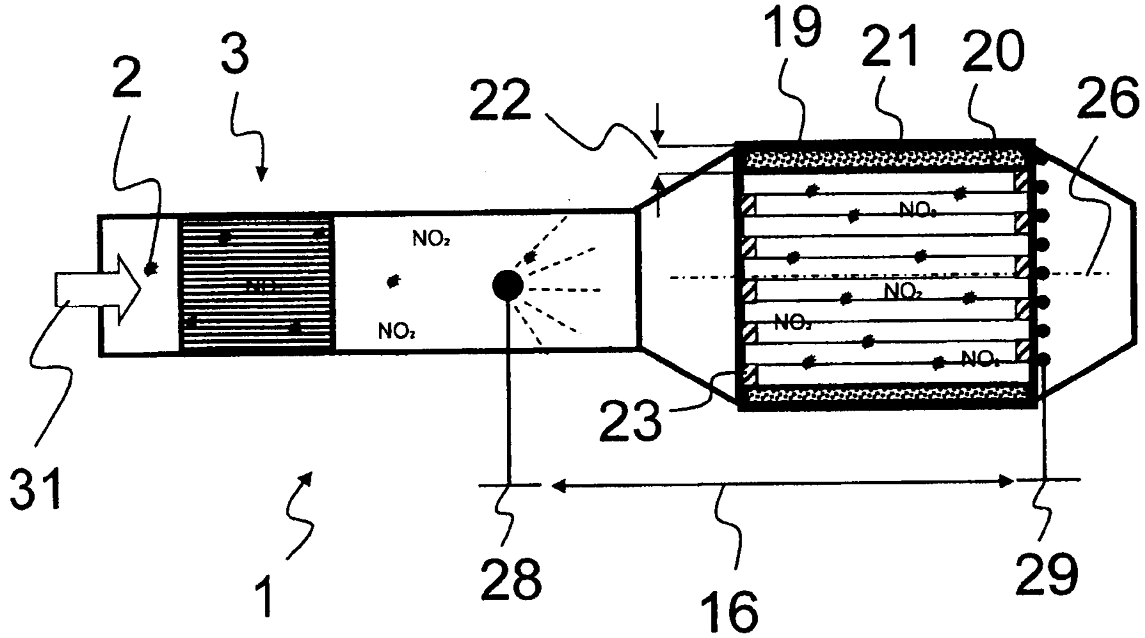

FIG. 5

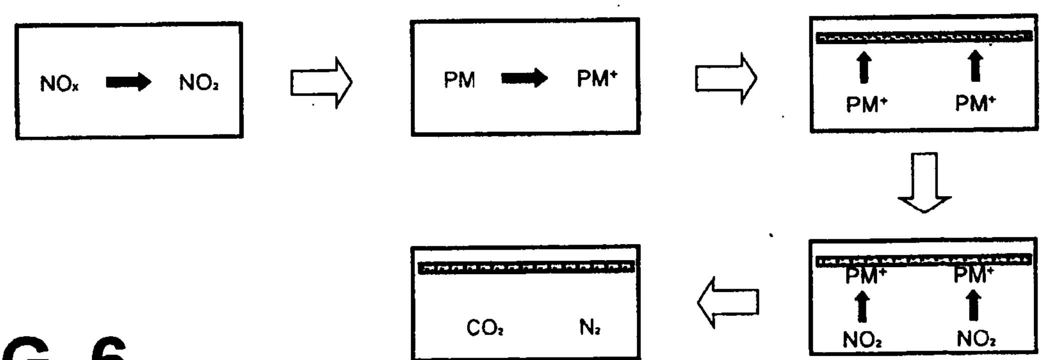

FIG. 6

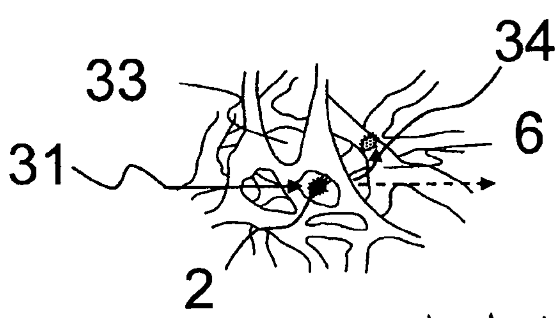

FIG. 7

MANISHA SINGH NAIR
Agent for the Applicant [IN/PA-740]
LEX ORBIS IP PRACTICE

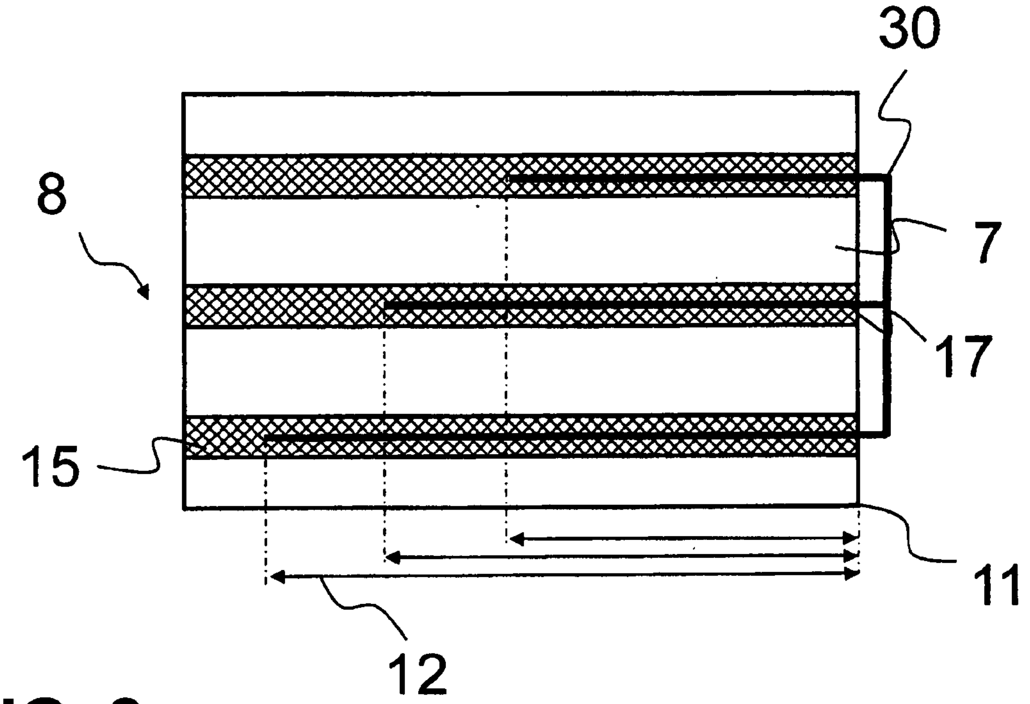

FIG. 8

MANISHA SINGH NAIR
Agent for the Applicant [IN/PA-740]
LEX ORBIS IP PRACTICE

The present invention relates to a device for treating exhaust gas containing soot particles, in particular with what is referred to as an electrostatic filter or electric filter, as well as a suitable method for converting soot particles of an exhaust gas. The invention is used, in particular, in the treatment of exhaust gases of mobile internal combustion engines in the field of automobiles, in particular in the treatment of exhaust gases resulting from diesel fuel.

A multiplicity of different concepts for eliminating soot particles from exhaust gases of mobile internal combustion engines have already been discussed. In addition to wall-flow filters which are alternately closed, open secondary flow filters, gravity precipitators etc., systems have already been proposed in which the particles in the exhaust gas are charged electrically and then deposited using electrostatic attraction forces. These systems are known, in particular, by the term "electrostatic filter" or "electric filter".

Generally (a plurality of) discharge electrodes and collector electrodes, positioned in the exhaust line, are proposed for such electric filters. In this context, for example a central discharge electrode which runs approximately centrally through the exhaust line and a surrounding lateral surface of the exhaust line as a collector electrode are used to form a capacitor. By means of this arrangement of the discharge electrode and the collector electrode, an electrical field is formed transversely with respect to the direction of flow of the exhaust gas, wherein the discharge electrode can be operated, for example, with a high voltage which is in the region of approximately 15 kV. As a result, in particular Corona discharges can be formed through which the particles which flow through the electrical field with the exhaust gas are charged in a unipolar fashion. As a result of this charging, the particles migrate to the collector electrode as a result of electrostatic Coulomb forces.

In addition to systems in which the exhaust line is embodied as a collector electrode, systems are also known in which the collector electrode is embodied, for example, as a wire mesh. In this context, the accumulation of particles on the wire mesh serves the purpose of combining the particles, where appropriate, with further particles in order therefore to form an agglomeration. The exhaust gas which flows through the grill then carries the relatively large particles along with it again and carries them to conventional filter systems.

Even if the systems described above have hitherto proven suitable for the treatment of soot particles, at least in trials, the implementation of this concept for series production in motor vehicles presents serious challenges. This applies, in particular, with respect to the greatly fluctuating, at times very heavy, soot load in the exhaust gas, as well as the desired retrofitability of such a system for currently existing exhaust systems. In addition, it is necessary to take into account the fact that the improved performance of such exhaust systems in terms of the elimination of soot particles also makes it necessary to perform regeneration (periodic or continuous) of the filter systems, involving the soot being converted into gaseous components.

With respect to the regeneration of filter systems, it is also known, in addition to the intermittent regeneration by brief heating, that is to say burning off of the soot (catalytically motivated oxidative conversion), to convert soot by means of nitrogen dioxide (NO_2). The advantage of the continuous regeneration with nitrogen dioxide is that the conversion of soot can already take place here at significantly lower temperatures (in particular lower than 250°C). For this reason, the continuous regeneration is preferred in many applications. However, this leads to the problem that it is necessary to ensure that the nitrogen dioxide in the stream of exhaust gas comes into contact to a sufficient degree with the deposited soot particles.

In this context there are also technical difficulties in the implementation of continuous operation of such exhaust systems in motor vehicles, wherein the different loadings of the internal combustion engines lead to different streams of exhaust gas, compositions of exhaust gas and temperatures.

Taking this as a basis, the object of the present invention is to at least partially solve the problems described in relation to the prior art. In particular, the intention is to describe a device for treating exhaust gas containing soot particles, which device similarly makes available a large precipitation effect for soot particles and which can be satisfactorily regenerated. The intention is also to specify a corresponding method for converting soot particles of an exhaust gas. The device and the method are to be easily integrated into existing mobile exhaust systems and to be equally capable of being manufactured cost-effectively.

These problems are solved with a device according to the features of claim 1 and a method for converting soot particles of an exhaust gas according to the steps of claim 11. Further advantageous embodiments of the invention are specified in the respectively dependently formulated claims. It is to be noted that the features which are disclosed individually in the claims can be combined with one another in any desired technologically appropriate way and indicate further embodiments of the invention. The description explains the invention, in particular in conjunction with the figures, and specifies additional exemplary embodiments.

The inventive device for treating exhaust gas containing soot particles comprises at least:

- at least one nitrogen dioxide source or an oxygen source,
- at least one ionization element for ionizing soot particles,
- at least one neutralization element for neutralizing electrically charged soot particles,
- at least one surface precipitator which has a multiplicity of ducts through which the exhaust gas can flow and which extend between an inlet region and an outlet region, wherein at least one deposition inhibitor for electrically charged soot particles is provided at least partially at the inlet region.

The device proposed here may be, in particular, part of an exhaust system of a motor vehicle which has a diesel engine. However, the device can also be made available as a modular kit for an exhaust system.

Accordingly, firstly a nitrogen dioxide source is provided. Such a nitrogen dioxide source is, for example, a catalytic converter which assists (together with other components of the exhaust gas, in particular oxygen) the conversion of nitrogen oxides (in particular nitrogen monoxide NO) contained in the exhaust gas into nitrogen dioxide. Basically, a plurality of such nitrogen dioxide sources may also be present, but this is not absolutely necessary. The nitrogen dioxide source can usually be implemented with a catalytic converter which has a honeycomb element with a coating, wherein the coating has platinum, rhodium, palladium or the like. The nitrogen dioxide source is therefore connected downstream of the internal combustion engine, and is therefore located at least partially in the exhaust system.

While the nitrogen dioxide source is usually preferably used in relatively "cold exhaust systems" (for example diesel engine applications), an oxidative conversion of the soot particles with oxygen from an oxygen source can also be carried out at relatively high temperatures (for example petrol engine applications). For example, the internal combustion engine itself or what is referred to as a secondary air input, that is to say in particular the feeding in of an oxygen-containing gas into the exhaust line, is preferably considered as an oxygen source. If appropriate, chemical conversion with a catalyst can also generate oxygen, with the result that this can also be considered as an oxygen source.

In particular a device which alternatively has at least one nitrogen dioxide source or at least one oxygen source upstream of the surface precipitator in the exhaust line is preferred.

Furthermore, at least one ionization element for ionizing soot particles is provided. It is preferred here that the exhaust gas firstly reaches the nitrogen dioxide source before it reaches the section of the device with the at least one ionization element. The ionization element preferably comprises an ionization electrode or a multiplicity of ionization electrodes. The at least one ionization element is connected to a voltage source, in particular to a high voltage source. It is also possible to regulate the voltage by means of a control unit. Basically a direct-current voltage source or an alternating-current voltage source can be made available.

Furthermore, at least one neutralization element for neutralizing electrically charged soot particles is provided. The at least one neutralization element carries out at least the task of feeding electrical charge to the electrically charged soot particles or discharging it therefrom (depending on the electrical charge), with the result that when contact occurs with the electrically charged soot particles, electrical neutralization or de-ionization of the soot particles takes place. The number of ionization elements and neutralization elements basically does not have to correspond, but it may be expedient that they do.

An electrical field is usually formed between the at least one ionization element and the at least one neutralization element. This electrical field extends, in particular, in the direction of the exhaust system and/or in the direction of flow of the exhaust gas, wherein the exhaust gas firstly reaches the at least one ionization element and later the at least one neutralization element. As a result, the at least one ionization element and the at least one neutralization element are offset with respect to one another in the direction of flow of the exhaust gas, in particular at a distance of several centimeters such as, for example, at least 5 cm, at least 15 cm or even at least 30 cm.

Furthermore, at least one surface precipitator is provided. The surface precipitator is characterized in that it has a plurality of ducts through which the exhaust gas flows, and in that the ducts extend between an inlet region and an outlet region. Basically, it would be possible to form a surface precipitator which only has two ducts, but an embodiment in which a plurality of ducts are provided, for example at least 30, at least 50 or even at least 100 ducts, is preferred. The term "surface precipitator" is intended to express the fact that a surface which is very large (in particular also in relation to its volume) is made available for the accumulation of soot particles. In contrast to known variants, in which, where possible, the soot particles were agglomerated one on top of the other in a tightly limited space, the objective here is to distribute the soot particles over a large area over the surfaces of the duct walls which are formed by the ducts. However, this does not rule out the possibility of the soot particles being deposited, for example, also in the interior of a porous duct wall. In particular, the external and internal surfaces of the duct walls can therefore here be considered to be surfaces which are suitable for the depositing of soot. A "duct" is understood here to be, in particular, a delimited flow path whose extent is clearly longer than its diameter, wherein the diameter is, in particular, significantly greater than the customary sizes of the soot particles. Even if it is sufficient for some purposes to form separate and discrete ducts, communicating ducts can nevertheless also be made available in which an exchange of partial streams of exhaust gas (for example through openings in the duct walls) is made possible. Providing ducts with an extent of, for example, at least 5 cm, but preferably even at least 10 cm, which are, in particular, relatively small in cross section, readily permits the individual ducts or surface precipitator to be configured in a way which is adapted to the flow profile.

However, so that in fact there is no accumulation of soot particles in just one plane perpendicularly with respect to the direction of flow (as in the case of a grill), at least one deposition inhibitor for electrically charged soot particles is provided at least partially at the inlet region. This inhibitor carries out the function of preventing deposition (exclusive or predominant) of the electrically charged soot particles in the inlet region. In this context, the deposition inhibitor can be configured in such a way that it is configured only for some of the ducts or configured differently for the ducts. The deposition inhibitor can, on the one hand, relate to the surface precipitator itself, but it is also possible for the at least one deposition inhibitor to act on the stream of exhaust gas and therefore bring about changed routing of the stream of exhaust gas through the surface precipitator. For this purpose, the at least one deposition inhibitor can be formed in a slightly offset fashion directly at the inlet region and/or starting from the inlet region in the direction of the outlet region. Under certain circumstances it is also possible for such a deposition inhibitor also to be provided for at least some of the ducts from the inlet region to the outlet region. The arrangement and/or distribution of the at least one deposition inhibitor for electrically charged soot particles in the surface inhibitor is to be selected in such a way that soot particles are deposited as uniformly as possible on the duct walls of the multiplicity of ducts (and not only on the front face). This leads, in particular, to a situation in which the deposited soot particles are arranged over a large surface, that is to say at a relatively large distance from one another, even in the case of a briefly increased soot load of the exhaust gas. This provides in a particular way the possibility of regenerating the soot particles there continuously with nitrogen dioxide. This is promoted by the fact that the exhaust gas, which is conducted through the ducts over a relatively long flow path and at a short distance from the duct wall, has the possibility of bringing about a conversion with small particles which are relatively free there. This results in a situation in which, in particular, an undesired drop of pressure over the surface inhibitors is avoided as the load with soot particles increases, since particularly effective continuous regeneration of the surface precipitator is carried out.

According to one preferred embodiment variant of the invention, the at least one neutralization element is formed in the region of the outlet region of the at least one surface precipitator. This is intended to mean, in particular, that the at least one neutralization element forms part of the outlet region, wherein it may be, in particular, part of the surface precipitator, may be positioned in (electrical) contact therewith or else may be arranged downstream thereof in the direction of flow. The at least one neutralization element can accordingly be accommodated in the surface precipitator, but a separate, downstream refinement of the at least one neutralization element is also possible. If the at least one neutralization element is an integral component of the surface precipitator, the surface precipitator simultaneously performs the function of neutralization, with the result that ultimately electrically neutral soot particles are deposited on the surfaces of the surface precipitator. If the at least one neutralization element can be formed downstream of the surface precipitator, the latter can be embodied in the manner of a conventional collector electrode in order to form the electrical field through the surface precipitator. The ducts are then configured, in particular, in such a way that the electrically charged soot particles impinge on the duct wall owing to the electrical forces.

It is preferred that the ionization element is arranged upstream of the surface precipitator in the direction of flow of the exhaust gas, with the result that ionization of the soot particles occurs upstream of the surface precipitator. It is particularly preferred if the ionization element is arranged at a distance of at least 5 cm, in particular of at least 10 cm, upstream of the surface precipitator. The surface precipitator therefore does not serve to perform ionization but rather essentially only as a collector for the soot particles which are already ionized (upstream).

Furthermore, it is particularly preferred that the at least one surface precipitator is embodied as a honeycomb element. The honeycomb elements can basically be constructed with different materials, in particular also with metallic and/or ceramic components. The manufacturing methods for such honeycomb elements have been known for many years and the honeycomb elements have proven particularly suitable in terms of formation of contact between the stream of exhaust gas and the walls in the ducts. The honeycomb element can have here (only) open and/or (partially) closed ducts. Basically it is preferred that the ducts extend essentially linearly and parallel to one another (such as, for example, in the case of an extruded honeycomb element), but this is not absolutely necessary. The ducts and/or the duct walls can also be embodied with structures (grooves, knobs, sliding surfaces etc.) in order to implement an additional improvement of the formation of contact between the retained soot particles and the nitrogen dioxide from the exhaust gas. As a result, the structur extends from the duct wall into the ducts and constricts, in particular, the duct cross section. The duct walls may be impermeable and/or permeable to gas here, it being possible to implement the latter by porosity of the material and/or by openings (for example holes).

In particular it is also proposed that various refinements of the at least one deposition inhibitor can be assigned to the ducts. That is to say in other words, in particular, that during operation the at least one deposition inhibitor results in different deposition regions of the individual ducts being influenced chronologically and/or spatially. Deposition inhibitors can therefore be embodied differently in the region of the centrally arranged ducts than the deposition inhibitors in the ducts in the edge region of the surface precipitator. Alternatively or cumulatively it is possible to embody the deposition inhibitors near to the inlet region differently than in the region of the outlet region for a number of ducts. If the surface precipitator is itself a neutralization element, it is therefore possible to implement different electrical conductivity of the duct wall in particular in the profile direction of the ducts and/or as a function of the position of the ducts, as a result of which the embodiment of the electrical field and therefore the effect of the Coulomb's forces on the electrically charged soot particles is adapted.

According to one development of the invention there is also provision that the at least one deposition inhibitor extends in various axial zones of the ducts. Consequently, in some of the ducts, a deposition inhibitor may be embodied from the inlet region to several millimeters into a duct, but it is also possible for the deposition inhibitor to extend as far as the outlet region. In this context, a plurality of deposition inhibitors (of the same type and/or different) can also be provided in the respective ducts.

Furthermore it is also proposed that the at least one deposition inhibitor be formed by various forms of duct. In this specific embodiment of the surface precipitator, in particular if the latter constitutes a neutralization element, it should be made possible that the probability of impacting and/or the depositing capability and/or the flow paths for soot particles be adapted to the flow profile of the exhaust gas and/or the exhaust gas volume flow. This is intended in particular to counteract a situation in which different quantities of particles are made to flow into the ducts. Instead, it is possible to implement a situation in which there are differing (and on average therefore uniform) flows into the ducts given different streams of exhaust gas. The term "duct shape" therefore includes considering its cross section and the profile shape of the duct. Different duct shapes are provided, in particular, when the ducts differ in one of the following properties: size (diameter) of the duct cross section, shape of the duct cross section, inclination of the duct profile, curvature of the duct profile, widening of the duct profile, constriction of the duct profile, position and/or type of the structures of the duct walls, etc.

Furthermore, particularly in this variant it is proposed that ducts in which there is a central flow are made at least larger or more structured than ducts in which there is an off-center flow. This means, in other words, that relatively large duct cross sections and/or a smaller duct density is provided in the central region of the surface precipitator, and/or in the region thereof in which there is a central flow, than in the region of the surface precipitator which is off-center or near to the edge. Alternatively or cumulatively to this it is possible for the duct walls of the ducts in which there is a central flow to be embodied to a relatively large degree with structures, that is to say with respect to the size of the structures, the frequency of the structures etc. This measure takes into account, in particular, the fact that the pressure loss of the exhaust gas increases quadratically with the mass flow of exhaust gas as it flows through the surface precipitator. The provision of structures in the central region then leads to a situation in which overproportionally large parts of the stream of exhaust gas are also conducted into the edge regions for this part, with the result that in total approximately the same flow can be detected in the ducts.

According to a further embodiment of the invention, the at least one deposition inhibitor can be formed by at least one electrical insulator. In particular ceramic coating is possible for this, which coating can also be applied, for example, on metal surfaces. Alternatively, separate components which form an electrical insulator can also be added.

However, it is basically also possible for the at least one surface precipitator to have, as a basic material, an electrical insulator which forms a deposition inhibitor, that is to say in other words, that the surface precipitator itself has at least partially no electrical conductivity. Then, in particular by taking into account the duct shape (for example twisted and/or structured ducts) or the concept of the surface precipitator (for example wall-flow filter with alternately closed ducts) it is possible to ensure that the particles can be deposited on or in this basic material.

In order also to achieve the selective desposition of particles in a uniform fashion here over the entire surface of the surface precipitator, it is possible to integrate electrical conductivity, for example in such a way that the surface precipitator has at least one neutralization element, wherein the at least one neutralization element is embodied differently in the ducts. Consequently, electrically conductive materials can be arranged in and/or on the basic material of the surface precipitator and are connected to an electrical ground. This can be achieved by correspondingly electrically conductive conductors, fibers, particles and the like (which are, if appropriate, in contact with one another). In particular metal inlays are suitable for this.

The surface precipitator preferably has porous duct walls which are formed in particular, with sintered material, ceramic, silicon carbide (SiC) or mixtures thereof. This is particularly preferably an (at least partially) extruded honeycomb element.

According to a further aspect of the present invention, a method for converting soot particles of an exhaust gas is proposed, comprising at least the following steps:

a) provision of at least nitrogen dioxide or oxygen in the exhaust gas,
b) ionization of soot particles by means of an electrical field,
c) depositing of electrically charged soot particles on inner duct walls of at least one surface precipitator, and
d) placing of nitrogen dioxide in contact with the deposited soot particles on inner duct walls of the at least one surface precipitator.

As a result, in particular continuous regeneration of soot particles is also specified with the device proposed according to the invention. For this reason it is also necessary to point out that the features which are presented with respect to the devices can be used to explain the method, and vice-versa. It is also necessary to note that the steps a) and b) can be carried out in succession and/or simultaneously, wherein emphasis is placed on the respective effect on a partial stream of exhaust gas. It is preferred that all the steps a) to d) are carried out continuously during the operation of a mobile internal combustion engine. Furthermore it is preferred that step a) alternatively comprises the provision/generation of nitrogen dioxide or oxygen within the exhaust line.

According to one development of the method it is also proposed that the flow behavior of the exhaust gas through the ducts of the at least one surface precipitator or the configuration of the electrical field is varied as a function of an exhaust gas parameter. If appropriate it is also possible to carry out both measures simultaneously or alongside one another. The flow behavior can be changed independently, for example by correspondingly configuring the surface precipitator with the result that there is a flow through different ducts given differing flow behavior. However, it is also possible to perform active variation in that, for example, the frequency and/or field strength of the electrical field are regulated. In particular, the temperature, the mass flow, the volume flow and/or the flow speed of the exhaust gas are considered as exhaust gas parameters. Of course, other characteristic values of the operation of the internal combustion engine can also be used as an alternative thereto or additionally in order to draw conclusions about a corresponding exhaust gas parameter.

The method serves preferably to perform continuous regeneration of the at least one surface precipitator. For this purpose, the soot is placed in contact with nitrogen dioxide which has been generated upstream in the flow of exhaust gas, and is chemically converted. For a further explanation, recourse can be made to what is referred to as the CRT method (CRT = *continuous regeneration trap,* cf. for example EP-A-0341832).

Furthermore, a method is also preferred in which the electrically charged soot particles are deposited uniformly on all the ducts of the at least one surface precipitator. This is to be understood, in particular, as meaning that the device and/or the surface precipitator is configured in such a way that the probability of deposition of the electrically charged soot particles on all the inner duct faces of the surface precipitator is essentially the same. The measures which are to be taken, if appropriate, to achieve this have already been presented above.

The invention is preferably used in a motor vehicle having an internal combustion engine, in particular a diesel engine, with a downstream exhaust system which has a device according to the invention. For this purpose, the motor vehicle has, for example, a control unit for operating this device with the method according to the invention, wherein the control unit is configured, in particular by means of corresponding software, to implement the operation according to the invention during the operation of the motor vehicle. If appropriate, the control unit can interact with sensors of the exhaust system and/or of the internal combustion engine and/or stored data models in order to adapt this system.

The invention and the technical field are explained in more detail below with reference to the figures. It is to be noted that the figures present particularly preferred embodiment variants of the invention but are not restricted thereto. In said figures, in each case in a schematic form:

fig. 1: shows a first embodiment variant of a device according to the invention,

Fig. 2: shows a first detail of a first embodiment variant of a surface precipitator,

fig. 3: shows a second detail of a second variant of a surface precipitator,

fig. 4: shows a third detail of a third embodiment variant of a surface precipitator,

fig. 5: shows a further embodiment variant of the device,

fig. 6: shows an illustration of the method according to the invention,

fig. 7: shows an illustration of the attraction forces acting on a soot particle, and

fig. 8: shows a detail of a further embodiment variant of a surface precipitator.

Fig. 1 shows a first exemplary embodiment of a device 1 according to the invention. Here, exhaust gas flows with a direction 31 of flow through an exhaust system, which is illustrated here in an approximately tubular shape, which is not significant. The exhaust gas contains soot particles 2. The exhaust gas with the soot particles 2 is firstly conducted through a nitrogen dioxide source 3, in particular through a honeycomb-shaped catalytic converter with platinum coating. This nitrogen dioxide source converts nitrogen monoxides (NO) contained in the exhaust gas into nitrogen dioxides (NO_2), with the result that the proportion of nitrogen dioxides in the exhaust gas is increased (making up, in particular, at least 25% by weight or even at least 50% by weight of the entire nitrogen oxides). The exhaust gas which is prepared in this way flows on to an (individual) surface precipitator 6. The surface precipitator 6 has an inlet region 8 and an outlet region 9. Linear ducts 7, which extend parallel to one another, run between the inlet region 8 and the outlet region 9. The ducts 7 are embodied here (partially) with a catalytic coating 18, but this is not absolutely necessary.

Before the exhaust gas reaches the surface precipitator 6, it enters an electrical field which is formed by means of an ionization element 4 upstream of the surface precipitator 6 and the neutralization element at the outlet region 9 of the surface precipitator 6. In the illustrated case, the neutralization element 5 is integrated into the duct walls of the surface precipitator 6. In order then to prevent electrically charged soot particles from impacting directly on the front face of the honeycomb element in the region of the inlet region 8, so that the ducts 7 themselves do not serve for the accumulation of soot particles any more, a deposition inhibitor 10 is formed in the region of the inlet region 8, said deposition inhibitor 10 actually reducing or preventing accumulation there. Different refinements of this deposition inhibitor 10 are also presented with reference to the following figures.

Fig. 2 shows, for example, a detail of a surface precipitator having a multiplicity of ducts 7 which are bounded by duct walls 17. As a result, in particular what is referred to as a honeycomb element 11 is formed. In order then to prevent the soot particles from being deposited only in the inlet region 8 of the honeycomb element 11, an electrical insulator 15 (embodied in the manner of a coating on the duct walls) is provided there as a deposition inhibitor. In this figure it is also indicated that the embodiment of the deposition inhibitor or, as shown here, of the electrical insulator, can relate to different zones 12 of the ducts 7. The zones

12 can therefore differ from one another in particular in terms of their extent and/or position.

Fig. 3 shows an embodiment variant of a honeycomb element 11 which is formed with conically and/or tapering/widening ducts. While the duct shape in Fig. 2 is, for example, essentially round and is constant over its length, the cross section in the case of the conical duct shape changes in its longitudinal direction. Owing to the changed duct cross sections, the flow can also be influenced here and/or deposition of soot particles can also be achieved in the rear part of the honeycomb element 11. An oxygen source 32 is also indicated in purely schematic form upstream of this honeycomb element 11, it being possible to integrate said oxygen source 32 into an exhaust system, for example instead of the nitrogen dioxide source.

Furthermore, a refinement of the honeycomb element 11 in which the duct walls 17 are embodied with a basic material which acts as an electrical insulator 15, for example ceramic or silicon carbide, is shown here. However, in order, as it were, to motivate a movement of the soot particles to the duct walls 17 on the basis of Coulomb's forces, the duct walls 17 (which can, if appropriate, also be porous) have electrical conductors 30, for example in the manner of a reinforcement, embedded fibers, etc. The attraction force from the duct wall 17 to the soot particles therefore becomes stronger over the length of the ducts 7, and/or this attraction force is smaller in the inlet region 8. This axially staggered conductivity can occur on a zone-by-zone basis here, with the result that in each case approximately the same conductivity is provided over predefined zones 12, but the transition can also be stepless or continuous.

Fig. 4 illustrates a further detail of a honeycomb element 11 as a surface precipitator, wherein the ducts 7 have different duct shapes 13. In a center 24, that is to say in a region of the surface precipitator 6 in which there is a central flow, the duct cross section 7 is relatively large. If the duct shape 13 is considered in the direction of the radius 27, it is to be noted that the cross section of the ducts is smaller in the region of the edge 25, that is to say a region in which there is an off-center flow. In addition, it is to be noted that (only) the ducts 7 have structures 14 in the region of the center 24, which structure builds up a relatively large pressure drop, in particular as the flow speed of the exhaust gas increases or the volume flow of the exhaust gas becomes larger, with the result that the exhaust gas is also conducted to a greater extent in radially outer ducts. These measures contribute, in particular, to bringing about uniform loading with soot particles and uniform provision of nitrogen dioxide for the deposited soot particles.

Fig. 5 shows a further exemplary embodiment of the device 1 according to the invention. In the left-hand partial region it is illustrated again how the exhaust gas containing soot particles 2 flows through the nitrogen dioxide source 3 in the direction 31 of flow, with the result that more nitrogen dioxide is formed. In turn, an electrical field 16 is formed below, but this time by means of an ionization electrode 18 which serves as an ionization element 4 and a ground electrode 29 which is arranged downstream of the surface precipitator 6 and serves as a neutralization element. Consequently, the surface precipitator is completely located in the electrical field 16.

The surface precipitator 6 illustrated here is, in particular, a conventional wall-flow filter made of ceramic or silicon carbide, the ducts of which are alternately closed, with the result that in each case flow dead ends are formed. However, the ducts 7 do not, as illustrated here, have to extend parallel to the central axis 26 of the honeycomb element. The alternately positioned stoppers 23 which are provided for the closure can constitute a corresponding deposition inhibitor for electrically charged soot particles or be embodied as such. The duct walls are embodied here in a porous and/or gas-permeable fashion, with the result that the soot particles are filtered out. If electrical conductivity is present in such a surface precipitator 6, for example as a result of direct contact with the ground electrode 29 and with a corresponding configuration of the honeycomb element, correspondingly selected conduction of the electrical charge should also take place. For this purpose, it is proposed that the honeycomb element be surrounded by a mat 21 which brings about a sufficient distance 22 from the housing 19 in order to avoid a voltage rollover from the surface precipitator 6 to the housing 19. If the honeycomb element is metallic and has its own casing 20, the same applies.

Fig. 6 is intended to be another figurative illustration of individual method steps. Here, in a first step, nitrogen oxides (NO_x) and/or nitrogen monoxide (NO) is converted into nitrogen dioxide (NO_2) by means of the nitrogen dioxide source (and/or a corresponding catalytic coating). Furthermore, the soot particles (PM) or some of the soot particles are ionized, with the result that they have a purely electrical charge. The electrically charged soot particles (PM^+) are then deposited uniformly on a duct wall with the aid of corresponding electrostatic attraction forces, wherein this where possible takes place very uniformly. The soot particles (PM^+/PM) which are spaced apart to a greater extent and are, if appropriate, still electrically charged or even already neutralized, are freely accessible to the generated nitrogen dioxide (NO_2), with the result that simple and effective regeneration of the deposition surface and/or of the filter material is made possible. Catalysts can also be used in supportive fashion for this conversion process. After the conversion of the soot particles, the gaseous residues such as, for example, carbon dioxide (CO_2) and elementary nitrogen (N_2) are removed from the surface precipitator.

Fig. 7 is now an exemplary and illustratative view of the effect of the surface precipitator 6 on the soot particle 2. Said soot particle 2 accordingly flies, for example in the direction 31 of flow, through the pores 33 of the surface precipitator 6, being electrically charged in the process. Owing to the potential toward the surface precipitator 6, this said soot particle 2 does not fly linearly onward (as indicated by dashes) but instead experiences a deflection 34 and comes to bear on the surface precipitator 6. The soot particle 2 can then be correspondingly converted there.

Fig. 8 shows a detail of a further embodiment variant of a surface precipitator according to the invention with a multiplicity of ducts 7 which are bounded by duct walls 17. As a result, in particular what is referred to as a honeycomb element 11 is formed. The honeycomb element 11 is formed from an insulating material, preferably ceramic. In order then to bring about preferred deposition of soot particles in the honeycomb element 11 even downstream of the inlet region 8 of the honeycomb element 11, electrical conductors 15, which extend to different degrees in the direction of the inlet region 8 in different zones 12 of the honeycomb element, are provided in the honeycomb element which is embodied as an electrical insulator 15.

The invention provides, in particular, uniform deposition of the soot particles and continuous regeneration of the surface precipitator.

List of reference numerals

1	Device
2	Soot particle
3	Nitrogen dioxide source
4	Ionization element
5	Neutralization element
6	Surface precipitator
7	Duct
8	Inlet region
9	Outlet region
10	Deposition inhibitor
11	Honeycomb element
12	Axial zone
13	Duct shape
14	Structure
15	Electrical insulator
16	Electrical field
17	Duct wall
18	Catalytic coating
19	Housing
20	Casing
21	Mat
22	Distance
23	Stopping
24	Center
25	Edge
26	Axis
27	Radius
28	Ionization electrode
29	Ground electrode
30	Electrical conductor

31 Direction of flow

32 Oxygen source

33 Pore

34 Deflection