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(71) Applicant: **MAZDA MOTOR CORPORATION**
Hiroshima 730-8670 (JP)

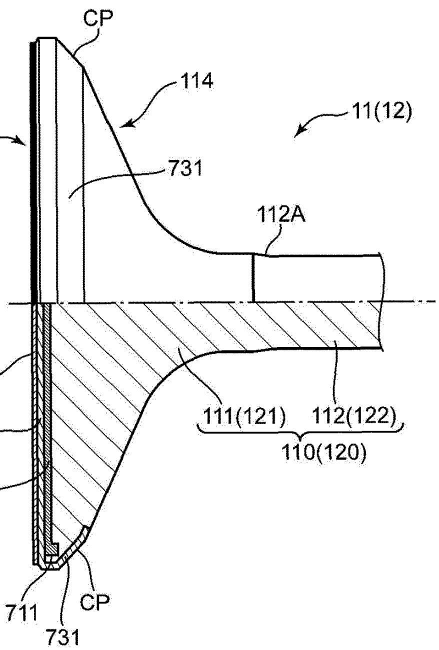
(72) Inventors:
- **NOU, Yoshihisa**
  Fuchu-cho, Aki-gun, Hiroshima 730-8670 (JP)
- **AOKI, Osamu**
  Fuchu-cho, Aki-gun, Hiroshima 730-8670 (JP)
- **HARADA, Yuji**
  Fuchu-cho, Aki-gun, Hiroshima 730-8670 (JP)
- **UCHIDA, Kenji**
  Fuchu-cho, Aki-gun, Hiroshima 730-8670 (JP)
- **GE, Xiyao**
  Fuchu-cho, Aki-gun, Hiroshima 730-8670 (JP)

(74) Representative: **Müller-Boré & Partner**
Patentanwälte PartG mbB
Friedenheimer Brücke 21
80639 München (DE)

(54) VALVE, COMBUSTION-CHAMBER STRUCTURE, ENGINE AND VEHICLE

(57) A combustion chamber is partitioned by a cylinder block, a cylinder head, a piston, an intake valve, and an exhaust valve. The intake valve (exhaust valve) comprises an intake valve body including an umbrella part having a valve head and a valve face, a heat-insulation layer provided at the valve head and having smaller heat conductivity than the valve body, a heat-barrier layer provided to cover the valve head with the heat-insulation layer and having smaller heat conductivity than the valve body and the heat-insulation layer, and a heat-diffusion layer provided between the heat-insulation layer and the heat-barrier layer and having larger heat conductivity than the heat-insulation layer and the heat-barrier layer. The heat-diffusion layer comprises a contact portion which contacts with the cylinder head when the intake valve is closed.

FIG. 6



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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a valve, particularly a valve which comprises a heat-barrier layer to suppress heat loss. The present invention also relates to a combustion chamber, an engine, and a vehicle.

[0002] A combustion chamber of a gasoline engine or the like for a vehicle is required to reduce heat dissipation (heat loss) through a wall surface of the combustion chamber. A technology that a heat-barrier layer made of a small heat-conductivity material is coated on the combustion-chamber wall surface, such as a crown surface of a piston, for heat-loss reduction is known. A temperature difference between combustion gas generated in the combustion chamber and the combustion-chamber wall surface is made so small by providing the heat-barrier layer that the heat loss can be reduced.

[0003] Japanese Patent Laid-Open Publication No. 2018-172997 discloses a combustion-chamber structure in which a heat-insulation layer is provided at a piston crown surface in addition to the heat-barrier layer. The heat-barrier layer covers an entire part of the piston crown surface, thereby suppressing the heat dissipation through a piston body. The heat-insulation layer is provided below the heat-barrier layer and in a central area, in a radial direction, of the piston crown surface, thereby making this central area be the area where the heat does not escape easily. Thereby, a temperature distribution in which the temperature of an central area, in a radial direction, of the combustion chamber is relatively high, whereas the temperature of an outside area, in the radial direction, of the combustion chamber is relatively low is formed. This temperature distribution has a merit that in a case where a homogeneous-charge compression-ignition combustion (in other words, a premixed compression-ignition combustion) is performed, the combustion is made properly slow and thereby a rapid increase of a cylinder internal pressure or heat loss can be properly suppressed.

[0004] The combustion chamber is also partitioned by an intake valve and an exhaust valve. Accordingly, it is necessary to suppress the heat dissipation from the intake valve and the exhaust valve as well for reduction of the heat loss of the combustion chamber. Herein, it may be considered that the heat-barrier layer and the heat-insulation layer are also provided at respective valve heads of the intake valve and the exhaust valve, similarly to the structure of the above-described patent document. There is a problem, however, that the heat may be excessively stored at the heat-insulation layer, thereby making the temperature of the valves improperly high. That is, the heat-insulation layer may store the heat which has not been insulated (blocked) by the heat-barrier layer, so that this heat-insulation layer having the high temperature may heat the heat-barrier layer. This heating may cause a temperature increase of the valve itself, thereby increasing the cylinder temperature. Thereby, the air taken in an intake stroke of the engine may be heated excessively, so that improper preignition may occur in a compression stroke of the engine.

SUMMARY OF THE INVENTION

[0005] An object of the present invention is to suppress the temperature increase of the valve which may cause the preignition, attaining the heat-loss reduction.

[0006] An engine, or a combustion-chamber structure for an engine comprises a cylinder block, a cylinder head, a piston, a valve, and a combustion chamber partitioned by the cylinder block, the cylinder head, the piston, and the valve. The valve is configured to open and/or close a port opening to the combustion chamber and comprises a valve body which includes an umbrella part and a stem part. The umbrella part of the valve includes a valve head facing the combustion chamber and a valve face positioned on an opposite side to the combustion chamber. In other words, the umbrella part includes, on one side, a valve head facing the combustion chamber and, on the other side, a valve face. The valve further comprises a heat-insulation layer which is provided at the valve head and has smaller heat conductivity than the valve body, a heat-barrier layer which is provided to cover the valve head provided with the heat-insulation layer and has smaller heat conductivity than the valve body and the heat-insulation layer, and a heat-diffusion layer which is provided between the heat-insulation layer and the heat-barrier layer and has larger heat conductivity than the heat-insulation layer and the heat-barrier layer, and the heat-diffusion layer comprises a contact portion which is provided to extend up a position of the umbrella part of the valve which contacts with the cylinder head when the valve is closed. In other words, the heat-insulation layer has a heat conductivity smaller than a heat conductivity of the valve body. The heat-barrier layer has a heat conductivity smaller than the heat conductivity of the valve body and the heat conductivity of the heat-insulation layer. The heat-diffusion layer has a heat conductivity larger than the heat conductivity of the heat-insulation layer and the heat conductivity of the heat-barrier layer.

[0007] According to the present valve or combustion-chamber structure, the valve head is covered with the heat-barrier layer having the smaller heat conductivity than the valve body and the heat-insulation layer. Accordingly, the temperature difference between the valve head and the combustion chamber is made so small that heat transfer to the valve body can be suppressed. Further, the heat which has passed through the heat-barrier layer is stored at the heat-insulation layer. Accordingly, the high temperature of the heat-barrier layer (valve head) can be maintained. Meanwhile, the heat-diffusion layer is provided between the heat-insulation layer and the heat-barrier layer. This heat-diffusion layer has the larger heat conductivity than both the heat-barrier layer and the heat-insulation layer and comprises the contact portion contacting with the cylinder head. Accordingly, even in a case where the heat-insulation layer has stored the heat excessively, this heat can be made to escape to the cylinder head through the heat-diffusion layer. Consequently, the temperature increase of the valve which may cause the preignition can be prevented properly.

[0008] In the above-described valve or combustion-chamber structure for the engine, it is preferable that the cylinder head have the larger heat conductivity than the valve body. In other words, the cylinder head has a heat conductivity larger than the heat conductivity of the valve body.

[0009] According to this valve or combustion-chamber structure, the heat of the heat-insulation layer which is transferred through can be made to escape to the cylinder head more than the valve body.

[0010] In the above-described valve or combustion-chamber structure for the engine, it is preferable that the cylinder head comprise a valve seat which is provided at the port opening and with which a portion of the umbrella part of the valve body contacts, and/or the contact portion of the heat-diffusion layer be provided at the portion of the umbrella part which contacts with the valve seat.

[0011] The valve seat provided at the port opening necessarily contacts with the umbrella part of the valve when the intake or exhaust port is closed. Accordingly, a heat dissipation path (route) from the valve body to the cylinder head can be secured by providing the contact portion of the heat-diffusion layer at the portion of the umbrella part which contacts with the valve seat.

[0012] In the above-described valve or combustion-chamber structure for the engine, it is preferable that the valve be an intake valve, and/or the heat-barrier layer be provided on the valve face of the umbrella part of the valve as well. In this case, it is preferable that the heat-barrier layer be provided on the stem part of the valve as well.

[0013] According to this valve or combustion-chamber structure, the heat dissipation from the valve face or the stem part of the valve can be suppressed by the heat-barrier layer even in a case where the temperature of the valve body of the intake valve increases. Accordingly, the air passing through the intake port is suppressed from being heated excessively by the intake valve, so that the preignition can be prevented properly.

[0014] In the above-described valve or combustion-chamber structure for the engine, it is preferable that the valve be an exhaust valve, and/or the heat-barrier layer be provided on the valve face of the umbrella part of the valve as well. In this case, it is preferable that the heat-barrier layer be provided on the stem part of the valve as well.

[0015] According to this valve or combustion-chamber structure, the surface temperature of the valve face of the umbrella part and the stem part of the exhaust valve can be maintained at the high temperature by the heat-barrier layer. The exhaust valve provided at the exhaust port is exposed to high temperature by exhaust heat of the combustion gas. Accordingly, the heat transfer to the valve body of the exhaust valve, i.e., the heat loss, can be suppressed properly by providing the heat-barrier layer on the valve face and the stem part of the exhaust valve.

[0016] In the above-described valve or combustion-chamber structure for the engine, it is preferable that the heat-diffusion layer include a first portion which is provided between the heat-insulation layer and the heat-barrier layer at the valve head, the contact portion, and a second portion which is an underlayer of the heat-diffusion layer which is provided at the valve face and the stem part.

[0017] According to this valve or combustion-chamber structure, the first portion of the heat-diffusion layer receives the heat of the valve head and the second portion receives the heat of the valve face and the stem part of the valve. The heat received by the first portion and the second portion of the heat-diffusion layer is made to escape from the contact portion to the cylinder head. The exhaust valve receives the heat from exhaust gas passing through the exhaust port, so that its temperature increases. Meanwhile, the intake valve receives the heat from EGR gas or blow-back gas of the combustion gas from the combustion chamber which is caused by setting a valve overlap term, so that its temperature possibly increases. Accordingly, by configuring the heat-diffusion layer to comprise the above-described first portion and the above-described second portion, the excessive temperature increase of the exhaust valve and the intake valve can be prevented properly.

[0018] In the above-described valve or combustion-chamber structure for the engine, it is preferable that the valve be an exhaust valve. It is also preferable that the heat-insulation layer and the heat-diffusion layer be provided to cover an entire part of the umbrella part of the valve. It is also preferable that the heat-barrier layer be provided to cover the entire part of the umbrella part of the valve except the contact portion of the heat-diffusion layer. In this case, it is preferable that the heat-insulation layer, the heat-diffusion layer, and the het-barrier layer be provided to cover at least a section of the stem part of the valve which is continuous to the umbrella part of the valve.

[0019] According to this valve or combustion-chamber structure, the umbrella part of the exhaust valve is covered with three layers of the heat-insulation layer, the heat-diffusion layer, and the heat-barrier layer except the above-described contact portion. More preferably, at least a portion of the stem part which is continuous to the umbrella part is covered with these three layers as well. That is, the heat-insulation layer is provided at not only the valve head facing the combustion chamber but the valve face positioned on its opposite side and the stem part. Accordingly, the temperature of the heat-barrier layer provided on the valve face and the stem part can be maintained at the high temperature by means of the heat-insulation layer, so that the heat loss at the exhaust valve can be suppressed properly. Further, the heat dissipation path (route) made by the heat-diffusion layer can be secured so that the heat-insulation layer does not store the heat excessively, so that the excessive temperature increase of the exhaust valve can be prevented properly.

[0020] In the above-described valve or combustion-chamber structure for the engine, it is preferable that the valve be an exhaust valve with cooling function in which a coolant sealing portion is formed at the valve body. It is also preferable that the heat-insulation layer and the heat-diffusion layer be provided to cover the umbrella part of the valve . It is also preferable that the heat-barrier layer be provided to cover the umbrella part of the valve except the contact portion of the heat-diffusion layer. It is also preferable that the heat-insulation layer and the heat-diffusion layer be provided to extend up to a position which overlaps with the coolant sealing portion of the valve body.

[0021] According to this valve or combustion-chamber structure, the heat stored at the heat-insulation layer or the heat received by the heat-barrier layer can be carried to the coolant sealing portion via the heat-flowing layers. Accordingly, the excessive temperature increase of the exhaust valve can be prevented properly.

[0022] In the above-described valve or combustion-chamber structure for the engine, it is preferable that the heat-barrier layer be made of heat-resistant silicon resin which has the heat conductivity of 0.05 - 1.50W/mK, and/or the heat-diffusion layer be made of copper-based material, Corson alloy, beryllium copper, fiber-reinforced aluminum alloy, or titanium aluminum which have the heat conductivity of 35 - 600W/mK.

[0023] The present invention will become apparent from the following description which refers to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024]

FIG. **1** is a schematic sectional view showing an engine to which a combustion-chamber structure according to an embodiment of the present invention is applied.

FIG. **2** is a sectional view showing details of an intake valve shown in FIG. **1.**

FIG. **3** is a partially-sectional side view showing a valve of a comparative example 1.

FIG. **4** is a partially-sectional side view showing a valve of a comparative example 2.

FIG. **5** is an explanatory diagram of preignition which may be generated in a combustion chamber of a comparative example.

FIG. **6** is a partially-sectional side view showing a valve according to a first embodiment of the present invention.

FIG. **7** is a diagram explaining a behavior (operation) of heat in a case where the valve of the first embodiment is used.

FIG. **8** is a chart showing materials which are applicable to respective structural members of the combustion-chamber structure of the engine.

FIG. **9** is a partially-sectional side view showing an intake valve according to a second embodiment.

FIG. **10** is a partially-sectional side view showing an intake valve according to a third embodiment.

FIG. **11** is a partially-sectional side view showing an exhaust valve according to a fourth embodiment.

FIG. **12** is a partially-sectional side view showing an exhaust valve according to a fifth embodiment.

FIG. **13** is a partially-sectional side view showing an exhaust valve according to a sixth embodiment.

DETAILED DESCRIPTION OF THE INVENTION

[Entire Structure of Engine]

[0025] Hereafter, a valve or a combustion-chamber structure of an engine according to embodiments of the present invention will be described specifically referring to the drawings. All of the features shown in the drawings may not necessarily be essential. FIG. **1** is a schematic sectional view showing an engine to which the combustion-chamber structure according to the embodiments of the present invention is applied. The engine described here is a multi-cylinder engine which includes cylinders and pistons and is installed to the vehicle as a power source for driving the vehicle, such as an automotive vehicle. The engine includes an engine body **1,** intake-exhaust manifolds, not illustrated, which are assembled to the engine body **1,** and auxiliary devices, such as various kinds of pumps.

[0026] The engine body **1** of the present embodiments is capable of performing the spark-ignition combustion (SI combustion) in which the mixture of fuel and air is ignited by spark in the combustion chamber and the homogeneous-charge compression-ignition combustion (HCCI combustion) in which the mixture is self-ignited. A principle ingredient of the fuel supplied to the engine body **1** is gasoline. Generally, the spark-ignition combustion is performed in a high-load high-speed engine operation, whereas the homogeneous-charge compression-ignition combustion is performed in a middle/low-load middle/low-speed engine operation at the engine body **1.** Operation ranges in which the SI combustion or the HCCI combustion are not limited. Herein, the present invention is applicable to a combustion chamber of the engine which is unable to perform the homogeneous-charge compression-ignition combustion.

[0027] The engine body **1** comprises a cylinder block **3,** a cylinder head **4,** and pistons **5.** The cylinder block **3** has plural cylinders **2** (only one of these is illustrated in the figure) which are arranged in a direction perpendicular to a paper plane of FIG. **1.** The cylinder head **4** is attached to an upper face of the cylinder block **3** such that it closes respective upper openings of the cylinders

2. The piston **5** is stored in each cylinder **2** such that the piston **5** reciprocates therein, and connected to a crankshaft **7** via a connecting rod **8.** The crankshaft **7** rotates around a central axis thereof according to a reciprocating movement of the piston **5.** A cavity **5C** which is concaved downwardly, in a cylinder axial direction, is formed at a crown surface **5H** of the piston **5.**

[0028] A combustion chamber **6** is partitioned above the piston **5** (between the piston **5** and cylinder head **4**). An intake port **9** and an exhaust port **10** which respectively connect to the combustion chamber **6** are formed at the cylinder head **4.** At a bottom surface **4a** (ceiling surface **6U**) of the cylinder head **4** are formed an intake-side opening portion **41** (port opening) which is a downstream end of the intake port **9** and an exhaust-side opening portion **42** (port opening) which is an upstream end of the exhaust port **10** as an opening to the combustion chamber **6.**

[0029] An intake valve **11** to open/close (open and/or close) the intake-side opening portion **41** and an exhaust valve **12** to open/close (open and/or close) the exhaust-side opening portion **42** are assembled to the cylinder head **4.** In a case of a doble overhead camshaft (DOHC) type engine, for example, the two intake-side opening portions **41** and the two exhaust-side opening portions **42** are provided at each of the cylinders **2,** and the two intake valves **11** and the two exhaust valves **12** are provided as well. The number of the camshaft may be one. Respective structures of the intake valve **11** and the exhaust valve **12** will be described specifically later.

[0030] The combustion chamber **6** is partitioned by the cylinder block **3,** the cylinder head **4,** and the piston **5.** More specifically, a combustion-chamber wall surface which partitions the combustion chamber **6** comprises an inner wall surface of the cylinder **2,** the piston crown surface **5H** (hereafter, referred to as "crown surface **5H**" simply) which is the upper surface of the piston **5,** the combustion-chamber ceiling surface **6U** which is a bottom surface of the cylinder head **4,** and respective umbrella parts (valve heads **113, 123**) of the intake valve **11** and the exhaust valve **12.**

[0031] An intake-side valve driving mechanism **13** and an exhaust-side valve driving mechanism **14** which drive the intake valves **11** and the exhaust valve **12,** respectively, are provided at the cylinder head **4.** The respective stem parts of the intake valves **11** and the exhaust valve **12** are driven linked with the rotation of the crankshaft **7** by these valve driving mechanisms **13, 14.** Thus, the valve head of the intake valve **11** opens/closes the intake-side opening portion **41,** and the valve head of the exhaust valve **12** opens/closes the exhaust-side opening portion **42.**

[0032] The intake-side valve driving mechanism **13** comprises an intake-side variable valve timing mechanism (intake-side S-VT) **15.** The intake-side S-VT **15** is particularly an electrical type of S-VT which is provided at an intake camshaft and configured to change an opening/closing (opening and/or closing) timing of the intake valve **11** by continuously changing a rotational phase of the intake camshaft relative to the crankshaft **7** within a specified angle range. Likewise, the exhaust-side valve driving mechanism **14** comprises an exhaust-side variable valve timing mechanism (exhaust-side S-VT) **16.** The exhaust-side S-VT **16** is particularly an electrical type of S-VT which is provided at an exhaust camshaft and configured to change an opening/closing (opening and/or closing) timing of the exhaust valve **12** by continuously changing a rotational phase of the exhaust camshaft relative to the crankshaft **7** within a specified angle range.

[0033] A single spark plug **17** to supply ignition energy to the mixture in the combustion chamber **6** is attached to the cylinder head **4** for each cylinder **2.** The spark plug **17** is attached to the cylinder head **4** such that it is arranged at a central space, in a radial direction, of combustion chamber **6** and its ignition point is exposed to an inside space of the combustion chamber **6.** The spark plug **17** discharges a spark from its tip according to a power supply from an ignition circuit, not illustrated, thereby igniting the mixture in the combustion chamber **6.** The ignition plug **17** of the present embodiments is used to perform the spark-ignition combustion in the high-load high-speed engine operation. The spark-ignition combustion and/or the homogeneous-charge compression-ignition combustion may be performed at any load and speed. Further, this is also used, when the homogeneous-charge compression-ignition combustion is performed, in a case where it is hard to perform the self-ignition right after an engine start during a cold time, the homogeneous-charge compression-ignition combustion is assisted under a specified load or speed conditions (spark assist), or the like.

[0034] A single injector **18** to inject the gasoline, as the principle ingredient of the fuel, from its tip portion into the combustion chamber **6** is attached to the cylinder head **4** for each cylinder **2.** A fuel supply pipe **19** is coupled to the injector **18.** The injector **18** injects the fuel supplied through the fuel supply pipe **19** toward the cavity **5C.** A high-pressure fuel pump (not illustrated) which includes a plunger type of pump and the like and is operationally connected to the crankshaft **7** is coupled to an upstream side of the fuel supply pipe **19.** A common rail for pressure accumulation which is common to the all cylinders **2** is provided between the high-pressure fuel pump and the fuel supply pipe **19.** The fuel pressure-accumulated in the common rail is supplied to the injector **18** of each cylinder **2,** and the high-pressure fuel is injected from the injector **18** into the combustion chamber **6.**

[Specific Structure of Valve]

[0035] Subsequently, a specific structure of the intake valve **11** (valve) will be described. Herein, a basic structure of the exhaust valve **12** is similar to the intake valve **11.** FIG. **2** is a sectional view showing details of the intake valve **11.** The intake valve **11** (exhaust valve **12**) is a so-called poppet valve and comprises an intake valve body

110 (valve body) which comprises an umbrella part **111** and a stem part **112.**

[0036] The umbrella part **111** comprises a valve head **113** which faces the combustion chamber **6** and a valve face **114** which is positioned on an opposite side to the combustion chamber **6.** In other words, the umbrella part **111** comprises, on one side, the valve head **113** which faces the combustion chamber **6** and, on the other side, the valve face **114.** The valve face **114** and the stem part **112** may be provided at the same side. As described above, the valve head **113** is a combustion-chamber wall surface which partitions a part of the combustion chamber **6.** The stem part **112** comprises a tip section **112A** which is connected to the umbrella part **111** and a base end section **112B** to which a driving force is applied from the intake-side valve driving mechanism **13.** The stem part **112** is held by a valve guide **131** so as to move in an axial direction.

[0037] A valve spring **132** is attached around the stem part **112.** The valve spring **132** is interposed between the a spring seat **133** which is fixed around the base end section **112B** and an upper face of the cylinder head **4.** The valve spring **132** presses the spring seat **133,** so that the intake valve **11** is biased in a direction in which the umbrella part **111** seals the intake-side opening portion **41** (in an upward direction).

[0038] A ring-shaped valve seat **4S** is provided at an opening edge of the intake-side opening portion **41.** A part of the umbrella part **111** contacts with the valve seat **4S.** Specifically, a portion of the valve face **114** around its outer peripheral edge contacts with an inner peripheral wall of the valve seat **4S** when the intake valve **11** is closed. This contacting of the umbrella part **111** with the valve seat **4S** makes the intake port **9** and the combustion chamber **6** be shut off, so that the combustion chamber **6** is sealed. Meanwhile, when the intake valve **11** is opened, the umbrella part **111** moves separately from the valve seat **4S** according to a downward move of the intake valve **11,** so that the intake port **9** and the combustion chamber **6** have a connection state.

[Explanation of Comparative Examples of Valve]

[0039] Before describing a valve according to the embodiments of the present invention, valves of the comparative examples will be described. FIG. **3** is a partially-sectional side view showing an intake valve **11P1** (an exhaust valve is similar to this intake valve) of a comparative example 1. The intake valve **11P1** has a heat-barrier layer **720** only. Specifically, the intake valve **11P1** comprises the intake valve body **110** including the umbrella part **111** and the stem part **112,** and an entire portion of the umbrella part **111** (the valve head **113** and the valve face **114**) is covered with the heat-barrier layer **720.** The heat-barrier layer **720** is a coating layer which is made of a material having the sufficiently-smaller heat conductivity than the intake valve body **110,** such as heat-resistant silicon resin.

[0040] The umbrella part **111** of the intake valve **11P1**, especially the valve head **113,** faces the combustion chamber **6,** so that it is exposed to the high temperature. In a case of an intake/exhaust four-valve type of engine body **1,** for example, an area which the four valve heads **113** occupy shows a considerably large rate relative to an entire area of the combustion-chamber wall surface. Accordingly, it is necessary to take some countermeasures for suppressing heat loss through the intake valve **11P1**.

[0041] The heat-barrier layer **720** covering the umbrella part **111** is the layer having the small heat conductivity, and therefore its temperature changes depending on the temperature of an inside of the combustion chamber **6.** Therefore, a difference between the temperature of the combustion gas inside the combustion chamber **6** and the surface temperature of the umbrella part **111** is made so small that heat transfer to the intake valve body **110** can be blocked to a certain degree. Accordingly, the heat loss can be reduced to a certain degree. However, the heat-barrier layer **720** is generally a thin layer which is made of a material having the small volume specific heat. Therefore, the heat-barrier layer **720** has the poor (inferior) heat-storage performance and cannot block the heat transfer to the intake valve body **110** perfectly, so that the heat loss cannot be reduced sufficiently.

[0042] FIG. **4** is a partially-sectional side view showing an intake valve **11P2** (an exhaust valve is similar to this intake valve) of a comparative example 2. The intake valve **11P2** has a heat-insulation layer **710** in addition to the heat-barrier layer **720.** The intake valve **11P2** of the comparative example 2 is the same as the intake valve **11P1** of the comparative example 1 regarding a structure in which an entire portion of the umbrella part **111** of the intake valve **11P2** is covered with the heat-barrier layer **720.** Further, in an area of the intake valve **11P2** which corresponds to the valve head **113,** the heat-insulation layer **710** is arranged adjacently to a back-face side of the heat-barrier layer **720.** That is, the valve head **113** is covered with two layers of the heat-insulation layer **710** and the heat-barrier layer **720** positioned above the heat-insulation layer **710.**

[0043] The heat-insulation layer **710** is made of a material having the large volume specific heat and has the heat-storage performance. The heat-insulation layer **710** stores the heat which has passed through the heat-barrier layer **720.** Therefore, the heat-insulation layer **710** heats (retains the heat of) the heat-insulation layer **710** provided on the valve head **113.** Accordingly, the surface temperature of the valve head **113** is made high, so that a difference between the surface temperature of the valve head **113** and the temperature of the combustion gas in the combustion chamber **6** can be made small. In other words, the heat transfer from the combustion chamber **6** to the intake valve body **110** is blocked, so that the heat dissipation is suppressed. Consequently, the heat loss can be reduced considerably.

[0044] Herein, according to the research conducted by the inventors and others, it has been found that the structure of the intake valve **11P2** has the following problems. In a case where the temperature inside the combustion chamber **6** is not made relatively high, for example, when the homogenous-charge compression-ignition combustion using the lean mixture is performed in the low-load engine operation, the intake valve **11P2** of the comparative example 2 works effectively. That is, the heat-insulation layer **710** retains an appropriate stored temperature, thereby heating the heat-barrier layer **720** properly. Accordingly, the surface of the valve head **113** can be made to reach the temperature which is suitable for suppressing the heat loss.

[0045] Meanwhile, in a case where the temperature inside the combustion chamber **6** is made relatively high, the heat-insulation layer **710** stored the high temperature heats the heat-barrier layer **720** excessively. The engine body **1** performs the homogenous-charge compression-ignition combustion using the lean mixture in the middle-load engine operation and performs the spark-ignition combustion with the air-fuel ratio: λ = 1 in the high-load engine operation, for example. Since the amount of fuel injection becomes relatively large in the middle/high-load engine operation, the temperature of the combustion gas in the combustion chamber **6** becomes relatively high. Therefore, the valve head **113** comes to receive the high temperature as well, so that the heat-insulation layer **710** comes to store the high heat as well. Since the heat-barrier layer **720** is heated by this heat-insulation layer **710,** the surface temperature of the valve head **113** becomes considerably high.

[0046] FIG. **5** is a diagram showing a phenomenon which may occur in the middle/high-load engine operation in a combustion-chamber structure using the intake valve **11P2** of the comparative example. In FIG. **5,** not only the intake valve **11P2** but the exhaust valve **12P2** having the similar structure thereto are shown. The exhaust valve **12P2** comprises an umbrella part **121** and a stem part **122,** and the umbrella part **121** comprises the heat-insulation layer **710** and the heat-barrier layer **720** which are similar to those of the intake valve **11P2.**

[0047] When the heat-insulation layer **710** stores the high-temperature heat and the heat-barrier layer **720** is heated by this heat, the respective valve heads **113, 123** of the intake valve **11P1** and the exhaust valve **12P2** come to have the high temperature. The valve heads **113, 123** which have been excessively heated generate the heat operative to heat the combustion chamber **6** (an arrow **H** in FIG. **5**), so that the cylinder internal temperature is made excessively high. Accordingly, the temperature of the air taken into the combustion chamber **6** in an intake stroke of the engine increases, and when this air having the increased is compressed in a compression stroke of the engine, preignitions **PIG** may occur. That is, there may occur the phenomenon in which a part of the mixture is ignited at an earlier timing than a normal (appropriate) compression-ignition timing. In this case, some problems, such as an improper torque fluctuation or output decrease of the engine body **1,** may be caused.

[Description of Embodiments of Valve]

[0048] The present embodiments provide combustion-chamber structures which can suppress of occurrence of the preignitions **PIG** shown in FIG. **5,** reducing the heat loss through the intake valve **11** and the exhaust valve **12.** In the embodiments 1 - 6 described below, various structures of the intake valve **11** and the exhaust valve **12** which can provide the above-described combustion-chamber structure will be exemplified.

< Embodiment 1>

[0049] FIG. **6** is a partially-sectional side view showing the intake valve **11** according to a first embodiment. FIG. **7** is an enlarged view of a sectional portion of the intake valve **11** of FIG. **6,** which shows a positional relationship of the intake valve **11** with the vale seat **4S** (cylinder head **4**). The structure of the intake valve **11** which is shown here is applicable to the exhaust valve **12.** The intake valve **11** comprises the intake valve body **110** which includes the umbrella part **111** and the stem part **112,** the heat-insulation layer **71** and the heat-barrier layer **72** which are shown in the comparative example 2 as well, and the heat-diffusion layer **73** which is not provided in the comparative example 2.

[0050] The heat-insulation layer **71** is provided at the valve seat **113** of the umbrella part **111.** The heat-insulation layer **71** has a specified thickness in a valve shaft (axial) direction and is of a circular shape which is similar to the valve head **113** in a plan view of the valve shaft direction. A circular-shaped outer peripheral edge **711** of the heat-insulation layer **71** extends up to a position near an outer peripheral edge of the valve head **113** (umbrella part **111**). Of course, this circular shape, in the plan view, of the heat-insulation layer **71** is just one example, and this layer **71** may have any other shape, such as a polygon. Further, the heat-insulation layer **71** may have a smaller size than the valve head **113,** and the heat-insulation layer **71** may be provided only in a central area, in a radial direction, of the valve head **113,** for example. The thickness, in the valve shaft direction, of the heat-insulation layer **71** can be selected from a range of 1 - 6mm or about 1 - about 6mm, for example.

[0051] It is preferable that the heat conductivity of the heat-insulation layer **71** be as small as possible from viewpoints of suppressing the heat from escaping from the combustion chamber **6** through the intake valve **11** (the exhaust valve **12**) (suppression of the heat loss), and at least a material which has the smaller heat conductivity than the intake valve body **110** (an exhaust valve body **120**) is used. Further, it is preferable that the heat-insulation layer **71** have the volume specific heat which is as large as possible, i.e., the high heat-storage performance, from viewpoints of maintaining the valve head **113** at the high temperature.

[0052] The heat-barrier layer **72** is provided to cover the valve head **113** where the heat-insulation layer **71** is provided for suppression of the heat loss through the intake valve body **110.** That is, the heat-insulation layer **72** is exposed to the surface of the valve head **113.** The heat conductivity of the heat-barrier layer **72** is set to be smaller than those of the intake valve body **110** and the heat-insulation layer **71** from viewpoints of suppressing the heat from escaping from the valve head **113** to the intake valve body **110.** By providing the heat-barrier layer **72,** the temperature difference between the combustion gas generated in the combustion chamber **6** and the valve head **113** can be made small, thereby reducing the heat loss. The thickness, in the valve shaft direction, of the heat-barrier layer **72** can be selected from a range of 0.03 - 0.25mm or about 0.03 - about 0.25mm, for example.

[0053] The heat-diffusion layer **73** is provided between the heat-insulation layer **71** and the heat-barrier layer **72** such that its combustion-chamber-side face contacts with the heat-barrier layer **72** and its opposite-side face contacts with the heat-barrier layer **72.** The heat-diffusion layer **73** is the layer which has the function of making the heat stored at the heat-insulation layer **71** escape to the cylinder head **4** so that the temperature of the valve head **113** where the heat-insulation layer **71** is provided does not become too high. It is preferable that the heat conductivity of the heat-diffusion layer **73** be as large as possible from viewpoints of immediate transfer of the heat stored at the heat-insulation layer **71** to the cylinder head **4.** Therefore, the heat-diffusion layer **73** is configured to have the larger heat conductivity than the heat-insulation layer **71** and the heat-barrier layer **72.** The thickness, in the valve shaft direction, of the heat-diffusion layer **73** can be selected from a range of 1 - 5mm or about 1 - about 5mm, for example. Herein, it is preferable that the heat resistance, which is represented by "heat conductivity/thickness," of the heat-diffusion layer **73** be as small as possible from viewpoints of appropriate heat diffusion. Therefore, the thickness of the heat-diffusion layer **73** is set properly considering the heat conductivity of the material of which the heat-diffusion layer **73** is made.

[0054] Referring to FIG. **7,** the heat-diffusion layer **73** comprises a contact portion **731** which is provided to extend up to a position of a part of the valve face **114** from the outer peripheral edge of the valve head **113.** A portion around an outer peripheral edge (a portion having the largest diameter) of the valve face **114** becomes a contact face **CP** (contacting position) of the umbrella part **111** which contacts with the valve seat **4S** when the intake valve **11** is closed. The above-described contact portion **731** extends up to the position of the contact face **CP.** That is, the contact portion **731** is located at a position which directly contacts with a reception face **43** of the valve seat **4S** when the intake valve **11** is closed. The heat-diffusion layer **73** receives the heat which is excessively stored at the heat-insulation layer **71** and makes this heat escape from the contact portion **731** to the cylinder head **4** through the valve seat **4S.**

[0055] An operation (move) of the above-described heat dissipation (heat escaping) will be described referring to arrows **D1** - **D3** show in FIG. **7.** As shown by the arrow **D1**, since the heat-barrier layer **72** has the extremely-low heat conductivity and changes its temperature depending on the chamber temperature of the combustion chamber **6,** the heat transfer from the combustion gas in the combustion chamber **6** to the intake valve body **110** can be blocked considerably. That is, the heat can be prevented from escaping from the combustion chamber **6** through the valve head **113.** Thereby, the heat loss can be reduced. However, since the heat-barrier layer **72** cannot block the heat transfer perfectly, the heat is made to pass through to a certain degree as shown by the arrow **D2.** The heat-insulation layer **71** of the present embodiment is made of the material having the large volume specific heat, thereby providing the superior heat-storage performance. Accordingly, the heat passed through the heat-barrier layer **72** (the arrow **D2**) and the surrounding heat are stored at the heat-insulation layer **71.**

[0056] Then, the heat-insulation layer **71** which has stored the heat comes to heat the heat-barrier layer **72.** Accordingly, the valve head **113** where the heat-insulation layer **71** is provided can be maintained at the high temperature. However, as described regarding the comparative example 2, the heat-insulation layer **71** stores the high-temperature heat in a certain engine operation where the temperature of the combustion gas is relatively high. Accordingly, the heat-insulation layer **72** is excessively heated, so that the preignition is caused. In order to prevent this problem, the heat-diffusion layer **73** is provided between the heat-insulation layer **71** and the heat-barrier layer **72** such that the heat-diffusion layer **73** receives the heat stored at the heat-insulation layer **71.** Further, as shown by the arrow **D3,** when the contact portion **731** contacts with the valve seat **4S,** the heat-diffusion layer **73** makes the heat received from the heat-insulation layer **71** escape to the valve seat **4S.** This heat is transferred from the valve seat **4S** to the cylinder head **4.** Accordingly, the excessively high temperature of the valve head **113** is so suppressed that the preignition can be prevented from occurring previously.

[0057] Subsequently, examples of the material which can be appropriately used as a structural member of the combustion chamber **6** are shown. A casting of a metal-based material, such as aluminum alloy AC4B (the heat conductivity = 96W/mK or about 96W/mK, the volume specific heat = 2667kJ/m^{3}K or about 2667kJ/m^{3}K), can be used as respective base materials of the cylinder block **3** and the cylinder head **4.** Further, aluminum alloy AC8A (the heat conductivity = 125W/mK or about 125W/mK, the volume specific heat = 2600kJ/m^{3}K or about 2600kJ/m^{3}K) can be used as a base material of the piston **5** (piston body **50**).

[0058] Heat-resistant steel which is superior in the heat-resistant performance, the wear-resistant performance, and the corrosion-resistant performance can be used for the intake valve body **110** and the exhaust valve body **120.** Martensite-based heat-resistant steel SUH11 based on chrome, silicon, and carbon (the heat conductivity = 25W/mK or about 25W/mK, the volume specific heat = 3850kJ/m^{3}K or about 3850kJ/m^{3}K) can be used for the intake valve body **110,** for example. Martensite-based heat-resistant steel SUH35 based on chrome, silicon, and carbon (the heat conductivity = 18W/mK or about 18W/mK, the volume specific heat = 3565kJ/m^{3}K or about 3565kJ/m^{3}K) can be used for the exhaust valve body **120,** for example.

[0059] Like the above-described examples, it is preferable that the cylinder head **4** have the larger heat conductivity than the intake valve body **110** and the exhaust valve body **120.** Since the contact portion **731** of the heat-diffusion layer **73** contacts with the valve face **114** of the umbrella part **111,** the heat can be made to escape to the intake valve body **110** as well. However, by setting the heat conductivity of the cylinder head **4** to be larger than those of the intake valve body **110** and the exhaust valve body **120,** the heat can be made to escape from the contact portion **731** to the valve bodies **110, 120** actively.

[0060] The material which has the smallest heat conductivity and the smallest volume specific heat is selected for the heat-barrier layer **72** among the structural members of the intake valve **11** and the exhaust valve **12** (the intake valve body **110** and the exhaust valve body **120,** the heat-insulation layer **71,** the heat-barrier layer **72,** and the heat-diffusion layer **73**). That is, the appropriate material of the heat-barrier layer **72** is selected such that this layer **72** does not diffuse the heat easily and does not store the heat easily. A range of the preferable heat conductivity of the heat-barrier layer **72** is about 0.05 - 1.50W/mK, and a range of the preferable volume specific heat of the heat-barrier layer **72** is about 500 - 1500kJ/m^{3}K.

[0061] For example, the heat-resistant silicon resin can be exemplified as the material of the heat-barrier layer **72** which meets the above-described requirements. The silicon resin made of three-dimensional polymer having the high branching degree which is represented by methyl silicon resin and methylphenyl silicon resin can be exemplified as the above-described silicon resin, and polyalkylphenylsiloxane or the like are preferably used, for example. This silicon resin may contain microballoon particles, such as Shirasu balloons. The heat-barrier layer **72** can be formed by a coating process in which the above-described silicon resin is coated on the valve face **114** of the umbrella part **111** where the heat-insulation layer **71** and the heat-diffusion layer **73** are formed, for example.

[0062] The heat-insulation layer **71** does not diffuse the heat easily but stores the heat easily. The material which has the larger heat conductivity than the heat-barrier layer **72** and the extremely-smaller heat conductivity than the intake valve body **110** and the exhaust valve body **120** is selected for the heat-insulation layer **71** in order to suppress the heat diffusion. Further, the material which has the larger volume specific heat and the larger heat resistance than the heat-barrier layer **72** is selected for the heat-insulation layer **71** in order to provide the appropriate heat-storage performance. A range of the preferable heat conductivity of the heat-insulation layer **71** is about 0.2 - 10W/mK, and a range of the preferable volume specific heat of the heat-insulation layer **71** is about 1800 - 3500kJ/m^{3}K.

[0063] A ceramics material can be exemplified as the material of the heat-insulation layer **71** which meets the above-described requirements, for example. In general, since the ceramics material has the small heat conductivity but has the large volume specific heat and the superior heat resistance, this material is suitable for the heat-insulation layer **71.** Specifically, a preferable ceramics material is zirconia (the heat conductivity = 3W/mK or about 3W/mK, the volume specific heat = 2576kJ/m^{3}K or about 2576kJ/m^{3}K). Alternatively, the ceramics material, such as silicon nitride, silica, cordierite, or mullite, a porous SUS based material, calcium silicate, or the like can be used as the material of the heat-insulation layer **71** as well.

[0064] The heat-diffusion layer **73** makes the heat stored at the heat-insulation layer **71** escape to the cylinder head **4** from the contact portion **731,** and therefore this layer **73** is the layer which easily diffuses the heat. Thus, the heat-diffusion layer **73** has the largest heat conductivity among the structural members of the intake valve **11** or the exhaust valve **12.** A range of the preferable heat conductivity of the heat-diffusion layer **73** is about 35 - 600W/mK. Further, it is preferable that the thickness of the heat-diffusion layer **73** be set such that the heat resistance is within a range of 0.002 - 0.06m^{2}K/W or about 0.002 - about 0.06m^{2}K/W. A copper-based material (the heat conductivity = 400W/mK or about 400W/mK, the volume specific heat = 3500kJ/m^{3}K or about 3500kJ/m^{3}K), Corson alloy, beryllium copper, fiber-reinforced aluminum alloy, titanium aluminum, or the like can be used as the material of the heat-diffusion layer **73** which meets the above-described requirements. The above-described copper-based material is particularly preferable because even in a case where the thickness is set at 2mm, the heat resistance of the heat-diffusion layer **73** can be controlled (suppressed) at a value of 0.005m^{2}K/W or about 0.005m^{2}K/W.

[0065] FIG. **8** shows a preferred material selection example of the base materials of the intake valve body **110** and the exhaust valve body **120** (valve base materials), the cylinder block **3,** the cylinder head **4** and the piston **5,** the heat-insulation layer **71,** the heat-barrier layer **72,** and the heat-diffusion layer **73.** FIG. **8** shows the heat conductivity λ, the volume specific heat ρc, the heat diffusivity ($\lambda/\rho c$), the Z-directional thickness t, the heat resistance (t/λ), and the heat permeability ($\sqrt{\lambda\rho c}$) of each of these materials. Herein, a right-side small column of the heat diffusivity shows each value of the respective layers in a case where the heat diffusivity of the heat-barrier layer **72** is considered as "1".

< Embodiment 2 >

[0066] In a second embodiment, a preferable example as the intake valve will be shown. FIG. **9** is a partially-sectional side view showing an intake valve **11A** according to the second embodiment. The intake valve **11A** comprises the intake valve body **110** including the umbrella part **111** and the stem part **112,** the heat-insulation layer **71,** the heat-barrier layer **72,** and the heat-diffusion layer **73.** What is different from the above-described first embodiment is that there is provided a valve-face heat-barrier layer **721** which covers over the valve face **114** of the umbrella part **111.**

[0067] The valve-face heat-barrier layer **721** covers the valve face **14** over an area from a base end section **111A** (a portion connected to the tip section **112A** of the stem part **112**) of the umbrella part **111** to a position of the umbrella part **111** which partially overlaps with the contact portion **731.** That is, the structure in which the contact portion **731** is exposed to the contact face **CP** of the umbrella part **111** is the same as that of the first embodiment. The valve-face heat-insulation layer **721** can have the same material and thickness as the heat-barrier layer **72.** Herein, the heat-barrier layer **721** may be provided to extend up to a position located above a portion of the stem part **112** (a specified length from the tip section **112A** toward the base end section **112B**).

[0068] Even if the heat-insulation layer **71** and the heat-barrier layer **72** are arranged on the side of the valve head **113,** the intake valve body **110** has the heat. The higher the temperature of the combustion chamber in the combustion chamber becomes, the higher the temperature of the intake valve body **110** becomes. As shown in FIG. **2,** the umbrella part **111** of the intake valve body **110** is positioned in the intake port **9** when the valve **11** is closed. At this moment, the intake air inside the intake port **9** contacts with the valve face **114** of the umbrella part **111.** Further, when the valve **11** is opened as well, the intake air flowing from the intake port **9** into the combustion chamber **6** hits against the valve face **114.** Therefore, if the temperature of the surface of the valve face **114** becomes high, the temperature of the intake air is increased. If the excessively-heated intake air is introduced into the combustion chamber **6** in the intake stroke of the engine, the preignition occurs in the compression stroke of the engine.

[0069] The valve-face heat-barrier layer **721** prevents the heat of the umbrella part **111** from escaping to the outside from the valve face **114.** That is, as shown by the arrow **D4** in FIG. **9,** the valve-face heat-barrier layer **721** performs the function of capturing the heat inside the umbrella part **111.** Accordingly, even in a case where the temperature of the umbrella part **111** of the intake valve **11** becomes high, the heat can be prevented from escaping from the valve face **114.** Accordingly, the temperature of the intake air passing through the intake port **9** is suppressed from increasing excessively, so that the preignition can be prevented.

[0070] Herein, the heat of the umbrella part **111** is made to escape to the cylinder head through the contact portion **731** of the heat-diffusion layer **73** to a certain degree. This point is similar to a case of the intake valve **11** of the first embodiment in which the valve-face heat-barrier layer **721** is not provided. However, since there are many cases where the above-described heat dissipation (escaping) through the contact portion **731** is not enough, it is preferable that the heat dissipation from the valve face **114** be suppressed by providing the valve-face heat-barrier layer **721** like the present embodiment.

< Embodiment 3 >

[0071] A preferable example of the intake valve will be shown as a third embodiment as well. FIG. **10** is a partially-sectional side view showing an intake valve **11B** according to the third embodiment. The intake valve **11B** comprises the intake valve body **110** including the umbrella part **111** and the stem part **112,** the heat-insulation layer **71,** the heat-barrier layer **72,** and the heat-diffusion layer **73.** What is different from the above-described second embodiment is that there is provided a stem-part heat-barrier layer **722** which is provided to cover over the stem part **112** in addition to the valve-face heat-barrier layer **721,** and the heat-diffusion layer **73** extends from the valve face **114** to the stem part **112.**

[0072] Similarly to the second embodiment, the valve-face heat-barrier layer **721** is provided on the valve face **114** in an area from an end edge of the contact portion **731** to the base end section **111A.** The stem-part heat-barrier layer **722** is provided on the stem part **112** such that it is continuous to the valve-face heat-barrier layer **721.** That is, the valve-face heat-barrier layer **721** and the stem-part heat-barrier layer **722** cover the valve face **114** and the stem part **112** except the contact portion **731.** It is preferable that the stem-part heat-barrier layer **722** cover around the tip section **112A** of the stem part **112,** especially a section of the stem part **112** which projects downwardly from the valve guide **131** (FIG. **2**).

[0073] The heat-diffusion layer **73** comprises a valve-head heat-diffusion layer **730** (first portion), the above-described contact portion **731,** a valve-face heat-diffusion layer **732** (second portion), and a stem-part heat-diffusion layer **733** (second portion). The valve-head heat-diffusion layer **730** is provided between the heat-insulation layer **71** and the heat-barrier layer **72** at the valve head **113.** The contact portion **731** is exposed to the contact face **CP** of the stem part **111** and contacts with the valve seat **4S** similarly to the first and second embodiments. The valve-face heat-diffusion layer **732** is a base layer of the valve-face heat-barrier layer **721** which is provided on the valve face **114.** The stem-part heat-diffusion layer **733** is a base layer of the stem-part heat-barrier layer **722** which is provided on the stem part **112.**

[0074] The intake valve **11** receives the heat from the exhaust gas in some cases. For example, in a case where a closing timing of the intake valve is delayed by setting a valve overlap term, there may occur blow back of the exhaust gas from the combustion chamber **6** to the intake port **9** after the combustion. In this case, the intake valve **11** is heated by this blow-back exhaust gas. Especially, the umbrella part **111** is heated. Further, the intake valve **11** may be heated by the EGR gas as well. Thus, the intake valve **11** heated by the exhaust gas may increase the temperature of the intake air excessively.

[0075] Herein, the intake valve **11B** of the third embodiment is configured such that the heat-diffusion layer **73** is provided with the valve-face heat-diffusion layer **732** and the stem-part heat-diffusion layer **733** and thereby the heat received by the umbrella part **111** and the stem part **112** escapes from the contact portion **731** to the cylinder head **4.** That is, as shown by the arrow **D4** in FIG. **10,** the valve-face heat-barrier layer **721** performs the function of capturing the heat inside the umbrella part **111.** This is the same as the second embodiment. Further, as shown by an arrow **D41,** the stem-part heat-barrier layer **722** performs the function of capturing the heat inside the stem part **112.** Therefore, even in a case where the temperature of the umbrella part **111** and the stem part **112** of the intake valve **11** is made high, the heat dissipation from the surfaces of the valve face **114** and the stem part **112** can be suppressed.

[0076] Meanwhile, in a case where the valve-face heat-barrier layer **721** and the stem-part heat-barrier layer **722** are exposed to the high temperature through contacting with the exhaust gas and the like that, the heat-diffusion layer **73** performs of the function of the heat dissipation. That is, the valve-face heat-diffusion layer **732** receives the heat from the valve-face heat-barrier layer **721,** and the stem-part heat-diffusion layer **733** receives the heat from the stem-part heat-barrier layer **722.** This heat is made to escape from the contact portion **731** to the cylinder head **4** as shown by the arrow **D5.** Accordingly, the excessively-high temperature of the intake valve **11B** can be prevented.

< Embodiment 4 >

[0077] A preferable example of the exhaust valve will be shown as a fourth embodiment as well. FIG. **11** is a partially-sectional side view showing an exhaust valve **12A** according to the fourth embodiment. The exhaust valve **12A** comprises the intake valve body **120** including the umbrella part **121** and the stem part **122,** the heat-insulation layer **71,** the heat-barrier layer **72,** the heat-diffusion layer **73,** and a valve-face heat-barrier layer **721** which is provided to cover over a valve face **124** of the umbrella part **121.** A layer structure of the exhaust valve **12** of the fourth embodiment is the same as that of the intake valve **11A** of the second embodiment.

[0078] The valve-face heat-barrier layer **721** covers the valve face **124** in an area from a base end section **121A** to a position which partially overlaps with the contact portion **731** of the heat-diffusion layer **73.** Similarly to the above-described embodiments, the contact portion **731** is exposed to the contact face **CP** of the umbrella part **121** with the valve seat **4S.** Herein, the heat-barrier layer **721** may be provided to extend up to a position located above a portion of the stem part **122** (a specified length from the tip section **112A** toward the base end section **112B**).

[0079] The exhaust valve **12A** which is provided at the exhaust port **10** is exposed to the high temperature by the exhaust heat of the combustion gas. Differently from the second embodiment, the valve-face heat-barrier layer **721** suppresses the umbrella part **121** from receiving the exhaust heat. The temperature of the valve-face heat-barrier layer **721** increases through contacting with the high-temperature exhaust gas, so that the temperature difference between the exhaust gas and the valve face **124** is made small. Accordingly, as shown by the arrow **D6** in FIG. **11,** the heat transfer of the exhaust heat to the umbrella part **121** through the valve face **124** can be suppressed by providing the valve-face heat-barrier layer **721.** That is, the heat loss can be suppressed.

< Embodiment 5 >

[0080] A preferable example of the exhaust valve will be shown as a fifth embodiment as well. FIG. **12** is a partially-sectional side view showing an exhaust valve **12B** according to the fifth embodiment. The exhaust valve **12B** comprises the structure in which the exhaust valve body **120** is covered with three layers of the heat-insulation layer, the heat-barrier layer, and the heat-diffusion layer except the contact portion **731.** While the fifth embodiment shows an example in which a section of the stem part **122** which is continuous to the umbrella part **121** is covered with the above-described three layers, only the umbrella part **121** may be covered with the above-described three layers.

[0081] The exhaust valve **12B** comprises the heat-insulation layer **71** which is provided to correspond to the valve head **123,** a valve-face heat-insulation layer **712** which is provided to extend from the outer peripheral edge **711** of the heat-insulation layer **71** onto the valve face **124,** and a stem-part heat-insulation layer **713** which is provided on the stem part **122** as the heat-insulation layers. The exhaust valve **12B** further comprises the valve-face heat-barrier layer **721** and the stem-part heat-barrier layer **722** covering the stem part **122** as the heat-barrier layers, in addition to the heat-barrier layer **72** covering the valve head **123.**

[0082] The heat-diffusion layer **73** comprises the valve-head heat-diffusion layer **730** (first portion), the above-described contact portion **731,** the valve-face heat-diffusion layer **732** (second portion), and the stem-part heat-diffusion layer **733** (second portion). The valve-head heat-diffusion layer **730** is provided between the heat-insulation layer **71** and the heat-barrier layer **72** at the valve head **123.** The contact portion **731** is exposed to the contact face **CP** of the umbrella part **121** and contacts with the valve seat **4S.** The valve-face heat-diffusion layer **732** is provided between the valve-face heat-insulation layer **712** and the valve-face heat-barrier layer **721** at the valve face **124.** The stem-part heat-diffusion layer **733** is provided between the stem-part heat-insulation layer **713** and the stem-part heat-barrier layer **722** at the stem part **122.**

[0083] The valve-face heat-barrier layer **721** suppresses the umbrella part **121** from receiving the exhaust heat similarly to the fourth embodiment. As shown by the arrow **D6** in shown in FIG. **12,** it can be suppressed by providing the valve-face heat-barrier layer **721** that the exhaust heat is transferred to the umbrella part **121** through the valve face **124.** The stem-part heat-barrier layer **722** suppresses the exhaust heat from being transferred to the stem part **122** as shown by an arrow **D61** similarly to the stem-part heat-barrier layer **722.** The valve-face heat-insulation layer **712** and the stem-part heat-insulation layer **713** are provided to maintain the respective temperatures of the valve-face heat-insulation layer **721** and the stem-part heat-barrier layer **722** at a high temperature. The valve-face heat-insulation layer **712** and the stem-part heat-insulation layer **713** store the heat which passes through the valve-face heat-insulation layer **721** and the stem-part heat-barrier layer **722** as shown by the arrow **D7,** and heat the heat-barrier layers **721, 722.** Thereby, the heat loss through the exhaust valve **12B** can be securely suppressed.

[0084] The valve-face heat-diffusion layer **732** and the stem-part heat-diffusion layer **733** are provided to make the heat stored at the valve-face heat-insulation layer **712** and the stem-part heat-insulation layer **713** escape. The valve-face heat-diffusion layer **732** receives the heat from the valve-face heat-insulation layer **712** and the valve-face heat-insulation layer **721.** The stem-part heat-diffusion layer **733** receives the heat from the stem-part heat-insulation layer **713** and the stem-part heat-barrier layer **722.** This heat is made to escape from the contact portion **731** to the cylinder head **4** as shown by the arrow **D8.** That is, even in a case where the valve-face heat-insulation layer **712** and the stem-part heat-insulation layer **713** store the heat at the excessively high temperature, a heat dissipation route formed by the heat-diffusion layers **732, 733** is secured. Herein, the valve-head heat-diffusion layer **730** performs the heat-dissipation function of the heat-insulation layer **71** of the valve head **123,** which is the same as the other embodiments. Accordingly, the excessive increase of the temperature of the exhaust valve **12B** which may cause the preignition can be prevented properly.

< Embodiment 6 >

[0085] A preferable example of the exhaust valve will be shown as a sixth embodiment as well. FIG. **13** is a partially-sectional side view showing an exhaust valve **12C** according to the sixth embodiment. The exhaust valve **12C** is the valve having the cooling function in which a coolant sealing portion **125** is formed at the exhaust valve body **120.** The sealing portion **125** extends from the stem part **122** up to an area of the umbrella part **121** which is positioned on a slightly-deep side of the base end section **121A.** A coolant which is sealed into the coolant sealing portion **125** is metallic sodium, for example.

[0086] The heat-insulation layer **71** and the heat-diffusion layer **73** of the exhaust valve **12C** are provided to cover the umbrella part **121.** The heat-barrier layer **72** is provided to cover the umbrella part **121** except the contact portion **731.** Further, the heat-barrier layer **72** and the heat-diffusion layer **73** extend up to the stem part **122** such that they overlap with the coolant sealing portion **125.** That is, similarly to the above-described embodiment **5,** the three-layer structure of the heat-insulation layer **71,** the heat-barrier layer **72,** and the heat-diffusion layer **73** is formed in the area from the umbrella part **121** to an end edge of the coolant sealing portion **125** except the contact portion **731.** Meanwhile, a two-layer structure of the heat-barrier layer **72** and the heat-diffusion layer **73** is formed in an area which overlaps with the coolant sealing portion **125.**

[0087] Specifically, the valve-face heat-diffusion layer **732** is provided between the valve-face heat-insulation layer **712** and the valve-face heat-barrier layer **721** at the valve face **124.** Meanwhile, the stem-part heat-diffusion layer **733** contacts with the stem-part heat-barrier layer **722** at its outside face, but its inside face contacts with a surface of the stem part **122.** That is, the stem-part heat-diffusion layer **733** faces the coolant sealing portion **125.**

[0088] The heat transfer to the exhaust valve body **120** can be suppressed by providing the valve-face heat-barrier layer **721** and the stem-part heat-barrier layer **722** as shown by the arrows **D6, D61** in FIG. **13.** The valve-face heat-insulation layer **712** stores the heat which has passed through the valve-face heat-barrier layer **721** (arrow **D7**) and maintains the heat-barrier layer **721** at the high temperature. In a case where the valve-face heat-insulation layer **712** is heated at the high temperature excessively, as shown by the arrow **D8,** this high-temperature heat is transferred to the valve-face heat-diffusion layer **732** and made to escape from the contact portion **731** to the cylinder head **4.**

[0089] The heat of the heat-insulation layer **71** and the valve-face heat-insulation layer **712** is made to escape to the coolant sealing portion **125** as well by the heat-diffusion layer **73.** That is, the heat-diffusion layer **73** is configured such that the valve-head heat-diffusion layer **730** which contacts with the heat-insulation layer **71** and the valve-face heat-diffusion layer **732** which contacts with the valve-face heat-insulation layer **712** are connected by the contact portion **731,** and the heat-diffusion layer **73** comprises the stem-part heat-diffusion layer **733** which faces the coolant sealing portion **125.** Therefore, the heat of the heat-insulation layers **71, 712** is transferred to the stem-part heat-diffusion layer **733** and made to escape to the coolant sealing portion **125** as shown by the arrow **D9.** Even in a case where the stem-part heat-barrier layer **722** is exposed to the high temperature, the heat is made to escape to the coolant sealing portion **125.** Accordingly, the excessive temperature increase of the exhaust valve **12C** which may cause the preignition can be prevented properly.

[Operations/Effects]

[0090] According to the above-described combustion-chamber structure of the engine of the present embodiments, at least the valve heads **113, 123** are covered with the heat-barrier layer **72** having the smaller heat conductivity than the intake valve body **110,** the exhaust valve body **120,** and the heat-insulation layer **71.** Accordingly, the temperature difference between the valve heads **113, 123** and the combustion gas in the combustion chamber **6** is made so small that the heat transfer to the valve heads **113, 123** can be suppressed. Further, the heat which has passed through the heat-barrier layer **72** is stored at the heat-insulation layer **71.** Accordingly, the high temperature of the heat-barrier layer **72** (valve heads **113, 123**) can be maintained. Thus, the heat loss through the intake valve **11** and the exhaust valve **12** can be reduced properly.

[0091] Meanwhile, the heat-diffusion layer **73** is provided between the heat-insulation layer **71** and the heat-barrier layer **72.** The heat-diffusion layer **73** has the larger heat conductivity than both the heat-barrier layer **72** and the heat-insulation layer **71** and comprises the contact portion **731** contacting with the valve seat **4S** of the cylinder head **4.** Accordingly, even in a case where the heat-insulation layer **71** has stored the heat excessively, this heat can be made to escape to the cylinder head **4** through the heat-diffusion layer **73.** Consequently, the temperature increase of the intake valve **11** and the exhaust valve **12** which may cause the preignition can be prevented properly.

Claims

1. A valve (11; 11A; 11B; 12; 12A; 12B; 12C) for an engine including a cylinder block (3), a cylinder head (4), a piston (5), the valve (11; 11A; 11B; 12; 12A; 12B; 12C), and a combustion chamber (6) partitioned by the cylinder block (3), the cylinder head (4), the piston, and the valve (11; 11A; 11B; 12; 12A; 12B; 12C), wherein the valve (11; 11A; 11B; 12; 12A; 12B; 12C) is configured to open and/or close a port opening (41, 42) to the combustion chamber (6), the valve (11; 11A; 11B; 12; 12A; 12B; 12C) comprising:

   a valve body (110, 120) including an umbrella part (111, 121) and a stem part (112, 122), wherein the umbrella part (111, 121) includes a valve head (113, 123) facing the combustion chamber (6) and a valve face (114, 124) positioned on an opposite side to the combustion chamber (6);
   a heat-insulation layer (71) which is provided at the valve head (113, 123) and has a heat conductivity smaller than a heat conductivity of the valve body (110, 120);
   a heat-barrier layer (72) which is provided to cover the valve head (113, 123) provided with the heat-insulation layer (71) and has a heat conductivity smaller than the heat conductivity of the valve body (110, 120) and the heat conductivity of the heat-insulation layer (71); and
   a heat-diffusion layer (73) which is provided between the heat-insulation layer (71) and the heat-barrier layer (72) and has a heat conductivity larger than the heat conductivity of the heat-insulation layer (71) and the heat conductivity of the heat-barrier layer (72), and
   the heat-diffusion layer (73) comprises a contact portion (731) which is provided to extend up a position of the umbrella part (111, 121) of the valve (11; 11A; 11B; 12; 12A; 12B; 12C) which is configured to contact with the cylinder head (4) when the valve (11; 11A; 11B; 12; 12A; 12B; 12C) is closed.

2. The valve (11; 11A; 11B; 12; 12A; 12B; 12C) of claim 1, wherein the cylinder head (4) has a heat conductivity larger than the heat conductivity of the valve body (110, 120).

3. The valve (11; 11A; 11B; 12; 12A; 12B; 12C) of claim 1 or 2, wherein
   the cylinder head (4) comprises a valve seat (4S) which is provided at the port opening (41, 42) and with which a portion of the umbrella part (111, 121) of the valve body (110, 120) contacts, and/or
   the contact portion (731) of the heat-diffusion layer (73) is provided at the portion of the umbrella part (111, 121) which is configured to contact with the valve seat (4S).

4. The valve (11; 11A; 11B; 12; 12A; 12B; 12C) of any one of the preceding claims, wherein the valve (11; 11A; 11B; 12; 12A; 12B; 12C) is an intake valve (11; 11A; 11B), and/or the heat-barrier layer (72) is provided on the valve face (114, 124) of the umbrella part (111, 121) of the valve (11; 11A; 11B; 12; 12A; 12B; 12C) as well.

5. The valve (11; 11A; 11B; 12; 12A; 12B; 12C) of any one of the preceding claims, wherein the heat-barrier layer (72) is provided on the stem part (112, 122) of the valve (11; 11A; 11B; 12; 12A; 12B; 12C) as well.

6. The valve (11; 11A; 11B; 12; 12A; 12B; 12C) of any

one of the preceding claims, wherein the valve (11; 11A; 11B; 12; 12A; 12B; 12C) is an exhaust valve (12; 12A; 12B; 12C), and/or the heat-barrier layer (72) is provided on the valve face (114, 124) of the umbrella part (111, 121) of the valve (11; 11A; 11B; 12; 12A; 12B; 12C) as well.

7. The valve (11; 11A; 11B; 12; 12A; 12B; 12C) of any one of the preceding claims, wherein the heat-diffusion layer (73) includes
a first portion (730) which is provided between the heat-insulation layer (71) and the heat-barrier layer (72) at the valve head (113, 123),
the contact portion (731), and
a second portion (732) which is an underlayer of the heat-diffusion layer (73) which is provided at the valve face (114, 124) and the stem part (112, 122).

8. The valve (11; 11A; 11B; 12; 12A; 12B; 12C) of any one of the preceding claims, wherein
the valve (11; 11A; 11B; 12; 12A; 12B; 12C) is an exhaust valve (12; 12A; 12B; 12C), and/or
the heat-insulation layer (71) and the heat-diffusion layer (73) are provided to cover an entire part of the umbrella part (111, 121) of the valve (11; 11A; 11B; 12; 12A; 12B; 12C), and/or
the heat-barrier layer (72) is provided to cover the entire part of the umbrella part (111, 121) of the valve (11; 11A; 11B; 12; 12A; 12B; 12C) except the contact portion (731) of the heat-diffusion layer (73).

9. The valve (11; 11A; 11B; 12; 12A; 12B; 12C) of any one of the preceding claims, wherein the heat-insulation layer (71), the heat-diffusion layer (73), and the het-barrier layer are provided to cover at least a section of the stem part (112, 122) of the valve (11; 11A; 11B; 12; 12A; 12B; 12C) which is continuous to the umbrella part (111, 121) of the valve (11; 11A; 11B; 12; 12A; 12B; 12C).

10. The valve (11; 11A; 11B; 12; 12A; 12B; 12C) of any one of the preceding claims, wherein
the valve (11; 11A; 11B; 12; 12A; 12B; 12C) is an exhaust valve (12; 12A; 12B; 12C) with cooling function in which a coolant sealing portion is formed at the valve body (110, 120), and/or
the heat-insulation layer (71) and the heat-diffusion layer (73) are provided to cover the umbrella part (111, 121) of the valve (11; 11A; 11B; 12; 12A; 12B; 12C), and/or
the heat-barrier layer (72) is provided to cover the umbrella part (111, 121) of the valve (11; 11A; 11B; 12; 12A; 12B; 12C) except the contact portion (731) of the heat-diffusion layer (73), and/or
the heat-insulation layer (71) and the heat-diffusion layer (73) are provided to extend up to a position which overlaps with the coolant sealing portion of the valve body (110, 120).

11. The valve (11; 11A; 11B; 12; 12A; 12B; 12C) of any one of the preceding claims, wherein the heat-barrier layer (72) is made of heat-resistant silicon resin which has the heat conductivity of 0.05 - 1.50W/mK.

12. The valve (11; 11A; 11B; 12; 12A; 12B; 12C) of any one of the preceding claims, wherein the heat-diffusion layer (73) is made of copper-based material, Corson alloy, beryllium copper, fiber-reinforced aluminum alloy, or titanium aluminum which have the heat conductivity of 35 - 600W/mK.

13. A combustion-chamber structure comprising the valve (11; 11A; 11B; 12; 12A; 12B; 12C) of any one of the preceding claims.

14. An engine comprising the valve (11; 11A; 11B; 12; 12A; 12B; 12C) of any one of claim 1 to 12 or the combustion-chamber structure of claim 13.

15. A vehicle comprising the engine of claim 14.

FIG. 1

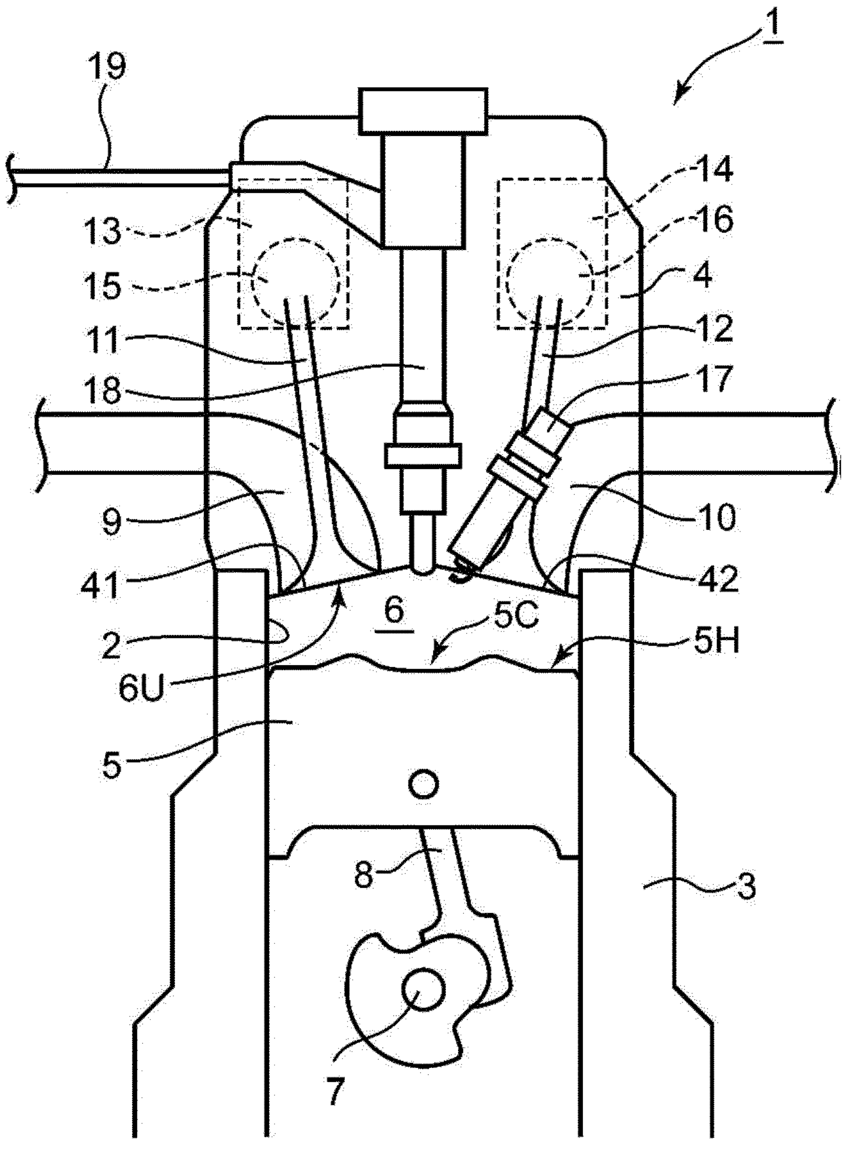
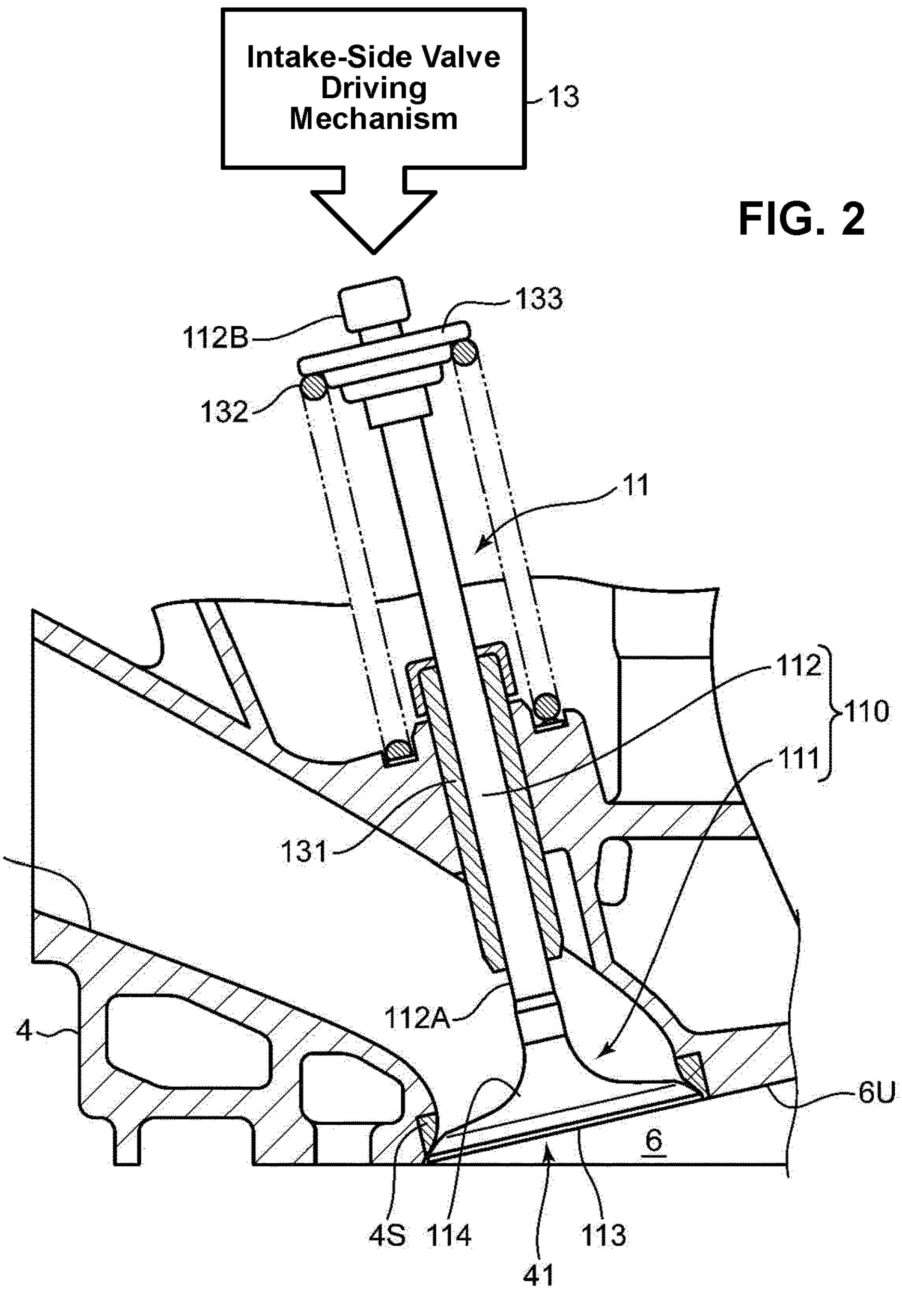


FIG. 2


Intake-Side Valve Driving Mechanism
13
133
112B
132
11
112
110
111
131
9
4
112A
6U
6
4S
114
113
41

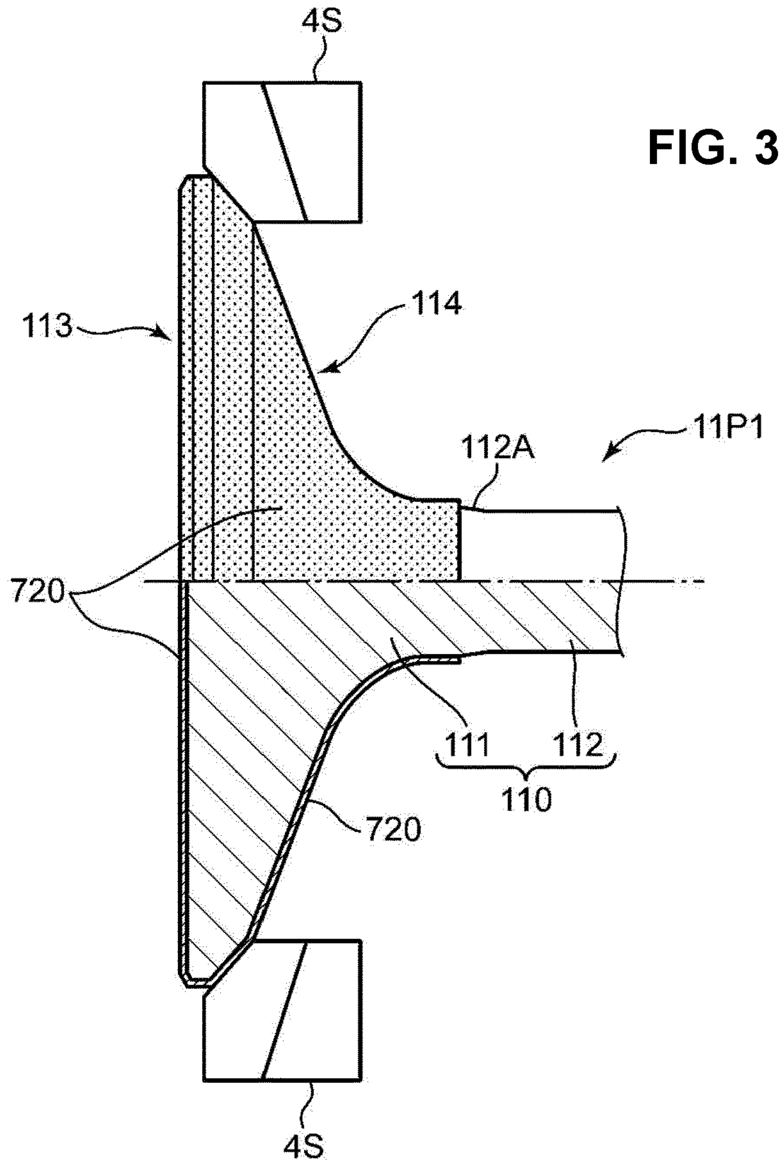
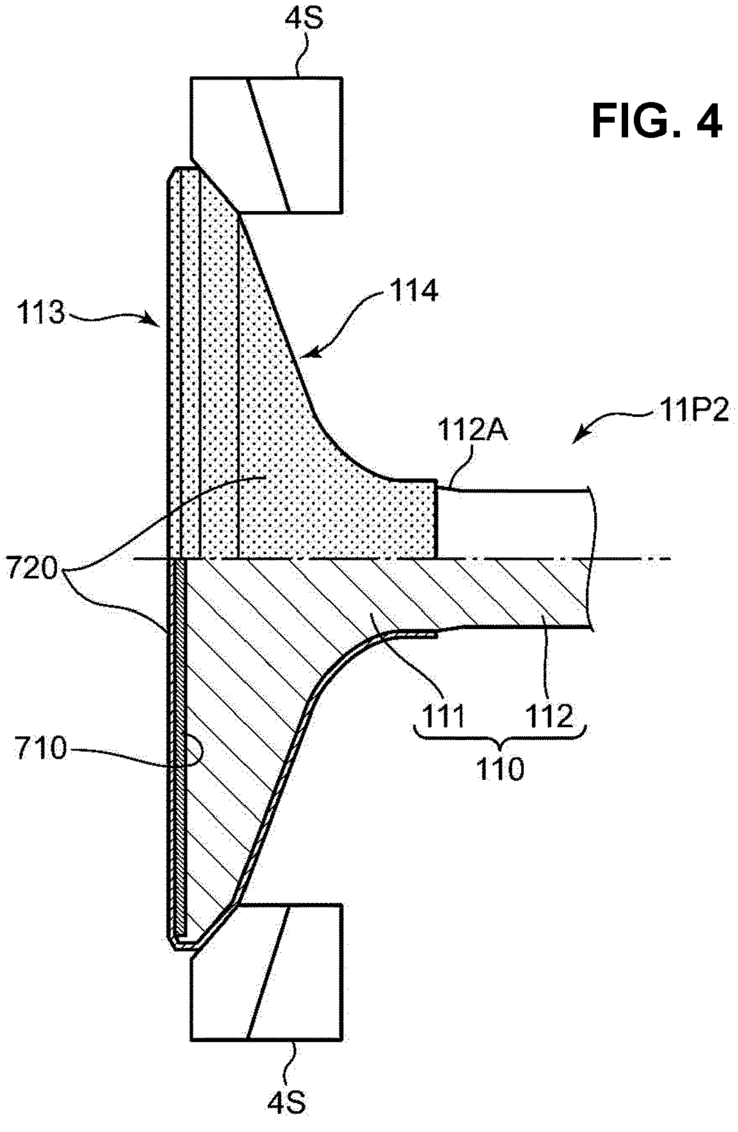


FIG. 3


4S
FIG. 4
114
113
11P2
112A
720
111
112
110
710
4S

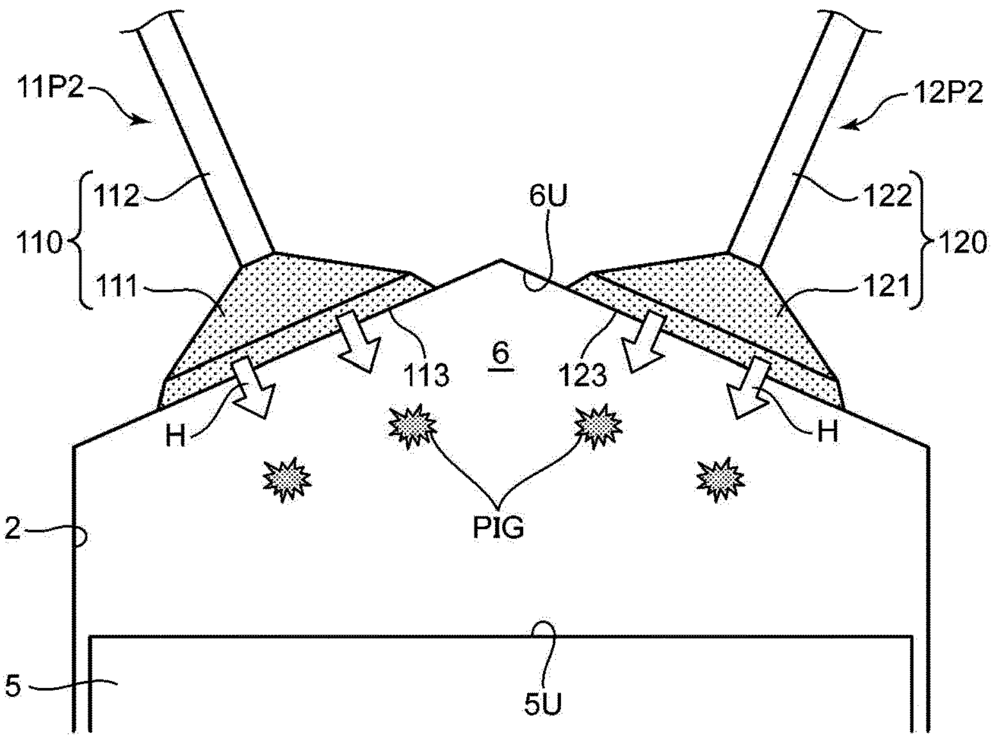
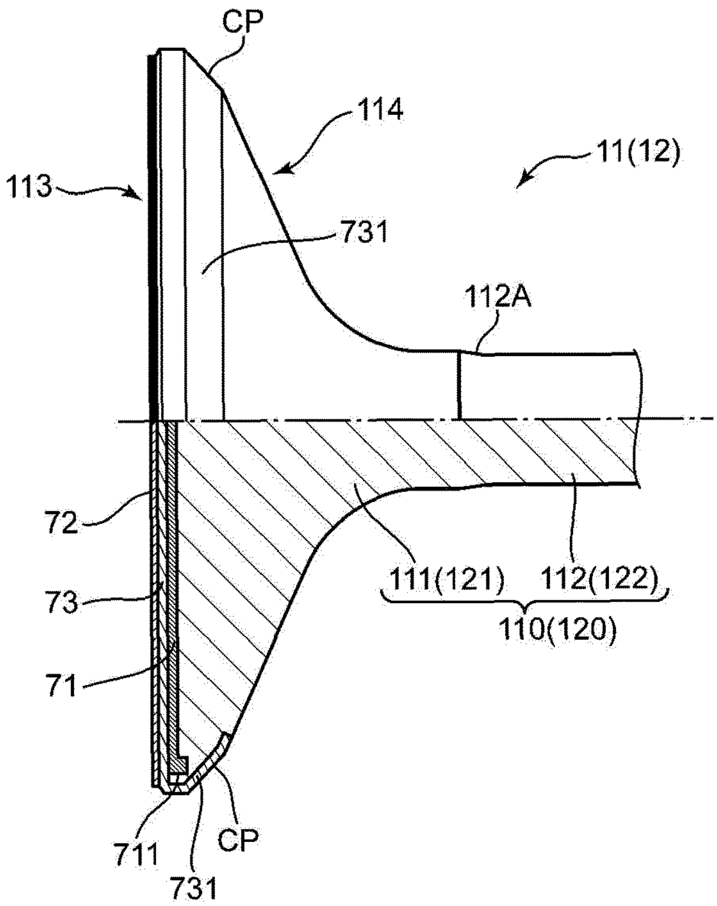


FIG. 5

FIG. 6


CP
114
11(12)
113
731
112A
72
73
71
111(121)
112(122)
110(120)
711
CP
731

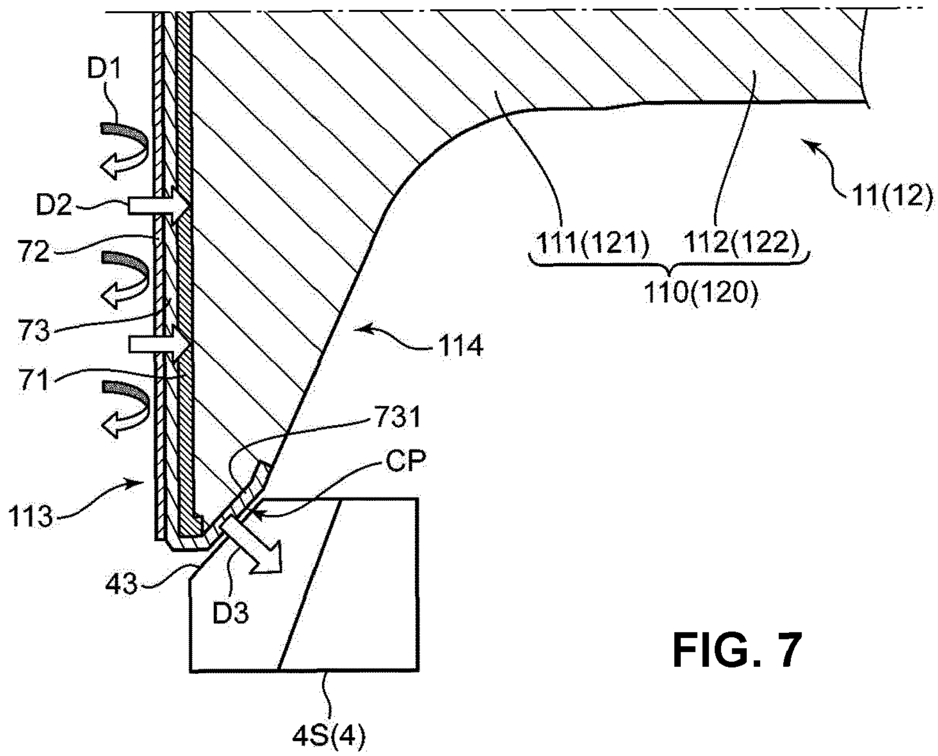

D1
D2
72
73
71
113
43
D3
731
CP
114
111(121)
112(122)
110(120)
11(12)
4S(4)

FIG. 7

FIG. 8

		heat conductivity λ	volume specific heat ρc	heat diffusivity $\lambda/\rho c$		Z-directional thickness t (mm)	heat resistance t/λ	heat permeability $\sqrt{\lambda \rho c}$
heat-barrier layer		0.2	1000	0.0002	1	0.075	0.3750	14
heat-diffusion layer	Cu based material	400	3500	0.1143	571	2	0.0050	1183
	Corson alloy	239	3349.5	0.0714	357	2	0.0084	895
	beryllium copper	125	3460	0.0361	181	2	0.0160	658
	fiber-reinforced aluminum	100	3120	0.0321	160	2	0.0200	559
	titanium aluminum	40	2340	0.0171	85	2	0.0050	306
heat-insulation layer	calcium silicate	0.24	2000	0.00012	0.6	2	8.3333	22
	ZrO_2 zirconia	3	2576	0.0012	6	2	0.6667	88
	porous SUS based material	5	2352	0.0021	11	3.5	0.7000	108
	↑(relative density: large)	8	2970	0.0027	13	5	0.6250	154
cylinder block/head base material	AC4B	96	2667	0.0360	180	6	0.0625	506
piston base material	AC8A	125	2600	0.0481	240	4	0.0320	570
intake valve base material	SUH11	25	3850	0.0065	32	4	0.1600	310
exhaust valve base material	SUH35	18	3565	0.0050	25	4	0.2222	253
		(W/mK)	($kJ/m^3 \cdot K$)				($m^2 \cdot K/W$)	

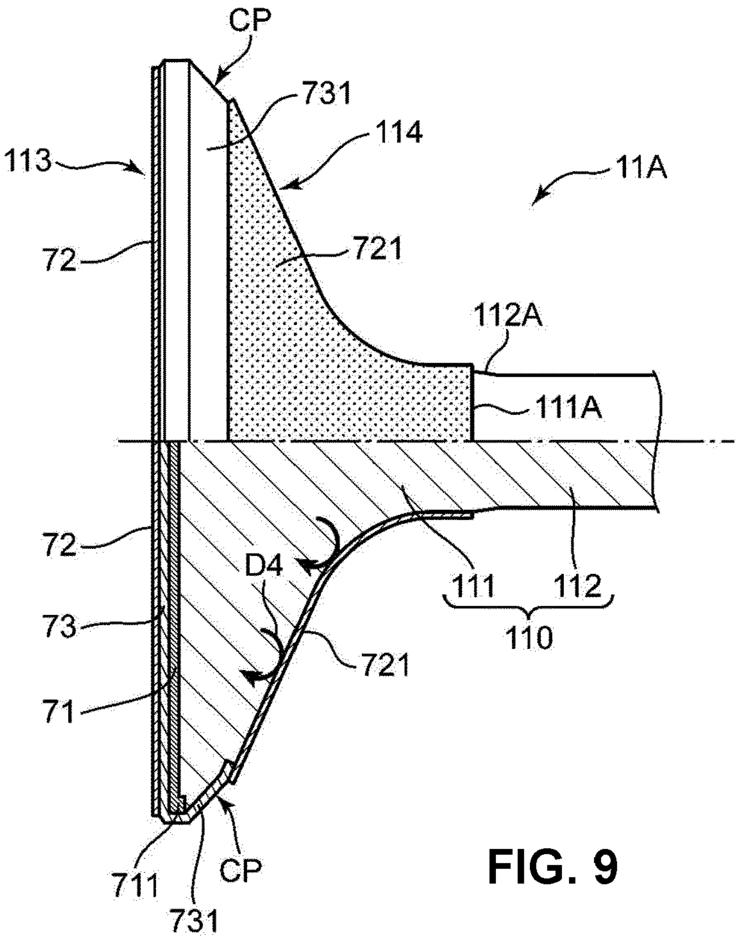
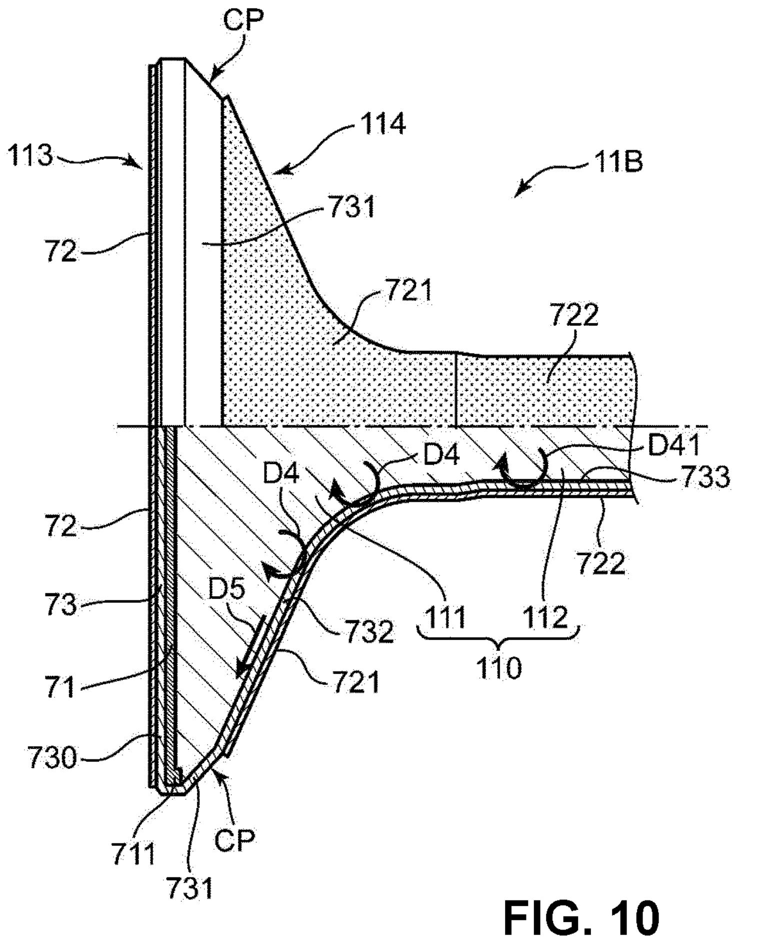

CP
731
114
11A
113
72
721
112A
111A
72
D4
111
112
110
73
721
71
711
CP
731

FIG. 9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11B
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733
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73
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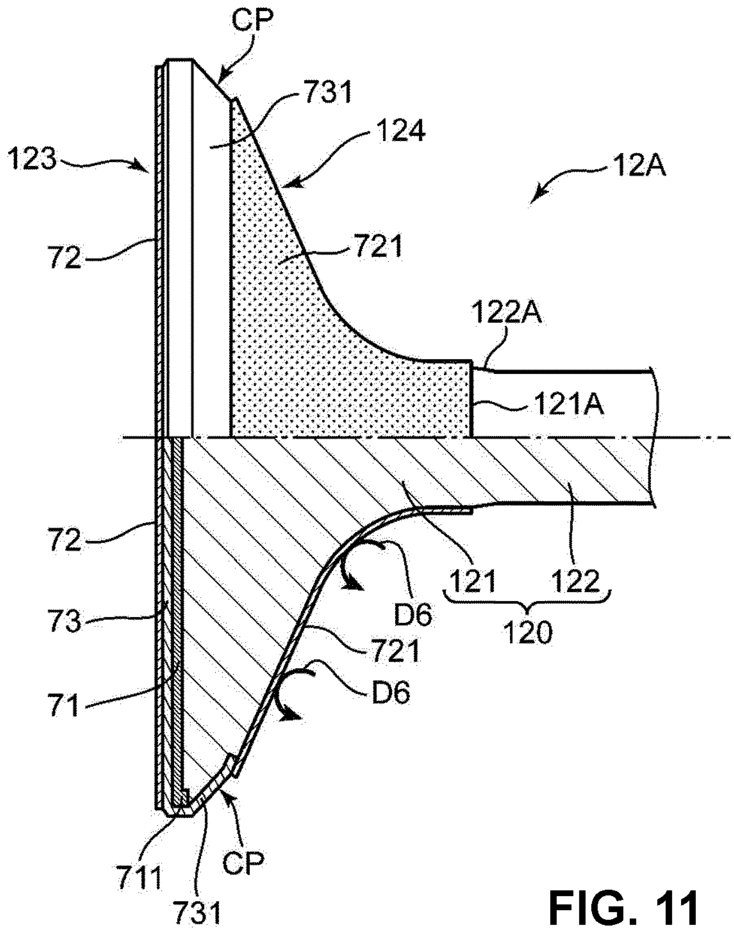
71
721
730
CP
711
731

FIG. 10


CP
731
124
123
12A
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D6
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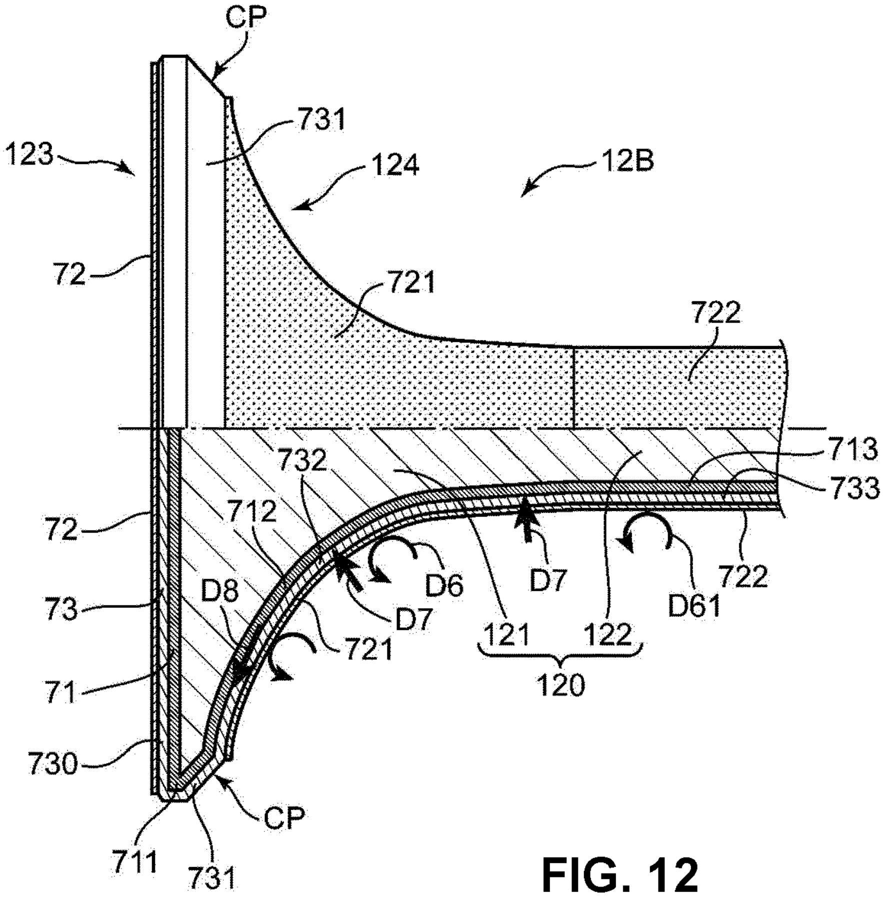
CP
731

FIG. 11


CP
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712
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D6
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D7
D61
721
121
122
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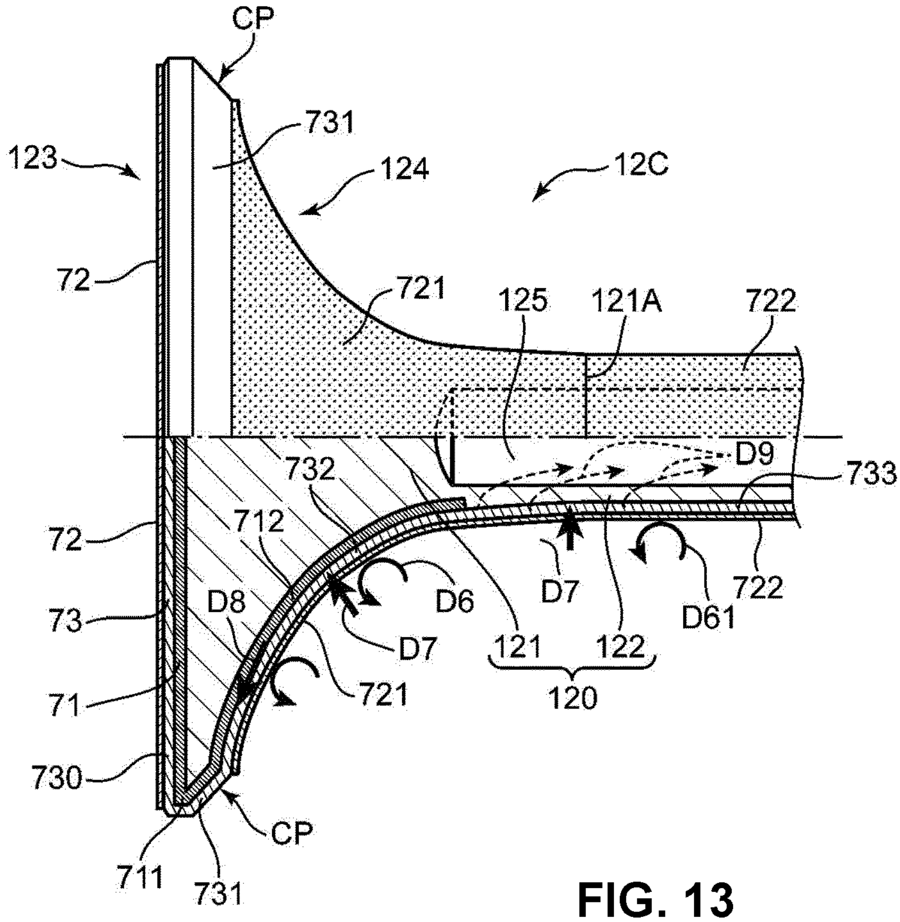
731

FIG. 12


CP
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722
73
D8
D7
121
122
D61
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71
721
730
CP
711
731

FIG. 13

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EUROPEAN SEARCH REPORT

Application Number
EP 21 16 0102

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A	JP S61 96115 A (MAZDA MOTOR) 14 May 1986 (1986-05-14) * abstract; figure 2 * -----	1-15	

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F01L
B21L
B21K

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	13 August 2021	Van der Staay, Frank

CATEGORY OF CITED DOCUMENTS

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13-08-2021

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REFERENCES CITED IN THE DESCRIPTION

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