ENHANCED ADSORBENT AND ROOM TEMPERATURE CATALYST PARTICLE AND METHOD OF MAKING AND USING THEREFOR

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

This invention relates generally to adsorbent particles that have improved adsorbent properties and/or improved or newly existing catalytic properties, including room temperature catalyltic capability.

BACKGROUND ART

Oxides of metals and certain non-metals are known to be useful for removing constituents from a gas or liquid stream by adsorbent mechanisms. For example, the use of activated alumina is considered to be an economical method for treating water for the removal of a variety of pollutants, gasses, and some liquids. Its highly porous structure allows for preferential adsorptive capacity for moisture and contaminants contained in gasses and some liquids. It is useful as a desiccant for gasses and vapors in the petroleum industry, and has also been used as a catalyst or catalyst-carrier in air and in water purification. Removal of contaminants such as phosphates by activated alumina are known in the art. See, for example, Yee, W., "Selective Removal of Mixed Phosphates by Activated Alumina," *J.Amer.Waterworks Assoc.*, Vol. 58, pp. 239-247 (1966).

U.S. Patent No. 5,242,879 to Abe *et al.* discloses that activated carbon materials, which have been subjected to carbonization and activation treatments, and then further subjected to an acid treatment and a heat treatment in an atmosphere comprising an inert gas or a reducing gas, have a high catalytic activity and are suitable as catalysts for the decomposition of hydrogen peroxide, hydrazines or other water pollutants such as organic acids, quaternary ammonium-salts, and sulfur-containing

compounds. Acid is used to remove impurities and not to enhance the adsorbent features.

Ion implantation has been used in integrated circuit fabrication. U.S. Patent No. 4,843,034 to Herndon *et al.* discloses methods and systems for fabricating interlayer conductive paths in integrated circuits by implanting ions into selected regions of normally insulative layers to change the composition and/or structure of the insulation in the selected regions. It is stated that a wide range of insulative materials can be rendered selectively conductive, including polymeric insulators and inorganic insulators, such as metal or semi-conductor oxides, nitrides or carbides. Insulators which can be processed according to this patent include silicone dioxide, silicon nitride, silicon carbide, aluminum oxides, and others. It is disclosed that implanted ions can include ions of silicon, germanium, carbon, boron, arsenic, phosphorous, titanium, molybdenum, aluminum, and gold. Typically, the implantation energy varies from about 10 to about 500 KeV. It is disclosed that the ion implantation step changes the composition and structure of the insulative layer and is believed also to have the effect of displacing oxygen, nitrogen, or carbon so as to promote the migration and alloying of metal from the conductive layer(s) into the implanted region during the sintering step. The implantation also is believed to have the physical effect of disrupting the crystal lattice, which may also facilitate the fusion of the metal. This results in a composite material in the implantation region essentially consisting of the disruptive insulator and implanted ions. In the working examples, ions of silicon were implanted into the particular region of the silicon dioxide layer using a direct implantation machine.

U.S. Patent No. 5,218,179 to Matossian *et al.* discloses a plasma source arrangement for providing ions for implantation into an object. A large scale object which is to be implanted with ions is enclosed in a container. The plasma is generated in a chamber which is separate from, and opens into the container for a plasma source ion implantation working volume. The plasma defuses from the chamber into the container to surround the object with substantially improved density compared to conventional

practice. High voltage negative pulses are applied to the object, causing the ions to be accelerated from the plasma toward and be implanted into the object.

Thus, there has been a need in the art for adsorbents that have improved ability to adsorb particular materials, especially contaminants from a gas or liquid stream, to thereby purify the stream. Also, there has been a need in the art for catalysts that have the ability or that have an improved ability to catalyze the reaction of contaminants into non-contaminant by-products.

Additionally, there has been a need in the art for adequately agglomerating adsorbent particles together to form a composite particle for performing simultaneous multiple applications and purifications. In the prior art, particles have been ground up and extruded together to hold them in an agglomerated or combined state. This has the drawback of requiring an expensive extrusion step, wherein particular equipment and processing time is needed to extrude the particles together.

None of the above-cited documents discloses compounds, compositions or processes such as those described and claimed herein.

SUMMARY OF THE INVENTION

In accordance with the purpose(s) of this invention, as embodied and broadly described herein, this invention, in one aspect, relates to a method for producing an enhanced adsorbent and/or enhanced catalytic particle and/or for producing a catalytic particle, comprising the steps of:

(a) removing an effective amount of air from a closed chamber containing an adsorbent and/or catalytic particle, wherein the resultant chamber pressure is less than one atmosphere;

(b) raising the chamber pressure with an inert gas to at least one atmosphere;

(c) contacting the particle with an energy beam of sufficient energy for a sufficient time to thereby enhance the adsorbent and/or catalytic

properties of the particle and/or produce catalytic properties in the particle.

The particle produced from this process can have room temperature catalytic capabilities towards particular contaminants.

The invention further provides a method for producing an enhanced adsorbent and/or enhanced catalytic particle and/or for producing a catalytic particle, comprising implanting oxygen into an adsorbent and/or catalytic particle.

In yet another aspect, the invention relates to the particle made by the process of the invention.

In yet another aspect, the invention relates to an enhanced adsorbent and/or enhanced catalytic particle and/or a catalytic particle comprising an adsorbent particle that has been treated to provide an excess of oxygen implanted at least on the surface of the particle to thereby form an enhanced adsorbent and/or enhanced catalytic particle and/or a catalytic particle.

In yet another aspect, the invention relates to a binder for binding adsorbent and/or catalytic particles to produce an agglomerated particle comprising colloidal aluminum oxide and an acid.

In yet another aspect, the invention relates to a method for binding adsorbent and/or catalytic particles, comprising the steps of:

(a) mixing colloidal aluminum oxide with the particles and an acid;

(b) agitating the mixture to homogeneity; and

(c) heating the mixture for a sufficient time to cause cross-linking of the aluminum oxide in the mixture.

In yet another aspect, the invention relates to a method for reducing or eliminating the amount of a contaminant from a liquid or gas stream comprising contacting the particle of the invention with the contaminant in the stream for a sufficient time to reduce or eliminate the amount of the contaminant from the stream.

In yet another aspect, the invention relates to a method for adsorbing a contaminant from a liquid or gas stream onto an adsorbent particle comprising contacting the particle of the invention with the contaminant in the stream for a sufficient time to adsorb the contaminant.

In yet another aspect, the invention relates to a method for catalyzing the degradation of a hydrocarbon comprising contacting the hydrocarbon with the particle of the invention for a sufficient time to catalyze the degradation of the hydrocarbon.

In yet another aspect, the invention relates to a method for reducing or eliminating the amount of a contaminant from a gas stream by catalysis comprising contacting the particle of the invention with a gas stream containing a contaminant comprising an oxide of nitrogen, an oxide of sulfur, carbon monoxide, or mixtures thereof for a sufficient time to reduce or eliminate the contaminant amount.

In yet another aspect, the invention relates to an apparatus for producing an enhanced adsorbent and/or enhanced catalytic particle and/or for producing a catalytic particle comprising:

(a) chamber means for containing the particle in a closed system having an inlet gas port, an exit gas port, and a target plate, said chamber means being capable of maintaining vacuum and positive pressures;

(b) means for providing an inert gas to the chamber means through the inlet gas port;

(c) means for withdrawing from the chamber means an effective amount of the ambient air therein so as to create a vacuum within the chamber means; and

(d) means for providing an energy beam to the chamber means, said energy beam means outlet being targeted at the target plate.

In yet another aspect, the invention relates to a method for increasing the surface area of an adsorbent and/or catalytic particle, comprising the steps of

(a) raising the chamber gauge pressure of a closed chamber containing the adsorbent and/or catalytic particle to at least 100 psi with an inert gas and

(b) rapidly decompressing the chamber pressure to thereby increase the surface area of the particle.

In yet another aspect, the invention relates to a method for producing an enhanced adsorbent and/or enhanced catalytic particle and/or for producing a catalytic particle, comprising the step of:

(a) contacting an adsorbent and/or catalytic particle with an energy beam of sufficient energy for a sufficient time to thereby enhance the adsorbent and/or catalytic properties of the particle and/or produce catalytic properties in the particle.

Additional advantages of the invention will be set forth in part in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The advantages of the invention will be realized and attained by means of the elements and combinations particularly pointed out in the appended claims. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as claimed.

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate several embodiments of the invention and together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows an apparatus of one embodiment of the present invention for producing an enhanced adsorbent and/or enhanced catalytic particle and/or for producing a catalytic particle.

Fig. 2 is a graph showing the reduction of NO using a particle of the invention.

Fig. 3 is a graph showing the reduction of CO using a particle of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention may be understood more readily by reference to the following detailed description of preferred embodiments of the invention and the Examples included therein and to the Figures and their previous and following description.

Before the present compositions of matter and methods are disclosed and described, it is to be understood that this invention is not limited to specific synthetic methods or to particular formulations, as such may, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting.

It must be noted that, as used in the specification and the appended claims, the singular forms "a," "an" and "the" include plural referents unless the context clearly dictates otherwise.

In this specification and in the claims which follow, reference will be made to a number of terms which shall be defined to have the following meanings:

"Optional" or "optionally" means that the subsequently described event or circumstance may or may not occur, and that the description includes instances where said event or circumstance occurs and instances where it does not.

The term "particle" as used herein is used interchangeably throughout to mean a particle in the singular sense or a combination of smaller particles that are grouped together into a larger particle, such as an agglomeration of particles.

The term "ppm" refers to parts per million and the term "ppb" refers to parts per billion. GPM is gallons per minute.

In accordance with the purpose(s) of this invention, as embodied and broadly described herein, this invention, in one aspect, relates to a method for producing an enhanced adsorbent and/or enhanced catalytic particle and/or for producing a catalytic particle, comprising the steps of:

(a) removing an effective amount of air from a closed chamber containing an adsorbent and/or catalytic particle, wherein the resultant chamber pressure is less than one atmosphere;

(b) raising the chamber pressure with an inert gas to at least one atmosphere;

(c) contacting the particle with an energy beam of sufficient energy for a sufficient time to thereby enhance the adsorbent and/or catalytic properties of the particle and/or produce catalytic properties in the particle.

The particle produced from this process can have room temperature catalytic capabilities towards particular contaminants.

The invention further provides a method for producing an enhanced adsorbent and/or enhanced catalytic particle and/or for producing a catalytic particle, comprising implanting oxygen into an adsorbent and/or catalytic particle.

In yet another aspect, the invention relates to the particle made by the process of the invention.

In yet another aspect, the invention relates to an enhanced adsorbent and/or enhanced catalytic particle and/or a catalytic particle comprising an adsorbent particle that has been treated to provide an excess of oxygen implanted at least on the surface of the particle to thereby form an enhanced adsorbent and/or enhanced catalytic particle and/or a catalytic particle.

In yet another aspect, the invention relates to a binder for binding adsorbent and/or catalytic particles to produce an agglomerated particle comprising colloidal aluminum oxide and an acid.

In yet another aspect, the invention relates to a method for binding adsorbent and/or catalytic particles, comprising the steps of:

(a) mixing colloidal aluminum oxide with the particles and an acid;

(b) agitating the mixture to homogeneity; and

(c) heating the mixture for a sufficient time to cause cross-linking of the aluminum oxide in the mixture.

In yet another aspect, the invention relates to a method for reducing or eliminating the amount of a contaminant from a liquid or gas stream comprising contacting the particle of the invention with the contaminant in the stream for a sufficient time to reduce or eliminate the amount of the contaminant from the stream.

In yet another aspect, the invention relates to a method for adsorbing a contaminant from a liquid or gas stream onto an adsorbent particle comprising contacting the particle of the invention with the contaminant in the stream for a sufficient time to adsorb the contaminant.

In yet another aspect, the invention relates to a method for catalyzing the degradation of a hydrocarbon comprising contacting the hydrocarbon with the particle of the invention for a sufficient time to catalyze the degradation of the hydrocarbon.

In yet another aspect, the invention relates to a method for reducing or eliminating the amount of a contaminant from a gas stream by catalysis comprising contacting the particle of the invention with a gas stream containing a contaminant comprising an oxide of nitrogen, an oxide of sulfur, carbon monoxide, or mixtures thereof for a sufficient time to reduce or eliminate the contaminant amount.

In yet another aspect, the invention relates to an apparatus for producing an enhanced adsorbent and/or enhanced catalytic particle and/or for producing a catalytic particle comprising:

(a) chamber means for containing the particle in a closed system having an inlet gas port, an exit gas port, and a target plate, said chamber means being capable of maintaining vacuum and positive pressures;

(b) means for providing an inert gas to the chamber means through the inlet gas port;

(c) means for withdrawing from the chamber means an effective amount of the ambient air therein so as to create a vacuum within the chamber means; and

(d) means for providing an energy beam to the chamber means, said energy beam means outlet being targeted at the target plate.

In yet another aspect, the invention relates to a method for increasing the surface area of an adsorbent and/or catalytic particle, comprising the steps of

(a) raising the chamber gauge pressure of a closed chamber containing the adsorbent and/or catalytic particle to at least 100 psi with an inert gas and

(b) rapidly decompressing the chamber pressure to thereby increase the surface area of the particle.

In yet another aspect, the invention relates to a method for producing an enhanced adsorbent and/or enhanced catalytic particle and/or for producing a catalytic particle, comprising the step of:

(a) contacting an adsorbent and/or catalytic particle with an energy beam of sufficient energy for a sufficient time to thereby enhance the adsorbent and/or catalytic properties of the particle and/or produce catalytic properties in the particle.

By enhanced adsorbent and/or enhanced catalytic particle, it is intended that the particles of this invention have improved adsorbent and/or improved catalytic properties over prior art adsorbent and/or catalytic particles. Also, by producing a catalytic particle, it is intended that some particles of the instant invention have catalytic properties for catalyzing the conversion of particular contaminants into other forms, whereas the same particles not treated by the process of the present invention possess no catalytic properties at least for those particular contaminants.

Enhanced adsorptive properties is intended to include both ion capture and ion exchange mechanisms. Ion capture refers to the ability of the particle to bond to other atoms due to the ionic nature of the particle. Ion exchange is well known in the art and refers to ions being interchanged from one substance to another. Adsorption is a term well known in the art and should be distinguished from absorption.

In the particle of this invention, typically any particle that initially has some adsorbent and/or catalytic properties can be used. For example, activated carbon and oxide particles can be oxygen implanted by the process of the present invention.

For oxide particles, oxides of metals or oxides of non-metals, such as silicon or germanium, are preferred. Even more preferred are oxides of transition metals, oxides of metals of Group III (B, Al, Ga, In, Tl) and IA (Li, Na, K, Rb, Cs, Fr) of the periodic table, and oxides of silicon. Particularly preferred oxides include aluminum oxide (Al_2O_3), silicon dioxide (SiO_2), manganese dioxide (MnO_2), copper

oxide (CuO), iron oxide black (Fe_3O_4), iron oxide red (ferric oxide or Fe_2O_3), zinc oxide (ZnO), zirconium oxide (ZrO_2), vanadium pentoxide (V_2O_5), and titanium dioxide (TiO_2).

In one embodiment, the particle comprises alumina oxide that has been pre-treated by a full calcination process. Calcined aluminum oxide particles are well known in the art. They are particles that have been heated to a particular temperature to form a particular crystalline structure. Processes for making calcined aluminum oxide particles are well known in the art as disclosed in, e.g., *Physical and Chemical Aspects of Adsorbents and Catalysts*, ed. Linsen *et al.*, Academic Press (1970), which is incorporated by reference herein. In one embodiment, the Bayer process can be used to make aluminum oxide precursors. Also, pre-calcined aluminum oxide, that is, the aluminum oxide precursor ($Al(OH)_3$), and calcined aluminum oxide are readily commercially available. Calcined aluminum oxide can be used in this dried, activated form or can be used in a partially or near fully deactivated form by allowing water to be adsorbed onto the surface of the particle. However, it is preferable to minimize the deactivation to maximize the adsorbent capability.

In a preferred embodiment, the aluminum oxide has been produced by calcining at a particle temperature of from 400°C to 700°C. These preferred aluminum oxide particles are preferably in the gamma, chi-rho, or eta forms and have a pore size of from 3.5 nm to 35 nm diameter and a BET surface area of from 120 to 350 m^2/g.

For activated carbon, any of the activated carbons useful in the adsorbent art can be used. Preferably coal based carbon or coconut based carbon are used. Generally, coal based carbon can be used to remediate aqueous contaminants while coconut based carbon can be used to remediate airborne or gaseous contaminants. Preferably, the activated carbon is less than 20 microns in size for ease of mixing and extrusion.

The particle of the invention can be used alone, in combination with identical or different type composition particles prepared by the processes of the invention, and/or in combination with other adsorbent or catalytic particles known in the art. The particles can be combined in a physical mixture or agglomerated using techniques known in the art or disclosed herein. In a preferred embodiment, different composition type particles are combined by agglomeration to form a multifunctional composite particle. In this embodiment, particles can be used to achieve multiple functions simultaneously, such as by removing multiple contaminants, by taking advantage of the individual effects from each of the types of particles. Co-particles that are preferably used in this invention include all particles previously disclosed and zeolite.

In one embodiment, the composite particle comprises aluminum oxide and a second particle of titanium dioxide, copper oxide, vanadium pentoxide, silicon dioxide, manganese dioxide, iron oxide, zinc oxide, activated carbon, or zeolite. In another embodiment, the composite particle comprises aluminum oxide and activated carbon. In another embodiment, the particle comprises activated carbon (coal-based), activated carbon (coconut-based), silicon dioxide, and aluminum oxide. In a preferred embodiment, this particle is used to remediate aqueous contamination. In one embodiment, this particle of coal-based activated carbon, coconut-based activated carbon, silicon dioxide, and aluminum oxide is used to remediate aqueous contaminants, such as 1,2-dibromo-3-chloropropane (DBCP), radon, and heavy metals, from a contaminated water source.

The particles of this invention can be subjected to other surface treatments prior to or after being treated by the process of the present invention. The particles of the invention can be pretreated by processes known in the art to improve their adsorptive capability, such as by calcination. Calcination refers to heating a solid to a temperature below its melting point to alter the crystal structure to a particular form. The calcinated particle can be dried or maintained in dry form creating an activated particle or, if water is absorbed on the particle, the particle can be partially or

near fully deactivated. In one embodiment, the particles of this invention can be in dry, slurry, or gel form. The particle size can vary depending on the end use, ranging in sizes known in the art, such as colloidal, microscopic, or macroscopic. Preferably, the particles prior to agglomeration are less than 20 microns in size for ease of mixing and extrusion.

Binders for binding the individual particles to form an agglomerated particle are known in the art or are described herein. In a preferred embodiment, the binder can also act as an adsorbent and/or a catalyst. A preferred binder for the agglomerated particle is colloidal alumina or colloidal silica. At approximately 450°C, the colloidal alumina goes through a transformation stage and cross-links with itself. Colloidal silica cross-links with itself if it is sufficiently dried to remove water. Preferably, from about 20 wt. % to about 99% of the total mixture is colloidal alumina or colloidal silica to provide the necessary crosslinking during heating to bind the agglomerated particle into a water-resistant particle. The particle can then withstand exposure to all types of water for an extended time and not degrade.

In one embodiment, the agglomerated particle is made by mixing colloidal alumina with the adsorbent particles. Typically, from about 20% to about 99% by weight of the mixture is colloidal alumina. The particle mixture is then mixed with an acid solution such as, for example, nitric, sulfuric, hydrochloric, boric, acetic, formic, phosphoric, and mixtures thereof. In one embodiment the acid is 5% nitric acid solution. The colloidal alumina, adsorbent particles, and acid solution are thoroughly mixed so as to create a homogenous blend of all elements. Then additional acid solution is added and further mixing is performed until the mixture reaches a suitable consistency for agglomeration. After agglomeration is complete, the agglomerated particles are heated to at least 450°C to cause the colloidal alumina crosslinking to occur.

Sources and/or methods of making the starting materials for the various adsorbent particles of the present invention are readily available and are well-known to those of ordinary skill in the art.

For an explanation of the process used to make a particle of one embodiment of this invention, reference is made to Figure 1. The apparatus of this embodiment is designated generally as 10. The particulate material or target media 20 to be treated is placed in a chamber 11 on ungrounded target plate 22. In one embodiment, the target plate can be rotated to provide more efficient treatment of the particle by the energy beam. Chamber 11 is preferably made of a dielectric material. Chamber 11 is sealed by a compression plate latched door 12 that has the ability to withstand high compression ratios both in the positive as well as negative pressures. Pressure is monitored with pressure gauge 18. Vacuum conditions are created in the chamber using vacuum pump 19 to evacuate an effective amount of air initially contained in the chamber. Air can be detrimental to the oxygen implantation step in that it reduces the efficiency of the energy beam's affect on the particle. Evacuating an effective amount of air is intended to mean that enough air is removed so that the energy beam has the ability to enhance the adsorbent and/or catalytic properties and/or produce catalytic properties in the particle. Typically, vacuum pump 19 is used to evacuate as much air as possible from chamber 11 to maximize the energy beam's efficiency and to allow a beam of lower energy to be used. The chamber is brought up to a pressure of at least atmospheric pressure using an inert gas from cylinder 13 through a high pressure injector 17. In one embodiment, the gauge pressure (pressure above atmospheric) is from 1 to 5,000 psi. Typically, the gauge pressure can be at least about 20 psi to prevent arcing.

The inert gas is typically any gas that is inert to chemically reacting with and degrading the adsorbent particle, and yet, does not impede the energy beam's effectiveness in implanting the oxygen. Typical inert gases include the noble gases, such as helium, neon, argon, krypton, xenon, and radon.

The energy source is targeted at the particle contained in the chamber through an energy injector 15 located at the end of the energy source 14. The energy source can be of any high energy that can force oxygen into the particle and/or add excess charge to the particle. Typically, the energy source is an ion machine which

concentrates an ion or electron beam, such as a broad beam ion source or a wide beam photoionizer. In a specific embodiment, the energy source can be a broad beam ion source, manufactured by Commonwealth, Alexandria, Virginia, U.S.A. having a maximum output of 25 eV. The energy source 14, utilizes a power supply 21. In a specific embodiment, the power supply can be a Commonwealth IBS-250 high voltage power supply rated up to 1500V with remote operation capabilities. Additionally, the energy beam causes the inert gas to become ionized. The charge introduced into the chamber is at a level sufficient to enhance the adsorbent and/or catalytic properties of the particle and/or produce catalytic properties in the particle. In one embodiment, an electron beam of 15 to 20 eV was used, although a smaller or larger amount of energy can be used. Once the proper charge has been attained for a sufficient time, the energy source is turned off. This sufficient time can be very short, on the order of less than a second to about 10 seconds, although a longer time is not detrimental. Then, the chamber pressure is decompressed via a release valve 16.

Not wishing to be bound by theory, it is theorized that the energy beam causes monoatomic oxygen present on the surface of the particle to be pushed below the surface of the particle, which then becomes tightly bound to the internal structure of the particle. For crystalline particles, the oxygen becomes tightly bound within the crystal lattice. The monoatomic oxygen originates from oxygen that is on the outer surface of the crystal lattice of the particle or from residual water or air on the surface of the particle. This increases the adsorbent and/or catalytic characteristics of the particle and can create catalytic properties, including room temperature catalytic capabilities, in the particle. It is additionally theorized that the advantageous properties of the particle of this invention result from the energy beam adding an electrical charge or increased electrical charge to the particle.

In another embodiment, in the energy beam proces above, after the air has been removed from the chamber, inert gas is added so that the chamber pressure is brought up to a high pressure. Typically, the gauge pressure can be from about at least 100 psi, more preferably at least 1,000 psi, even more preferably at least 5,000 psi.

Even higher pressures can be used if the chamber 15 of a high enough pressure rating. The high pressure or compression is maintained for a sufficient time to increase the density of the particle. Residual air is bled from the vessel, thereby removing any residual air from a puffed up particle, until a constant pressure can be maintained. Typically, about ten minutes of high pressure is sufficient. After the energy source has been introduced for a sufficient time in the chamber as described above, the energy source is turned off and then the chamber pressure is rapidly decompressed via release valve 16. By rapidly, it is preferably meant about 3 seconds. This increases the surface area of the particle.

Not wishing to be bound by theory, it is theorized that as the pressure from the chamber is rapidly released, the contents of the chamber expand simultaneously but at different rates of expansion. The charged inert gas expands at a much faster rate than that of the particulate matter due to the density differences between the two substances. Due to this expansion rate difference, the charged inert gas travels rapidly and penetrates or explodes into and through the particles. This rapid penetration alters the pore structure and increases the amount of pores of the particle. The surface area of the particle is thereby greatly increased, increasing the overall adsorption capability of the particle. Depending on the particle employed, the BET surface area can be increased at least 1%, more preferably at least 5%, even more preferably at least 10%, even more preferably at least 20%, even more preferably at least 30%. The lower density particles, such as activated carbon, can achieve a greater increase in surface area.

The chamber pressure and the energy level can be varied to produce different effects to meet the particular physical and chemical requirements for the specific particle end use. Varying the pressure and energy level parameters can alter the ability of the particle to adsorb a particular contaminant.

In another embodiment of this invention, the surface area enhancement aspect of the process can be practiced alone without the energy beam aspect. In this embodiment, the inert gas only needs to be inert to the particle and does not have to be

inert to the effects of the energy beam. Thus, gases such as air and CO_2 can also be used in the this embodiment.

In another embodiment, the energy beam aspect can be practiced alone without the surface area enhancement aspect. In this embodiment, the energy beam is targeted directly at the particle to implant oxygen within the particle. This can be done in the batch process described above or a semi-batch or continuous process. In a semi-batch process, particles are automatically moved into the chamber where they are treated and automatically removed from the chamber. In a continuous process, in one embodiment, the particles are provided on a conveyor belt system. Air is displaced from the area around the particles by inert gas to provide a viable path for the energy beam, which is set up along side or overhead of the conveyer belt system. The energy beam is either continuously on or is turned on as the particles reach a specific point along the conveyer belt system. In a variation of the embodiments of this invention, the air removal and replacement with inert gas steps in the batch or semi-batch processes and the air displacement by inert gas step in the continuous process can be avoided by using an extremely high level of energy source, such that, the air does not impede the oxygen from penetrating the surface of the particle. In another embodiment of a continuous process, the particles are filtered through a mesh screen sieve, which has been substantially ionized to cause the oxygen on the particle to penetrate the particle.

The particles of this invention are characterized by having an increased level of oxygen at least on the surface of the particle. This increased level of oxygen is higher than the total of the stoichiometric amount of oxygen expected in the particle and that found as residual oxygen on the surface of the particle. The oxygen implanted particle has at least 1.1 times the oxygen atom per cent to non-oxygen atom per cent ratio at its surface compared to the initial non-oxygen implanted particle, wherein the surface characterization is determined by an x-ray photoelectron spectroscopy (XPS or ESCA) spectrometer, a device well known to those of skill in the art. Even more preferably, the particle has at least a 1.5 fold increase in oxygen ratio, even more preferably the particle has at least a 2 fold increase in oxygen ratio, even more

preferably, at least a 4 fold increase in oxygen ratio, even more preferably at least a 6 fold increase in oxygen ratio.

The particle of this invention can be used in any adsorption and/or catalytic application known to those of ordinary skill in the art to achieve superior results over prior art particles. Additionally, the particle of the invention can be used in various adsorption and/or catalytic applications never before contemplated in the art. In one embodiment, the particle is used for environmental remediation applications. In this embodiment, the particle can be used to remove contaminants, such as heavy metals, organics, including for example but not limited to, chlorinated organics and volatile organics, inorganics, or mixtures thereof. Specific examples of contaminants include, but are not limited to, acetone, microbials, ammonia, benzene, carbon monoxide, chlorine, dioxane, ethanol, ethylene, formaldehyde, hydrogen cyanide, hydrogen sulfide, methanol, methyl ethyl ketone, methylene chloride, nitrogen oxides, propylene, styrene, sulfur dioxide, toluene, vinyl chloride, arsenic, lead, iron, phosphates, selenium, cadmium, uranium, plutonium, radon, 1,2-dibromo-3-chloropropane (DBCP), chromium, tobacco smoke, and cooking fumes. The particle of this invention can remediate individual contaminants or multiple contaminants from a single source.

For environmental remediation applications, typically, particles of the invention are placed in a container, such as a filtration unit. The contaminated stream enters the container at one end, contacts the particles within the container, and the purified stream exits through another end of the container. The flow rate of the contaminant stream and the amount of particle material needed can be determined by one of skill in the art with routine experimentation by determining the capacity needed. The particles contact the contaminants within the stream and bond to and remove the contamination from the stream. The particles can also eliminate certain contaminants by catalyzing the conversion of the contaminants into other components. Typically, in the adsorption application, the particles become saturated with contaminants over a period of time, and the particles must be removed from the container and replaced with fresh particles. The contaminant stream can be a gas, such as air, or liquid, such as water.

In the adsorption application, the particle of this invention bonds with the contaminant so that the particle and contaminant are tightly bound. This bonding makes it difficult to remove the contaminant from the particle, allowing the waste product to either be disposed of into any public landfill or used as a raw material in the building block manufacturing industry. Measurements of contaminants adsorbed on the particles of this invention using a Toxic Chemical Leachate Permit (TCLP) test known to those of skill in the art showed that there was a bond at least as strong as a covalent bond between the particles of this invention and the contaminants.

The particles of this invention have superior ability to adsorb contaminants due to enhanced physical and chemical properties of the particle. The particles of this invention can adsorb a larger amount of adsorbate per unit volume or weight of adsorbent particles than a non-enhanced particle. The particle of this invention surprisingly removes contaminants in various streams at both high and low concentrations of contaminants. Also, the particles of this invention can reduce the concentration of contaminants or adsorbate material in a stream to a lower absolute value than is possible with a non-enhanced particle. In particular embodiments, the particles of this invention can reduce the contaminant concentration in a stream to below detectable levels, never before achievable with prior art particles.

The particles of this invention can also have a newly added catalytic property. Specifically, the increased oxygen content in the particle matrix allows the particle to act as a catalyst. For example, the particle has the ability to catalyze the break down of hydrocarbon compounds and has the ability to catalyze the conversion of CO, SO_x, or NO_x into other components, even at low heat or room temperatures.

Particular end uses contemplated by this invention include, but are not limited to, reducing or eliminating contaminants for particular applications, such as waste water treatment facilities, sewage facilities, municipal water purification facilities, in-home water purification systems, smoke stack effluents, vehicle exhaust effluents, engine or motor effluents, home or building air purification systems, home radon

remediations, landfill leachates, manufacturing facility chemical waste effluents, and the like.

Prior art adsorbents, such as activated carbon, when sprayed with anti-microbials, tend to lose their adsorbent properties. Conversely, the increased adsorbent properties allow the particles of the present invention to be sprayed with anti-microbials while still retaining the particle's adsorbent properties. Moreover, unlike prior art particles, contact with water does not deactivate the adsorption capability of the inventive particles.

Experimental

The following examples are put forth so as to provide those of ordinary skill in the art with a complete disclosure and description of how the compounds claimed herein are made and evaluated, and are intended to be purely exemplary of the invention and are not intended to limit the scope of what the inventors regard as their invention. Efforts have been made to ensure accuracy with respect to numbers (e.g., amounts, temperature, etc.) but some errors and deviations should be accounted for. Unless indicated otherwise, parts are parts by weight, temperature is in °C or is at or near room temperature and pressure is at or near atmospheric.

Example 1.

Various particles were made in accordance with the procedures of this invention as follows. The procedures used to prepare the particle designated as 1a in Table 1 below, having a composition of 60% Al_2O_3, 20% carbon, 15% manganese dioxide and 5% copper oxide, is exemplified. The alumina utilized was a gamma calcined (550°C) alumina derived from a high density, low porosity pseudoboehmite alumina or alumina gel. The alumina was pretreated by calcining to 550° C to reach the desired gamma crystalline structure. The carbon utilized in this particle was a coconut based carbon, designated as Polynesian coconut based carbon purchased from Calgon

Carbon Corporation. Due to the use of coconut shells in the manufacture of this carbon, there exists a very large surface area as well as micro-pores which are useful for removing contaminants in a gas stream. The four individual particle types were mixed together in their appropriate weight per cents according to the dry weight. They were mixed together into a homogenous dry mixture. An acid solution of 20 parts by weight of 80% nitric acid was added to 80 parts by weight of water. The acid solution was added to the dry particle mixture slowly until the mixture obtained a moist pasty consistency. This consistency allowed the mixture to be extruded into the desired form. The mixture was extruded using a LCI model BTG® laboratory extruder. After the mixture was extruded, the extrudate was chopped up into approximately one-sixteenth to one-eighth inch particles and then was dried at a temperature of at least 450° C to cross-link the aluminum oxide. The particles were placed in a vacuum/pressure vessel chamber on an ungrounded target plate. The door to the chamber was secured, and air was pumped out of the chamber down to a negative pressure of two militorrs. Upon reaching this pressure, argon gas was allowed to bleed into the chamber and reach an internal gauge pressure of about 20 psi. Upon reaching this pressure, the energy beam source was activated to 15 to 20 eV and was applied to the particle on the target area. A Commonwealth broad beam ion source was used. Treatment times for the particles vary according to the amount and density of material on the target. For this example, a volume of 50 grams of material was used and a treatment time of ten seconds was used. The treatment times also vary according to the output power from the energy beam source and the internal pressure in the chamber. After ten seconds, the ion source was turned off and the chamber was evacuated to atmospheric pressure. The sample was then removed from the chamber.

Particles 1b through 1ac were similarly made in accordance with the above-described example for 1a except that the particular compositions were as set forth in Table 1. Also, the carbon utilized for aqueous particle designations 1v and 1w was a coal based carbon. This coal based carbon was purchased from Calgon Carbon Corporation as WHP grade carbon. The particular alumina utilized in particles 1b through 1ac was the same as described above for particle 1a, a gamma calcined alumina.

The other components listed below in Table 1 are well known and are readily available to one of skill in the art.

Each of the particle's composition made in accordance with the procedures of this invention described above and the contaminant it was tested with in Examples 2 and 3 are listed below in Table 1. The same particle designation system is used in Tables 1-3.

TABLE 1			
PARTICLE DESIGNATION	COMPOSITION[1] (weight %)	CONTAMINANTS	
		AIRBORNE	AQUEOUS
1a	60% Al_2O_3, 20% Carbon, 15% MnO_2, 5% CuO	Acetone	
1b	100% Al_2O_3	Ammonia	
1c	50% Al_2O_3, 40% Carbon, 10% SiO_2	Benzene	
1d	40% Al_2O_3, 30% V_2O_5, 20% MnO_2, 10% TiO_2	Carbon Monoxide	
1e	100% Al_2O_3	Chlorine	
1f	100 % Al_2O_3	1,4-Dioxane	
1g	100% Al_2O_3	Ethanol	
1h	100% Al_2O_3	Formaldehyde	
1i	40% Al_2O_3, 30% MnO_2, 20% V_2O_5, 5% Zeolite, 5% Fe_2O_3	Hydrogen Cyanide	
1j	30% Al_2O_3, 50% MnO_2, 5% Carbon, 5% SiO_2, 10% ZnO	Hydrogen Sulfide	
1k	90% Al_2O_3, 10% Carbon	Methanol	
1l	100% Al_2O_3	Methyl Ethyl Ketone	
1m	40% Al_2O_3, 20% MnO_2, 10% CuO, 30% V_2O_5	Methylene Chloride	
1n	40% Al_2O_3, 30% V_2O_5, 20% MnO_2, 10% TiO_2	Nitrogen Oxides	
1o	30% Al_2O_3, 70% Carbon	Propylene	
1p	30% Al_2O_3, 70% Carbon	Styrene	
1q	100% Al_2O_3	Sulfur Dioxide	
1r	40% Al_2O_3, 30% MnO_2, 30% Carbon	Toluene	
1s	30% Al_2O_3, 70% Carbon	Vinyl Chloride	
1t	100% Al_2O_3		Arsenic
1u	100% Al_2O_3		Cadmium
1v	40% Al_2O_3, 40% Carbon, 20% SiO_2		Chlorine

TABLE 1			
PARTICLE DESIGNATION	COMPOSITION[1] (weight %)	CONTAMINANTS	
		AIRBORNE	AQUEOUS
1w	40% Al_2O_3, 40% Carbon, 20% SiO_2		DBCP
1x	100% Al_2O_3		Iron
1y	100% Al_2O_3		Lead
1z	100% Al_2O_3		Phosphate
1aa	40% Al_2O_3, 40% Carbon, 20% SiO_2		Radon
1ab	100% Al_2O_3		Selenium
1ac	100% Al_2O_3		Uranium

[1] Activated carbon coconut based was used for the airborne contaminants and for 1aa (radon) and activated carbon coal based was used for aqueous contaminants 1v and 1w.

Example 2.

The particles made in Example 1 were tested for their ability for removal of various components from air. The tests for the airborne contaminants as summarized in Table 2 below were performed as follows. The contaminant source used was either solvent vapor or an off the shelf bottled gas mixture. Solvent vapor was mixed with humid air by injecting into the system with a syringe pump. A gas bottle with a needle valve and a flow meter, either a rotameter or a mass flow meter controller, was used to blend the gas bottle effluent with the humid air. Humid air at 30% relative humidity and 25°C was mixed with either the solvent vapor or gas stream. The humid air was generated by a flow-temperature-humidity control module which controlled temperature, relative humidity and the flow rate of the humid air. The concentration of the airborne contaminant in the humid air was then measured by an infrared analyzer. After the influent infrared analysis, the sample entered a sample holder. The sample holder was a three-inch diameter test vessel, which held a 200 gm amount of particle sample in place using a fritted disk. After passing through the particles, the concentration of the contaminant in the effluent exited the sample holder. The

concentration of the contaminent in the effluent side of the particle sample holder was also analyzed with an infrared analyzer. The test time was ten minutes. Percent removal was calculated as (initial contaminant concentration minus effluent contaminant concentration) divided by initial contaminant concentration.

The results are set forth in Table 2 below.

TABLE 2

PARTICLE DESIGNATION	AIRBORNE CONTAMINANT	INITIAL CONTAMINANT CONCENTRATION (ppm)	PERCENT REMOVAL	FLOW RATE[1]
1a	Acetone	750	100	40 ft/min.
1b	Ammonia	50	100	40 ft/min.
1c	Benzene	50	100	40 ft/min.
1d	Carbon Monoxide	10000	100	40 ft/min.
1e	Chlorine	34	100	40 ft/min.
1f	1,4-Dioxane	50	100	40 ft/min.
1g	Ethanol	1000	100	40 ft/min.
1h	Formaldehyde	10	100	40 ft/min.
1i	Hydrogen Cyanide	20	100	40 ft/min.
1j	Hydrogen Sulfide	20	100	40 ft/min.
1k	Methanol	200	100	40 ft/min.
1l	Methyl Ethyl Ketone	1000	100	40 ft/min.
1m	Methylene chloride	50	100	40 ft/min.
1n	Nitrogen Oxides	100	100	40 ft/min.
1o	Propylene	700	100	40 ft/min.
1p	Styrene	50	100	40 ft/min.
1q	Sulfur Dioxide	20	100	40 ft/min.
1r	Toluene	100	100	40 ft/min.
1s	Vinyl Chloride	20	100	40 ft/min.

[1] 40 ft/min velocity was 55.5 l/min volumetric flow.

In Table 2 above, for the formaldehyde test using particle 1h, formaldehyde was not detected on the particle after the test was completed and, as shown in Table 2, no formaldehyde was detected in the effluent stream. This particle 1h acts as a catalyst towards formaldehyde and breaks down the formaldehyde into what is believed to be CO_2 and water, even at room temperature. This was further evidenced by a separate test in which it was shown that the formaldehyde was removed from the system over a substantially longer period of time than can be explained if the particle acted only as an adsorbent.

As can also be seen from the above Table 2, carbon monoxide and nitrogen oxides were not detected in the effluent system. Because these two components do not normally adsorb to the particle of the type used in this test, these particles act as a catalyst towards CO and NO_x. It is believed that the CO is converted to CO_2 and water and the NO_x are converted to N_2 and O_2. It is also believed that the remediation of SO_2 was through, at least in part, a catalysis reaction that converted SO_2 into other components. The catalyzed reactions were surprisingly achieved even at room temperature.

Example 3.

The particles made in Example 1 were tested for their ability for the removal of various components from water. The test procedures were as follows. For each contaminant run, 5 glass columns of 0.875 inch inner diameter by 12 inches long were prepared, each having a bed volume of test particle of 95 mls. Each bed was flushed with five bed volumes of deionized water by downward pumping at 6 gpm/ft^2 of cross-sectional flow rate (*i.e.*, about 95 ml/min). Each of the flow rates listed in Table 3 is per foot squared of cross-sectional flow rate. Test solutions for each of the aqueous contaminants were prepared. A total of ten bed volumes, that is, about one liter per column of aqueous contaminant test solution, was pumped through each of the columns. During each run, the aqueous contaminant test solutions were continuously stirred at low speed prior to entry into the glass column to maintain a homogenous composition.

During the tenth bed volume, an effluent sample from each column was collected and analyzed for the particular aqueous contaminant. Additionally, a single influent sample for each test was collected and analyzed for the contaminant concentration.

The results of these tests are set forth in Table 3 below.

TABLE 3

PARTICLE DESIG-NATION	AQUEOUS CON-TAMINANT	INFLUENT	EFFLUENT	FLOW RATE	DETECTION LIMIT
1t	Arsenic	2,890 ppb	< 10 ppb	5-6 GPM	10 ppb
1u	Cadmium	1,003 ppb	<10 ppb	5-6 GPM	10 ppb
1v	Chlorine	263 ppb	<10 ppb	5-6 GPM	10 ppb
1w	DBCP 1,2-Dibromo-3-Chloropropane	(sw) 230.0 µg/l (sw) 210.0 µg/l (gw) 0.07 µg/l	<0.02 µg/l <0.02 µg/l <0.02 µg/l	5-6 GPM 5-6 GPM 5-6 GPM	0.02 µg/l 0.02 µg/l 0.02 µg/l
1x	Iron	1.15 mg/l	<0.03 mg/l	5-6 GPM	0.03 µg/l
1y	Lead	215 ppb	< 10 ppb	5-6 GPM	10 ppb
1z	Phosphates	40.45 mg/l	9.50 mg/l	5-6 GPM	N/A
1aa	Radon	1,104.2 pCi/l 911.6 pCi/l	303.2 pCi/l 306.1 pCi/l	5-6 GPM 5-6 GPM	N/A
1ab	Selenium	1.45 mg/l	<0.003 mg/l	5-6 GPM	0.003 mg/l
1ac	Uranium	50.5 ppm	0.08 ppm	5-6 GPM	N/A

sw = Synthetic water
gw = ground water

Example 4.

A particle of 100% activated carbon coconut based of the present invention was prepared in accordance with the procedures of Example 1 above. An ESCA spectrometer was used to analyze the surface composition for the original

activated carbon particle and the particle after it was prepared using the process of Example 1. The surface characterization results are as follows.

TABLE 4		
ELEMENT	INITIAL ACTIVATED CARBON PARTICLE (Atom %)	ACTIVATED CARBON PARTICLE OF THIS INVENTION (Atom %)
Carbon	96.47	61.65
Oxygen	3.53	16.37
Sodium		0.59
Fluorine		8.61
Potassium		7.60
Chlorine		1.61
Sulfur		0.86
Phosphorus		0.55
Magnesium		2.5

Thus, the initial particle had an oxygen/carbon ratio of about 0.04, whereas the treated activated carbon particle of this invention had an oxygen/carbon ratio of about 0.27, for an increased oxygen/carbon ratio of about 7 times the original ratio. A similar test was run on 100% aluminum oxide prepared according to the process of Example 1. The oxygen/aluminum ratio was increased at least about 2 fold over the original untreated particle oxygen/aluminum ratio.

Example 5.

A TCLP test was run on two different contaminant remediation applications of this invention. The particles were prepared by the procedures of Example 1 and were used to adsorb the particular contaminants in Table 5 below. In accordance with the EPA test methods, the particles were, *inter alia*, washed with an

acid solution and tumbled for the requisite length of time. The concentration of the contaminants removed from the particle were then measured. The results are set forth below in Table 5.

TABLE 5

PARTICLE	CONTAMINANT	EPA TCLP TEST METHOD	TCLP CONTAMINANT (mg/l)	PQL[1]
100% Al_2O_3	Lead	1311/6010	< 0.50	0.50
100% Al_2O_3	Phosphate	1311/365.4	<0.1[2]	0.1

[1] PQL is the practical quantitation limit, which is an EPA standard, and is different than the lowest detectable limit.

[2] TCLP measures for phosphorus.

Thus, the particles of the invention, when acting as an adsorbent, bond tightly to the contaminants.

Example 6.

A fixed bed reactor was charged with 158 g, 9.4 cubic inches (2 inches diameter x 3 inches high) of the particles of Example 1(d) (40% Al_2O_3, 30% V_2O_5, 20% MnO_2, 10% TiO_2). A mixture of 101.8 ppm NO and 1,035 ppm CO in air was fed into the fixed bed reactor at room temperature at a rate of 35 standard cubic feet per hour (SCFH). The effluent of the fixed bed reactor was fed into a Horiba CLA-510SS NO_x analyzer and a VIA-510 CO analyzer. The NO concentration dropped immediately reaching 5.4 ppm by 5 minutes (the first recorded measurement) and continued to drop to 4.0 ppm by 40 min. (*See*, Figure 2). The CO concentration dropped more slowly, dropping to 532 ppm at 40 min. (*See*, Figure 3). The test was stopped shortly after 40 minutes. The CO concentration was still decreasing at 40 min. and may decrease further

upon further reaction time. It is believed that the particles of the invention catalytically degrade the CO and NO.

Throughout this application, various publications are referenced. The disclosures of these publications in their entireties are hereby incorporated by reference into this application in order to more fully describe the state of the art to which this invention pertains.

It will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope or spirit of the invention. Other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the invention being indicated by the following claims.

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What is claimed is:

1. A method for producing an enhanced adsorbent and/or enhanced catalytic particle and/or for producing a catalytic particle, comprising the steps of:
   (a) removing an effective amount of air from a closed chamber containing an adsorbent and/or catalytic particle, wherein the resultant chamber pressure is less than one atmosphere;
   (b) raising the chamber pressure with an inert gas to at least one atmosphere;
   (c) contacting the particle with an energy beam of sufficient energy for a sufficient time to thereby enhance the adsorbent and/or catalytic properties of the particle and/or produce catalytic properties in the particle.

2. The method of Claim 1, wherein the particle comprises an oxide particle or activated carbon.

3. The method of Claim 1, wherein the particle comprises an oxide of metal, an oxide of silicon or activated carbon.

4. The method of Claim 1, wherein the particle comprises aluminum oxide, titanium dioxide, copper oxide, vanadium pentoxide, silicon dioxide, manganese dioxide, iron oxide, zinc oxide, activated carbon, or zeolite.

5. The method of Claim 1, wherein the particle comprises aluminum oxide.

6. The method of Claim 5, further comprising a second particle of titanium dioxide, copper oxide, vanadium pentoxide, silicon dioxide, manganese dioxide, iron oxide, zinc oxide, activated carbon, or zeolite.

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7. The method of Claim 1, wherein the particle comprises aluminum oxide and activated carbon.

8. The method of Claim 7, wherein the particle further comprises silicon dioxide and wherein the activated carbon is a mixture of coal based and coconut based activated carbon.

9. The method of Claim 1, wherein the particle is an agglomeration of smaller particles and a binder.

10. The method of Claim 9, wherein the smaller particles are of different composition type.

11. The method of Claim 1, wherein in step (b) the chamber gauge pressure is from 1 psi to 5,000 psi.

12. The method of Claim 1, wherein in step (b) the chamber gauge pressure is at least 100 psi, and further comprising after step (c), rapidly decompressing the chamber pressure to thereby increase the surface area of the particle.

13. The method of Claim 12, wherein in step (b) the chamber gauge pressure is at least 5,000 psi.

14. The method of Claim 1, wherein the inert gas is argon.

15. The method of Claim 1, wherein the energy beam is an ion or electron beam.

16. The method of Claim 1, wherein the method produces a room temperature catalytic particle.

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17. A method for producing an enhanced adsorbent and/or enhanced catalytic particle and/or for producing a catalytic particle, comprising implanting oxygen into an adsorbent and/or catalytic particle.

18. The method of Claim 17, wherein the method produces a room temperature catalytic particle.

19. The method of Claim 17, further comprising increasing the electrical charge on the particle.

20. The particle made by the process of Claim 1.

21. The particle made by the process of Claim 4.

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22. The particle made by the process of Claim 5.

23. The particle made by the process of Claim 6.

24. The particle made by the process of Claim 12.

25. The particle made by the process of Claim 17.

26. An enhanced adsorbent and/or enhanced catalytic particle and/or a catalytic particle comprising an adsorbent particle that has been treated to provide an excess of oxygen implanted at least on the surface of the particle to thereby form an enhanced adsorbent and/or enhanced catalytic particle and/or a catalytic particle.

27. The oxygen implanted particle of Claim 26, wherein the oxygen implanted particle has at least 1.5 times the oxygen atom per cent to non-oxygen atom per

cent ratio at its surface compared to the initial non-oxygen implanted particle, said surface characterization being determined by an ESCA spectrometer.

28. The oxygen implanted particle of Claim 26, wherein the particle comprises activated carbon and the oxygen implanted carbon has at least 6 times the oxygen to carbon ratio compared to the initial non-oxygen implanted carbon.

29. The oxygen implanted particle of Claim 26, wherein the particle comprises aluminum oxide and the oxygen implanted aluminum oxide has at least two times the oxygen to aluminum ratio compared to the initial non-oxygen implanted aluminum oxide.

30. A binder for binding adsorbent and/or catalytic particles to produce an agglomerated particle comprising colloidal aluminum oxide and an acid.

31. The binder of Claim 30, wherein the acid is nitric acid.

32. A method for binding adsorbent and/or catalytic particles, comprising the steps of:

(a) mixing colloidal aluminum oxide with the particles and an acid;

(b) agitating the mixture to homogeneity; and

(c) heating the mixture for a sufficient time to cause cross-linking of the aluminum oxide in the mixture.

33. The method of Claim 32, wherein the colloidal aluminum oxide is from 20% to 99% by weight of the mixture.

34. The method of Claim 32, wherein the acid is nitric acid.

35. A method for reducing or eliminating the amount of a contaminant from a liquid or gas stream comprising contacting the particle of Claim 20 with the

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contaminant in the stream for a sufficient time to reduce or eliminate the amount of contaminant from the stream.

36. The method of Claim 35, wherein the stream is a liquid.

37. The method of Claim 35, wherein the stream is water.

38. The method of Claim 35, wherein the stream is a gas.

39. The method of Claim 35, wherein the stream is air.

40. The method of Claim 35, wherein the contaminant is an organic compound.

41. The method of Claim 35, wherein the contaminant is a heavy metal.

42. The method of Claim 35, wherein the contaminant is carbon monoxide or an oxide of nitrogen or sulfur.

43. The method of Claim 35, wherein the contaminant is acetone, ammonia, benzene, carbon monoxide, chlorine, 1,4-dioxane, ethanol, ethylene, formaldehyde, hydrogen cyanide, hydrogen sulfide, methanol, methyl ethyl, ketone, methylene chloride, nitrogen oxide, propylene, styrene, sulfur dioxide, toluene, vinyl chloride, arsenic, cadmium, chlorine, DBCP, iron, lead, phosphate, radon, selenium, or uranium.

44. A method for adsorbing a contaminant from a liquid or gas stream onto an adsorbent particle comprising contacting the particle of Claim 20 with the contaminant in the stream for a sufficient time to adsorb the contaminant.

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45. A method for catalyzing the degradation of a hydrocarbon comprising contacting the hydrocarbon with the particle of Claim 20 for a sufficient time to catalyze the degradation of the hydrocarbon.

46. The method of Claim 45, wherein the catalysis reaction is at room temperature.

47. A method for reducing or eliminating the amount of a contaminant from a gas stream by catalysis comprising contacting the particle of Claim 20 with a gas stream containing a contaminant comprising an oxide of nitrogen, an oxide of sulfur, carbon monoxide, or mixtures thereof for a sufficient time to reduce or eliminate the contaminant amount.

48. The method of Claim 47, wherein the catalysis reaction is at room temperature.

49. The method of Claim 47, wherein the contaminant comprises an oxide of nitrogen or carbon monoxide.

50. An apparatus for producing an enhanced adsorbent and/or enhanced catalytic particle and/or for producing a catalytic particle comprising:

(a) chamber means for containing the particle in a closed system having an inlet gas port, an exit gas port, and a target plate, said chamber means being capable of maintaining vacuum and positive pressures;

(b) means for providing an inert gas to the chamber means through the inlet gas port;

(c) means for withdrawing from the chamber means an effective amount of the ambient air therein so as to create a vacuum within the chamber means; and

(d) means for providing an energy beam to the chamber means, said energy beam means outlet being targeted at the target plate.

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51. The apparatus of Claim 50, wherein the energy beam means produces an ion or electron beam.

52. A method for increasing the surface area of an adsorbent and/or catalytic particle, comprising the steps of

(a) raising the chamber gauge pressure of a closed chamber containing the adsorbent and/or catalytic particle to at least 100 psi with an inert gas and

(b) rapidly decompressing the chamber pressure to thereby increase the surface area of the particle.

53. The method of Claim 52, wherein the pressure in step (a) is at least 5,000 psi.

54. The method of Claim 52, wherein the surface area is increased by at least 20%.

55 A method for producing an enhanced adsorbent and/or enhanced catalytic particle and/or for producing a catalytic particle, comprising the step of:

(a) contacting an adsorbent and/or catalytic particle with an energy beam of sufficient energy for a sufficient time to thereby enhance the adsorbent and/or catalytic properties of the particle and/or produce catalytic properties in the particle.

56. The method of Claim 55, wherein the process is continuous.

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