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(71) Applicant: **Nissan Motor Co., Ltd.**
Kanagawa 221-0023 (JP)

(72) Inventors:
• **NIWA, Yusuke**
Atsugi-shi Kanagawa 243-0123 (JP)
• **SUGA, Katsuo**
Atsugi-shi Kanagawa 243-0123 (JP)

(74) Representative: **Holmes, Matthew William**
Nissan Motor Manufacturing (UK) Ltd
Nissan Technical Centre Europe
Cranfield Technology Park
Moulsoe Road
Bedfordshire MK43 0DB (GB)

(54) **Photocatalytic ignition system**

(57) A photocatalytic ignition system is provided that basically comprises an ignition chamber, a photocatalyst and a light source. The ignition chamber is configured to receive an air fuel mixture. The photocatalyst is arranged in the ignition chamber to contact an air fuel mixture. The

light source is arranged to shine light on the photocatalyst. The photocatalyst includes a photocatalytic material having an oxygen absorbing and a desorbing function. The photocatalytic ignition system is capable of igniting a lean air fuel mixture with a greatly reduced amount of light energy.

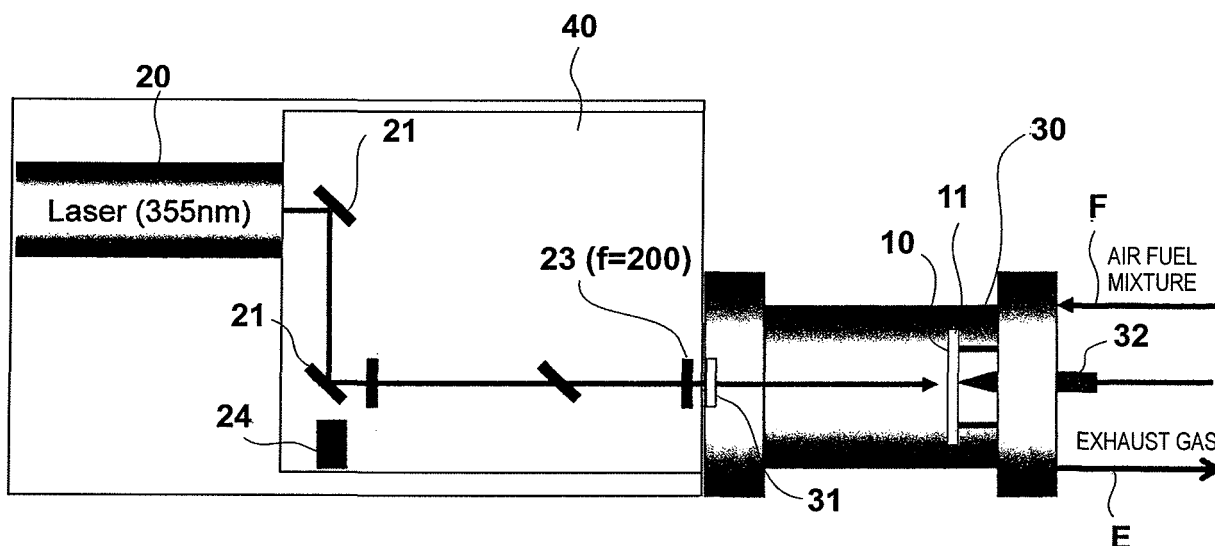


FIG. 1

Description

[0001] The present invention generally relates to a photocatalytic ignition system and particularly, but not exclusively, to a photocatalytic ignition system that uses a photocatalyst to ignite a mixture of a fuel gas and air. Aspects of the invention relate to an apparatus, to a system, to an engine and to a vehicle.

[0002] In recent years, attention has been directed toward photocatalysts. When a photocatalyst absorbs an amount of light energy equal to or exceeding a band gap energy, it develops holes due to the excitation of valence electrons to the conduction band. It is believed that the electrons and holes move to the surface of the catalyst and produce hydroxyl radicals, super oxide anions, and other active species. The active species have a very high oxidation strength and will readily oxidize and decompose organic substances. The photocatalytic action of photocatalysts has been used for air cleaning, water cleaning, anti-soiling, and anti-fogging (e.g., Ceramics, Akira Fujishima, 39, 2004, No. 7).

[0003] So long as a photocatalyst can absorb light, the photocatalytic reaction will proceed according to the mechanism described above and clean solar energy can be used. Thus, although a photocatalyst does not require a supply of heat energy or other external energy in order to stimulate the catalytic reaction in the manner of conventional technologies, it has been difficult to obtain a sufficient reaction rate with a photocatalyst. It has been suggested that a reason a sufficient reaction rate cannot be obtained is that the utilization efficiency of sunlight is small. Currently, titanium oxide is the most commonly used photocatalytic material due to its lower cost and chemical stability. However, the band gap energy of titanium oxide is 3.2 eV (which is high). Thus, titanium oxide can only absorb ultraviolet light. The content of ultraviolet light in sunlight is only approximately 3%. In fluorescent lamps for indoor use, the fluorescent material converts ultraviolet light into visible light. Since many vehicles use window glass that cuts ultraviolet rays, only visible light is actually available for use inside such vehicles.

[0004] The content of visible light in sunlight is approximately 50%. If visible can be used, then a faster reaction rate can be obtained. Ways of reducing the band gap energy are being investigated to enable the use of visible light. Since the energies of the conduction band and the valence band are determined by the orbitals of oxygen, the band gap energy can be reduced by controlling one of the orbitals. Based on previous observations, it is known that when an orbital of the metal atom is controlled, a recombination center for electrons and holes is produced and the activity level of the photocatalyst declines. Consequently, it is necessary to replace the oxygen with an element whose valence band has a higher energy level than the valence band of oxygen.

[0005] Since the valence electron of a nitrogen atom has a higher energy than the valence electron of an oxygen atom, the band gap energy can be decreased and

visible like can be utilized by using nitrogen. Proposals have been made for using an oxynitride material (e.g., Japanese Laid-Open Patent Publication No. 2002-066333 and Japanese Laid-Open Patent Publication No. 2004-230306) or titanium oxide that has been doped with nitrogen using a NO_x treatment or an ammonia treatment (What Is a Photocatalyst?, Shinri Sato, Kodansha, 2004).

[0006] Meanwhile, there are various research and development projects focusing on improving the catalytic activity of the catalyst. For example, catalysts are being combined with porous substances in order to increase the amount of reactant material that adheres to a surface of the catalyst and such techniques as improving crystallinity and reducing the particle size of powder are being used to enable electrons and holes produced by photoexcitation to reach the catalyst surface without losing their activity level (e.g., Japanese Laid-Open Patent Publication No. 2001-259436). Another idea is to provide a metal material in order to promote electric charge separation (e.g., Japanese Laid-Open Patent Publication No. 9-262473).

[0007] Much research and development is being conducted in relation to applications of photocatalysts and there are numerous reports of such applications as producing hydrogen by decomposing water and removing stains by decomposing organic matter. There are also applications in which a hydrophilic mesh sheet, particularly a hydrophilic mesh sheet having a photocatalyst-containing layer provided as a hydrophilic layer, is installed inside a greenhouse and used to adjust the temperature and/or humidity inside the greenhouse. Water is allowed to flow down onto the hydrophilic mesh sheet and evaporate. The heat of evaporation required to evaporate the water lowers the ambient temperature and the vaporized moisture can be used to adjust the ambient humidity. (e.g., Japanese Laid-Open Patent Publication No. 2005-013132)

[0008] More recently, the idea of using a photocatalyst to ignite an air fuel mixture was proposed (e.g., Japanese Laid-Open Patent Publication No. 2006-307839) and, thus, a method of igniting an air fuel mixture using light became publicly known. In the proposed method, light is focused in a space so as to form a thermal plasma and ignite an air fuel mixture. Consequently, the method has the disadvantage of a minimum ignition energy being high. It has been reported that the minimum ignition energy can be lowered by using a target (e.g., Japanese Laid-Open Patent Publication No. 58-133482 and Japanese Laid-Open Patent Publication No. 59-221523).

[0009] As described above, an air fuel mixture igniting system that uses a photocatalyst brings the advantage of enabling the minimum ignition energy to be reduced because the radicals necessary for igniting the air fuel mixture can be produced comparatively readily at the surface of the photocatalyst. However, a highly effective photocatalytic material has not been proposed and the ability of existing photocatalytic materials to lower the

minimum ignition energy is not sufficient. Consequently, a practical photocatalytic ignition system has yet to be proposed.

[0010] It is an aim of the present invention to address this issue and to improve upon known technology. Embodiments of the invention may provide an improved photocatalytic ignition system that uses a photocatalyst to ignite a mixture of a fuel gas and air and that can ignite a lean air fuel mixture with a much smaller amount of light energy than previously proposed systems. Other aims and advantages of the invention will become apparent from the following description, claims and drawings.

[0011] Aspects of the invention therefore provide an apparatus, a system, an engine and a vehicle as claimed in the appended claims.

[0012] According to another aspect of the invention for which protection is sought there is provided a photocatalytic ignition system comprising an ignition chamber configured to receive an air fuel mixture, a photocatalyst arranged in the ignition chamber to contact the air fuel mixture and a light source arranged to shine light on the photocatalyst, the photocatalyst including a photocatalytic material having an oxygen absorbing and a desorbing function.

[0013] In an embodiment, the photocatalytic material is at least one selected from a group consisting of cerium oxide, titanium oxide and copper oxide.

[0014] In an embodiment, the photocatalytic material is cerium oxide with an average particle size of 20 nm or smaller.

[0015] In an embodiment, the photocatalyst further includes a photothermal conversion material that includes at least one transition metal compound selected from a group consisting of transition metal sulfides, transition metal nitrides and oxides of transition metals other than cerium, titanium and copper.

[0016] In an embodiment, the photothermal conversion material includes at least one of iron and vanadium as a transition metal of the transition metal compound.

[0017] In an embodiment, the photocatalytic material is cerium oxide, the photothermal conversion material is an oxide of iron, and the mole ratio of cerium to iron contained in the photocatalyst lies in the range of 2/8 to 8/2.

[0018] In an embodiment, the photocatalyst further includes an auxiliary catalyst that includes at least one of a noble metal and nickel.

[0019] In an embodiment, the photocatalyst further includes an inorganic carrier material that is fixed to a base body with an inorganic adhesive.

[0020] For example, a photocatalytic ignition system may be provided that basically comprises an ignition chamber, a photocatalyst and a light source. The ignition chamber is configured to receive an air fuel mixture. The photocatalyst is arranged in the ignition chamber to contact an air fuel mixture. The light source is arranged to shine light on the photocatalyst. The photocatalyst includes a photocatalytic material having an oxygen ab-

sorbing and a desorbing function. The photocatalytic ignition system is capable of igniting a lean air fuel mixture with a greatly reduced amount of light energy.

[0021] Within the scope of this application it is envisaged that the various aspects, embodiments, examples, features and alternatives set out in the preceding paragraphs, in the claims and/or in the following description and drawings may be taken individually or in any combination thereof.

[0022] The present invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a system diagram showing a photocatalytic ignition system in accordance with one embodiment; and

Figure 2 is a graph showing a pressure change inside the ignition chamber in Working Example 1.

[0023] Selected embodiments of the present invention will now be explained with reference to the drawings. It will be apparent to those skilled in the art from this disclosure that the following descriptions of the embodiments of the present invention are provided for illustration only and not for the purpose of limiting the invention as defined by the appended claims and their equivalents.

[0024] Referring initially to Figure 1, a photocatalytic ignition system is illustrated in accordance with a first embodiment. This photocatalytic ignition system is a system that ignites a mixture of fuel gas and air using a photocatalyst and a light source. In this photocatalytic ignition system, the light source serves the function of supplying light to the photocatalyst and the photocatalyst contains a photocatalytic material that has both a photocatalytic function and an oxygen absorbing desorbing function. With this photocatalytic ignition system, an air fuel mixture can be headed in a localized fashion and ignited. As a result, a photocatalytic ignition system can be provided which can ignite a lean air fuel mixture with a much smaller amount of light energy than previously proposed systems. In both the claims and the description, concentrations, content amounts, and filling amounts expressed as a value followed by "%" are mass percentages unless otherwise specified.

[0025] In this embodiment, there are no particular limitations on the fuel contained in the air fuel mixture. Normally, the fuel used is a hydrocarbon or alcohol based fuel. In particular, examples of fuels used in internal combustion engines include gasoline, diesel fuel, heavy oil, biogasoline, liquefied petroleum gas (LPG), liquefied natural gas (LNG), methanol, and ethanol.

[0026] Any light source is acceptable so long as it can supply a light to the photocatalyst that activates the photocatalytic material used. A light source that emits ultraviolet light, visible light, infrared light, or a combination of these is acceptable. There are previously known light sources available that can be used as the light source.

Typically, if the light has a wavelength corresponding to an energy level equal to or higher than the band gap energy of the photocatalytic material, then electrons in the valence band of the photocatalytic material will be excited into the conduction band and holes will develop in the valence band, thus promoting a photocatalytic reaction.

[0027] While the photocatalytic material is a primary component of the photocatalyst that is used to ignite the fuel and air mixture, it is also acceptable to include other component such as a photothermal conversion material, an auxiliary catalyst, or an inorganic carrier material as needed and/or desired. The photocatalytic material contained in the photocatalyst will now be explained. There are no particular limits on the photocatalytic material so long as it causes a photocatalytic reaction to occur when light is shone thereon and it has an oxygen absorbing desorbing function. To ignite the fuel and air mixture, the photocatalytic material advantageously has an oxygen absorbing and a desorbing function, which will now be explained using a hypothetical example.

[0028] When light is shown onto the photocatalyst, electrons (e-) and holes are produced on the surface of the photocatalyst. The electrons produced react with oxygen molecules (O₂) in the air to make O₂⁻. The O₂⁻ receives another electron and forms O⁻, and the O⁻ pulls a hydrogen atom from the hydrocarbon of the fuel and causes the hydrocarbon of the fuel to become a hydrocarbon radical, thus promoting combustion via a chain reaction.

[0029] Meanwhile, since photocatalytic material has the oxygen absorbing desorbing function, the photocatalytic material desorbs oxygen in the O₂⁻ state. In such a case, there is the possibility that the O₂⁻ will react with holes at the surface of the photocatalyst and lose an electron, causing an O⁻ to be produced. The O⁻ is an active species necessary for the chain reaction described above. Thus, it is believed that the oxygen absorbing desorbing function causes more O⁻ to be produced than would occur otherwise, thus accelerating combustion. As a result, a lean air fuel mixture can be ignited with a greatly reduced amount of light energy.

[0030] Specific examples of photocatalytic materials having both an oxygen absorbing and a desorbing function include cerium oxide (CeO₂), titanium oxide (TiO₂), copper oxide (CuO), and any combination of these materials. For example, cerium oxide can be made to absorb and desorb oxygen in accordance with an oxidation/reduction atmosphere by utilizing an oxidation/reduction cycle between the quadrivalent and trivalent states of cerium. When cerium oxide is used as a photocatalytic material having an oxygen absorbing and a desorbing function, it is beneficial for the average particle size of the cerium oxide to be 20 nm or smaller. It is sometimes difficult to obtain sufficient performance when the average particle size is larger than 20 nm. By making the particle size smaller, the movement distances of electrons and holes are shorter during a photocatalytic reac-

tion and it is less likely that deactivation will occur. This phenomenon is not limited to cerium oxide. Additionally, when nanoparticles of cerium oxide crystallize having high crystallinity and few defects are used, electrons and holes are less likely to become deactivated in the process of moving along the surface of the photocatalyst. For these reasons, cerium oxide having the aforementioned particle size is an excellent material to use as the photocatalytic material.

[0031] The photothermal conversion material will now be explained. The photothermal conversion material is advantageously used as part of the photocatalyst along with the photocatalytic material. There are no particular limitations on the photothermal conversion material so long as it is a material that functions to convert light into heat and emit the heat. For example, transition metal compounds that can be used as a photothermal conversion material include oxides of transition metals other than cerium, titanium, and copper, sulfides of transition metals (including cerium, titanium, and copper), and nitrides of transition metals (including cerium, titanium, and copper). Any combination of these oxides, sulfides, and nitrides is also acceptable.

[0032] In this photocatalytic ignition system, particularly favorable results can be obtained by using iron (Fe) and/or vanadium (V) as a transition metal in the aforementioned transition metal compound of the photothermal conversion material. Compounds (i.e., oxide, sulfide, and nitride compounds) of iron and vanadium emit heat when they absorb light. The reason for the heat emission is thought to be either (1) that excitation energy is converted to thermal energy or (2) that the compound undergoes a reduction reaction when it absorbs light and then emits heat when it oxidizes again due to oxygen in the vicinity. Either way, the compound emits heat and heats the photocatalytic material, thereby causing the temperature of the catalyst surface to rise. It is believed that, as a result, the reaction is accelerated and the oxidizing performance, i.e., the igniting performance, is improved.

[0033] Among compounds of iron and vanadium, an oxide of iron is particularly good. Particularly good results are obtained when an iron oxide photothermal conversion material is used together with cerium oxide as the photocatalytic material. In such a case, it is acceptable for the iron (Fe) and the cerium (Ce) to form a composite oxide. In this invention, it is advantageous for the content ratio of cerium and iron (Ce/Fe) to be a mole ratio in the range of 2/8 to 8/2. If the mole ratio departs from this range such that the amount of iron is too small, then the heating effect will not be obtained and the performance will not be sufficiently improved. Conversely, if the amount of iron is too large, then the ignition performance may decline.

[0034] The auxiliary catalyst will now be explained. The auxiliary catalyst is used as part of the photocatalyst along with the photocatalytic material. During the photocatalytic reaction, it functions to collect separated charg-

es such that recombination of electrons and holes is suppressed, thereby promoting charge separation. More specifically, separated charges resulting from light absorption move to the surface of the catalyst and activate the reactants. If recombination occurs during the movement, then deactivation will occur. Any material that can separate charges effectively and suppress recombination, thereby collecting charges (electrons), can be used as an auxiliary catalyst.

[0035] There are no particular limitations on the material used as the auxiliary catalyst. Examples include at least one of or any combination of the noble metals and nickel, more specifically at least one of or any combination of rhodium (Rh), cobalt (Co), copper (Cu), ruthenium (Ru), palladium (Pd), iridium (Ir), platinum (Pt), and nickel (Ni).

[0036] The inorganic carrier material will now be explained. The inorganic carrier material is used as part of the photocatalyst along with the photocatalytic material. The inorganic carrier material functions to support and secure the photocatalytic material. Specific examples include alumina (Al_2O_3), zirconia (ZrO_2), and magnesia (MgO_2).

[0037] In this photocatalytic ignition system, a base body, typically a substrate plate, can be used to secure the photocatalyst. In such a case, it is beneficial to secure the photocatalyst to the base body with an inorganic adhesive. The inorganic adhesive should be configured to adhere to both the photocatalyst (i.e., the photocatalytic material and the inorganic carrier material) and the base body in order to prevent the photocatalyst from peeling or cracking. Examples of inorganic adhesives include alumina (Al_2O_3) and zirconia (ZrO_2).

[0038] Figure 1 is a system diagram showing an embodiment of a photocatalytic ignition system. As shown in Figure 1, this photocatalytic ignition system comprises a photocatalyst 10 and a laser device 20 constituting a light source.

[0039] The photocatalyst 10 is on a substrate plate 11 that is housed inside an ignition chamber 30. The ignition chamber 30 is configured such that a mixture of fuel and air can be supplied thereto as indicated with an arrow F and exhaust gas can be discharged therefrom as indicated with an arrow E. Internal pressure of the ignition chamber 30 can be detected with a pressure sensor 32, and laser light from the laser device 20 can be shone into the ignition chamber 30 through a light inlet window 31 made of quartz glass.

[0040] The laser light emitted from the laser device 20 is reflected by a reflection mirror 21 and the intensity of the laser light is adjusted by an attenuator 22. The laser light passes through a light collecting lens 23 ($f = 200$), and is directed through the light inlet window 31 into the ignition chamber 30, where the light strikes the photocatalyst 10.

[0041] As explained above, when the laser light shines on the photocatalyst 10, the photocatalyst 10 is activated and causes localized heating of the air fuel mixture, there-

by igniting the air fuel mixture.

[0042] Working examples of one photocatalytic ignition system and comparative examples will now be explained in detail. The photocatalytic ignition system is not limited by these working examples.

Working Example 1

[0043] The photocatalytic ignition system shown in Figure 1 was fabricated and the performance thereof was evaluated. The procedures of the fabrication and performance evaluation of the system will now be explained.

[0044] An aluminum plate having a diameter of 60 mm was used as the substrate plate 11. Oil was removed from the aluminum plate by treating it with alcohol and, afterwards, an inorganic adhesive (main ingredient: α alumina) was coated onto the aluminum plate. Next, the photocatalyst 10 was made by spraying cerium oxide sol having a particle size of 20 nm to a thickness of several micrometers and firing to remove moisture.

[0045] The laser light was provided by a Nd-YAG laser (355 nm) and pulsed at a pulse width of 5 to 7 nsec. The laser light was passed through a 355 nm wavelength separator mirror, an attenuator (1/2 wavelength plate and polarizer plate), a light collecting lens ($f = 200$), and a quartz glass window and shone onto the photocatalyst inside the ignition chamber. A mixture of CH_4 and air was supplied to the inside of the ignition chamber and controlled with a mass flow controller to a ratio of 10 % by volume of CH_4 to air. The pressure inside the chamber was 0.2 MPa and the temperature was room temperature. The volume of the ignition chamber was approximately 600 cc.

[0046] After the inside of the ignition chamber was evacuated with a vacuum pump, the mixture of CH_4 and air was supplied and the laser was energized. The laser light was shone while changing the energy of the laser in the following sequence: 38.6 mJ $\rightarrow$ 35.7 mJ $\rightarrow$ 31.9 mJ $\rightarrow$ 25.1 mJ. The irradiation energy of the laser light was measured with a power meter. The occurrence of ignition (combustion) was confirmed based on the internal pressure of the ignition chamber. The pressure change during combustion was measured by sampling a voltage from the pressure sensor at five (5) msec intervals. Figure 2 shows the pressure change measurement results that were obtained. Table 1 shows the minimum ignition energy (mJ) for the photocatalyst used in this working example.

Working Example 2

[0047] An aqueous solution was prepared with ferric nitrate and cerium nitrate at a mole ratio of Fe to Ce (Fe/Ce) equal to 0.8/0.2. The solution was agitated one day and one night while gradually dripping in an aqueous solution containing 28% ammonia such that a pH of 8 was achieved. The resulting solid material was then filtered out, rinsed with deionized water, and heated to 600

°C for five hours to obtain $\text{Fe}_{0.8}\text{Ce}_{0.2}$. The Fe-Ce material was used as the photocatalyst. Otherwise, the same operations as were performed in Working Example 1 were repeated. Table 1 shows the minimum ignition energy (mJ) for the photocatalyst used in this working example.

Working Example 3

[0048] An aqueous solution was prepared with ferric nitrate and cerium nitrate at a mole ratio of Fe to Ce (Fe/Ce) equal to 0.2/0.8. Otherwise the same operations as were performed in Working Example 2 were repeated. The minimum ignition energy (mJ) is shown in Table 1.

Working Example 4

[0049] Titanium oxide having a particle size of several micrometers was used as the photocatalyst. Otherwise, the same operations as were performed in Working Example 1 were repeated. The minimum ignition energy (mJ) is shown in Table 1.

Comparative Example 1

[0050] A photocatalyst was not fabricated (an aluminum substrate plate was not installed). Otherwise, the same operations as in Working Example 1 were repeated. The minimum ignition energy (mJ) is shown in Table 1.

Comparative Example 2

[0051] An aluminum substrate plate was installed but a photocatalyst was not fabricated. Otherwise, the same operations as in Working Example 1 were repeated. The minimum ignition energy (mJ) is shown in Table 1.

Comparative Example 3

[0052] An iron oxide was used as a photocatalyst. Otherwise, the same operations as in Working Example 1 were repeated. The minimum ignition energy (mJ) is shown in Table 1.

Table 1

Working Example 1	31.9
Working Example 2	25.1
Working Example 3	28.2
Working Example 4	33.0
Comparative Example 1	38.6
Comparative Example 2	36.0
Comparative Example 3	35.3

[0053] The photocatalyst used in Comparative Exam-

ple 1 was iron oxide and the photocatalyst used in Working Example 1 was cerium oxide (photocatalytic material). A comparison of Comparative Example 1 and Working Example 1 indicates that the amount of energy required to ignite the air fuel mixture can be reduced by using a material having an oxygen absorbing desorbing function as the photocatalytic material.

[0054] The photocatalysts used in Working Examples 2 and 3 were made of cerium oxide (photocatalytic material) and iron (photothermal conversion material). A comparison of Working Example 1 to Working Examples 2 and 3 indicates that the amount of energy required to ignite the air fuel mixture can be reduced even further by using a material having a photothermal conversion function as the photocatalytic material. The photocatalyst used in Working Example 4 was made of titanium oxide (photocatalytic material) only. A comparison of Working Example 1 and Working Example 4 indicates that the air fuel mixture can be ignited with a smaller amount of energy by using cerium oxide as the photocatalytic material.

[0055] In understanding the scope of the present invention, the term "comprising" and its derivatives, as used herein, are intended to be open ended terms that specify the presence of the stated features, elements, components, groups, integers, and/or steps, but do not exclude the presence of other unstated features, elements, components, groups, integers and/or steps. The foregoing also applies to words having similar meanings such as the terms, "including", "having" and their derivatives.

[0056] While only selected embodiments have been chosen to illustrate the present invention, it will be apparent to those skilled in the art from this disclosure that various changes and modifications can be made herein without departing from the scope of the invention as defined in the appended claims. For example, the size, shape, location or orientation of the various components can be changed as needed and/or desired. Components that are shown directly connected or contacting each other can have intermediate structures disposed between them. The functions of one element can be performed by two, and vice versa. The structures and functions of one embodiment can be adopted in another embodiment. It is not necessary for all advantages to be present in a particular embodiment at the same time. Every feature which is unique from the prior art, alone or in combination with other features, also should be considered a separate description of further inventions by the applicant, including the structural and/or functional concepts embodied by such feature(s). Thus, the foregoing descriptions of the embodiments according to the present invention are provided for illustration only, and not for the purpose of limiting the invention as defined by the appended claims and their equivalents.

[0057] This application claims priority from Japanese Patent Application Nos. 2007-201448, filed 2nd August 2007, and 2008-109006, filed 18th April 2008, the contents of which are expressly incorporated herein by ref-

erence.

Claims

1. An apparatus comprising:

an ignition chamber for receiving an air fuel mixture;
a photocatalyst arranged in the ignition chamber for contacting the air fuel mixture; and
a light source for shining light on the photocatalyst,

wherein the photocatalyst comprises a photocatalytic material having an oxygen absorbing and a desorbing function.

2. An apparatus as claimed in claim 1, wherein the photocatalytic material is at least one selected from a group consisting of cerium oxide, titanium oxide and copper oxide.

3. An apparatus as claimed in claim 1 or claim 2, wherein the photocatalytic material comprises cerium oxide with an average particle size of 20 nm or smaller.

4. An apparatus as claimed in any preceding claim, wherein the photocatalyst comprises a photothermal conversion material that includes at least one transition metal compound selected from a group consisting of transition metal sulfides, transition metal nitrides and oxides of transition metals other than cerium, titanium and copper.

5. An apparatus as claimed in claim 4, wherein the photothermal conversion material comprises at least one of iron and vanadium as a transition metal of the transition metal compound.

6. An apparatus as claimed in claim 4 or claim 5, wherein the photocatalytic material comprises cerium oxide, the photothermal conversion material is an oxide of iron, and the mole ratio of cerium to iron contained in the photocatalyst lies in the range of 2/8 to 8/2.

7. An apparatus as claimed in any preceding claim, wherein the photocatalyst comprises an auxiliary catalyst that includes at least one of a noble metal and nickel.

8. An apparatus as claimed in any preceding claim, wherein the photocatalyst comprises an inorganic carrier material that is fixed to a base body with an inorganic adhesive.

9. A photocatalytic ignition system comprising an apparatus as claimed in any preceding claim.

10. An engine comprising an apparatus or a system as claimed in any preceding claim.

11. A vehicle having an apparatus, a system or an engine as claimed in any preceding claim.

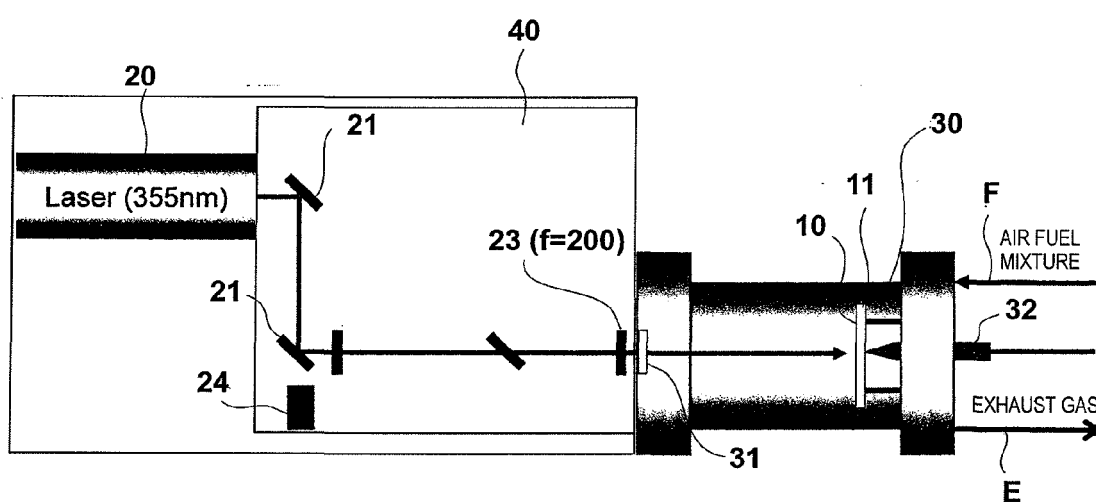
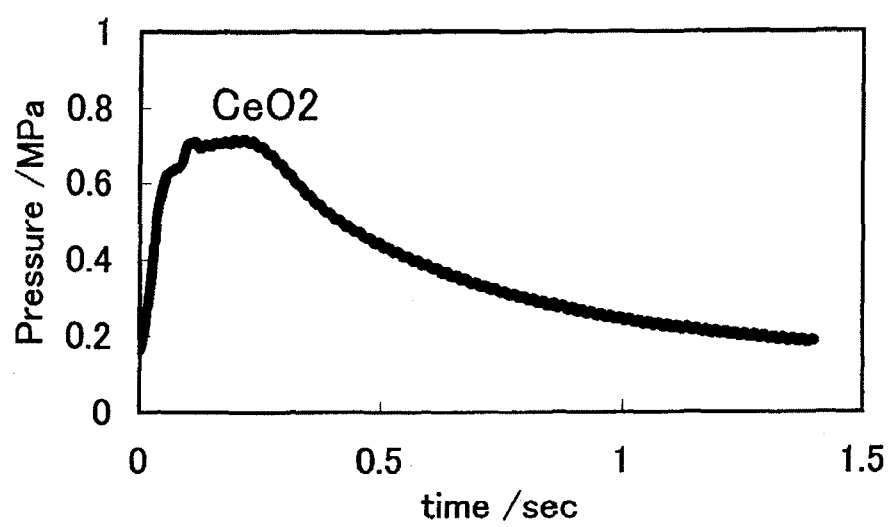


FIG. 1

*FIG. 2*

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