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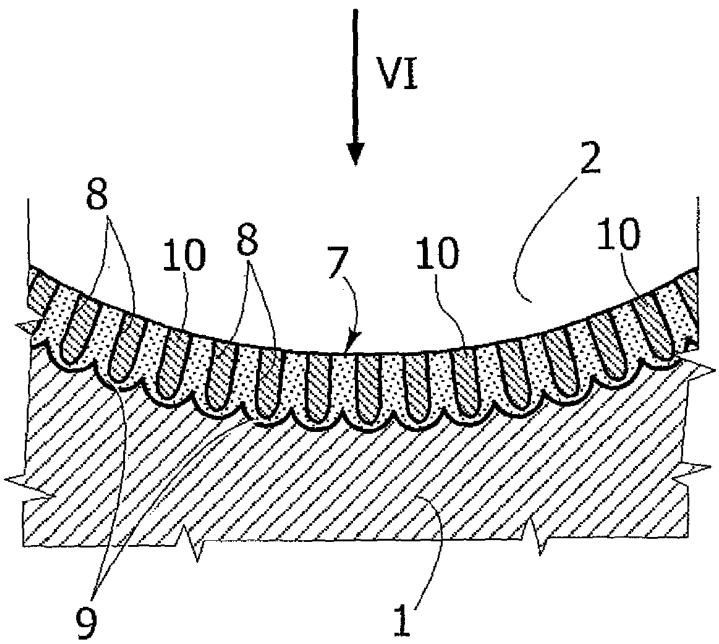
(54) **Internal combustion engine having cylinders and/or pistons with a nano-structured surface and method for obtaining this surface**

(57) In the engine block of an internal-combustion engine comprising a body made of aluminium (1) and at least one cylinder and a piston mounted slidably in the cylinder, in which the cylinder is defined by a cavity (2) formed in the body made of aluminium (1), the surface of said cavity and/or the surface of the piston undergoes a process of anodization so as to obtain a layer (7) of porous alumina, having a thickness comprised between a few nanometres and a few millimetres, which have pores (8) that receive, by means of electrodeposition or silk-screen printing, a filling material, for example a metal material with a base of iron, or else DLC (diamond-like carbon), or simple carbon in the form of graphite, silicon carbide or the like, so as to give rise to a composite layer (7) that functions as thermal barrier and as low-friction layer and at the same time has a high resistance to wear as well as a high capacity for carrying lubricant.

FIG. 5



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Description

[0001] The present invention relates to internal-combustion engines of the type comprising an engine block made of aluminium and at least one cylinder and one piston mounted slidably in the cylinder, in which the cylinder is defined by a cavity formed in the body made of aluminium of the engine block, the surface of which is covered with a material having a melting point higher than the melting point of aluminium.

[0002] According to the conventional technique, in engines of the type specified above, the wall made of aluminium of each cylinder is covered with a sleeve or "liner" made of cast iron or steel.

[0003] According to an alternative technique, which is also known, use is made of thin-film coatings, for example of graphite, silicon carbide, alumina or DLC (diamond-like carbon) deposited by means of high-vacuum technologies, which are very costly, such as physical vapour deposition (PVD) and chemical vapour deposition (CVD).

[0004] Both the cylinder liners and the aforesaid coatings function as heat barrier during operation of the engine, thanks to their high melting point, in comparison with that of aluminium, and also have the function of protecting the cavity in the engine block made of aluminium from scratches and from wear in general. Furthermore, the aforesaid coatings also have the function of reducing the friction between piston and cylinder.

[0005] Also at times adopted is surface treatment of the piston, for example by means of silk-screen printing (a technology that is economically advantageous with respect to high-vacuum technologies), a coating of graphite or iron, where the piston is subject to greater friction and wear.

[0006] The purpose of the present invention is to provide an engine of the type referred to above, in which it will be possible to avoid the use of cylinder liners and/or coating of the piston and at the same time guarantee reliability of operation also at high working temperatures.

[0007] A further purpose of the present invention is to obtain an engine in which the cylinders and/or pistons have surfaces that will guarantee a high resistance to wear and an excellent capacity for carrying an oil-groove for lubricant to provide an optimal guide for the piston.

[0008] A further purpose of the invention is to provide an engine having the characteristics referred to above that will be obtainable with a relatively simple and inexpensive process.

[0009] With a view to achieving said purpose, the subject of the invention is an internal-combustion engine of the type referred to at the start of the present description, characterized in that the surface of the cavity defining each cylinder and/or at least part of the surface of the piston is defined by a layer of porous alumina, having a thickness comprised between a few tens of nanometres and several millimetres, obtained by means of anodization of the aluminium constituting the body of the engine block or of the piston, said layer of porous alumina having pores giving out into said cavity that contain a filling material, applied by electrodeposition or silk-screen printing, so as to give rise to a composite layer that functions as heat barrier and as low-friction layer and at the same time has resistance to wear, as well as capacity for carrying a lubricant.

[0010] Said filling material is, for example, a metal material with a base of iron or else DLC (diamond-like carbon) or simple carbon in the form of graphite, silicon carbide, or the like, so as to give rise to a layer of composite material, in which the nanolayer of porous alumina functions as heat barrier and the filling material bestows high resistance to wear and a high capacity for receiving and carrying an oil-groove for lubricant.

[0011] A further subject of the invention is a process for obtaining the engine defined above, in which an engine block made of aluminium is provided with at least one cylinder defined by a cavity formed in the body made of aluminium, characterized in that a process of anodization of a surface layer having a thickness comprised between a few nanometres and a few millimetres) is carried out on the wall made of aluminium defining said cavity so as to obtain a layer of porous alumina which has pores giving out onto said cavity, and in that deposited in said pores by means of electrodeposition is a filling material (the filling can be either partial or total, or may even overflow from the pores), such as for example a metal material with a base of iron, or else DLC (diamond-like carbon), or simple carbon in the form of graphite, silicon carbide, or the like.

[0012] At the end of the operation of anodization that enables the layer of porous alumina to be obtained, the pores of the porous alumina are closed on the bottom by a barrier layer of alumina. Preferably, said barrier layer is thinned out by means of chemical erosion, by exploiting the acid solution that is in the electrolytic cell at the end of the operation of anodization. The thinning of the barrier layer of alumina enables use of the substrate made of aluminium underlying the porous alumina produced during the step of anodization as electrode in the subsequent step of electrodeposition of the material used for filling the pores of the alumina itself.

[0013] Thanks to the characteristics referred to above, the process according to the invention enables protection of the surface of the cylinders with a nanostructured layer of alumina that functions as heat barrier, thanks to the high melting point of alumina (which is in the region of 3 000°C). Said layer thus replaces the traditional cylinder liner made of cast iron and steel, which is mounted within the cylinders of engine blocks made of aluminium. Alumina has a high adhesion to aluminium and at the same time, thanks to the inclusion of the filling material within its pores, also guarantees a high resistance to wear, as well as a high capacity for carrying the lubricant that is to guide the movement of sliding of the piston.

[0014] Of course, the process described above is also applicable to the surface of the piston.

[0015] Further characteristics and advantages of the invention will emerge from the ensuing description with reference to the annexed plates of drawings, which are provided purely by way of non-limiting example and in which:

- Figure 1 is a schematic view of a detail of an engine block made of aluminium for internal-combustion engines, according to the known art;
- Figures 2, 3, 4 illustrate three subsequent steps of the process according to the invention, with reference to details of the surface of a cylinder;
- Figure 5 is a view of the same detail of the engine according to the invention, at the end of the process according to the invention;
- Figure 6 is a view according to the line VI of Figure 5; and
- Figure 7 illustrates a variant of Figure 5.

[0016] In Figure 1, the reference number 1 designates the body made of aluminium of an engine block for an internal-combustion engine, having a plurality of cylinders 2, one of which is visible in Figure 1. The cylinder 2 is defined by a cylindrical cavity 3, the axis of which is designated by 4.

[0017] According to the known art illustrated in Figure 1, mounted within the cavity 3 of the engine block 1 is a liner 5 constituted by a sleeve made of cast iron or steel that functions as thermal barrier, thanks to its melting point, which is higher than the melting point of aluminium constituting the engine block 1. Once again according to the known art, the internal surface of the liner 5 is provided with grooves 6, schematically illustrated in Figure 1, having the purpose of favouring the lubrication of the surface of the cylinder within which the respective piston of the engine is guided.

[0018] According to the invention, the liner 5 made of cast iron or steel is replaced with a layer of porous alumina obtained by means of anodization of the aluminium in a nanometric layer of thickness facing the cavity of the cylinder 2. For this purpose, starting from the condition illustrated in Figure 2, which shows a portion of the wall of the engine block 1 defining the cavity, a process of anodization is carried out, setting the body made of aluminium in an electrolytic cell containing an electrolyte and connecting the body made of aluminium to the anode of the cell, so as to grow on the surface 3 made of aluminium of the wall of the cavity 2 a nanometric layer of porous alumina, designated as a whole by the reference number 7 in Figure 3. The nanometric layer 7 has nanometric pores 8 facing the cavity 2 and closed each at the bottom by a barrier layer 9 of alumina. When the layer 7 has reached the desired thickness, the application of voltage to the electrolytic cell is interrupted and that the acid bath present in the cell is allowed to consume the barrier layer 9 partially so as to undergo thinning in order to obtain the configuration illustrated in Figure 4. In a subsequent step, the barrier layers 9 thus thinned out are connected to the cathode to carry out an electrodeposition within the nanopores 8 of a filling material 10 (Figure 5) made, for example, of a metal material with a base of iron, or DLC ("diamond like carbon"), or else simple carbon in the form of graphite, silicon carbide, or the like. Since the thinning of the barrier layer 9 illustrated in Figure 4 can differ from pore to pore, also the filling by means of the material 10 illustrated in Figure 5 can differ from pore to pore. In any case, the inclusion of the material 10 enables summing to the characteristics of thermal barrier proper to the layer of porous alumina 7 also characteristics of high resistance to wear, as well as high characteristics from the standpoint of the capacity for carrying a lubricant so as to obtain a layer capable of replacing advantageously the traditional cylinder liner made of cast iron or of steel.

[0019] The high adhesion between APA (anodic porous alumina) and the underlying aluminium, is a direct consequence of its process of fabrication. In fact, during anodization, the aluminium is oxidized following upon the diffusion of anions through the layer of alumina that has previously formed. The process of anodization converts aluminium into alumina atom by atom, giving form to the interface of characteristic complex shape (see Figures 3 and 4) of the process.

[0020] The electrodeposition of said filling material 10 is obtained by dipping the internal surface of the body made of aluminium on which the porous alumina has been formed in an electrolyte containing the material that it is desired to deposit and connecting the body made of aluminium itself to a pole of a power supply, in particular to the negative pole in the case where the chemical element to be deposited is present in solution in the form of positively charged ions, and by dipping the second pole of the power supply, of sign opposite to the previous one, in the electrolytic solution, the supply voltage to the electrolytic cell being adjusted according to of the material that it is desired to deposit.

[0021] Alternatively, the deposition of the filling material 10 is obtained by silk-screen printing.

[0022] Figure 5 shows the case where the deposition of the filling material is controlled so as not to cause the material 10 to overflow from the pores 8. Figure 7 shows a variant in which the filling material 10 is deposited so as to allow it to come out of said pores 8 until a continuous overlayer is formed.

[0023] Of course, without prejudice to the principle of the invention, the details of construction and the embodiments may vary widely with respect to what is described and illustrated herein, purely by way of example, without thereby departing from the scope of the present invention.

Claims

1. An internal-combustion engine, comprising:

- an engine block made of aluminium (1); and

- at least one cylinder (2) and a piston mounted slidably in the cylinder, in which the cylinder is defined by a cavity formed in the body made of aluminium (1) of the engine block, the surface (3) of which is covered with a material (7) having a melting point higher than the melting point of aluminium,

said internal-combustion engine being **characterized in that** the surface of the cavity (3) defining each cylinder (2) and/or at least part of the surface of the piston is defined by a layer (7) of porous alumina, having a thickness comprised between a few manometres and a few millimetres, obtained by means of anodization of the aluminium constituting the body (1) of the engine block, said layer (7) of porous alumina having pores (8) giving out into said cavity (2) that contain a filling material (10), applied for electrodeposition or silk-screen printing, so as to give rise to a composite layer (7) that functions as heat barrier, as low-friction layer and at the same time presents resistance to wear, as well as capacity for carrying a lubricant.

2. The engine according to Claim 1, **characterized in that** said filling material is a metal material with a base of iron or else DLC (diamond-like carbon), or simple carbon in the form of graphite, or silicon carbide.

3. The process for obtaining a surface resistant to heat and wear in a cylinder and/or on a piston of an internal-combustion engine, **characterized in that** a body made of aluminium (1) is provided, which defines said cylinder or said piston, and **in that** the surface (3) of said body undergoes a process of anodization so as to produce a layer of porous alumina, having a thickness comprised between a few manometres and a few millimetres, which has pores (8) giving out onto said surface (3), and **in that** filling material (10) is deposited within said pores (8), by means of electrodeposition or silk-screen printing, so as to give rise to a layer (7) functioning as heat barrier and at the same time having characteristics of resistance to wear and capacity for carrying lubricant.

4. The process according to Claim 3, **characterized in that** the filling material (10) is deposited so as not to allow it to come out of said pores (8).

5. The process according to Claim 3, **characterized in that** the filling material (10) is deposited so as to allow it to come out of said pores (8), until a continuous overlayer is formed.

6. The process according to Claim 3, **characterized in that** said filling material (10) is a metal material with a base of iron, or else DLC (diamond-like carbon), or simple carbon in the form of graphite, or silicon carbide.

7. The process according to Claim 3, **characterized in that**, after execution of the operation of anodization that enables the layer (7) of porous alumina to be obtained, a thinning of the barrier layer (9) that closes the pores (8) of the alumina (7) at the bottom is obtained by exploiting the chemical erosion due to the acid bath of the electrolytic cell used for the operation of anodization.

8. The process according to Claim 3, **characterized in that** the electrodeposition of said filling material (10) is obtained by dipping the internal surface of the body made of aluminium, on which the porous alumina has been formed in an electrolyte containing the material that it is desired to deposit, and by connecting the body made of aluminium itself to a pole of a power supply, in particular to the negative pole in the case where the chemical element to be deposited is present in solution in the form of positively charged ion, and by dipping the second pole of the power supply, of sign opposite to the previous one, in the electrolytic solution, the supply voltage to the electrolytic cell being adjusted according to of the material that it is desired to deposit.

FIG. 1 Prior Art

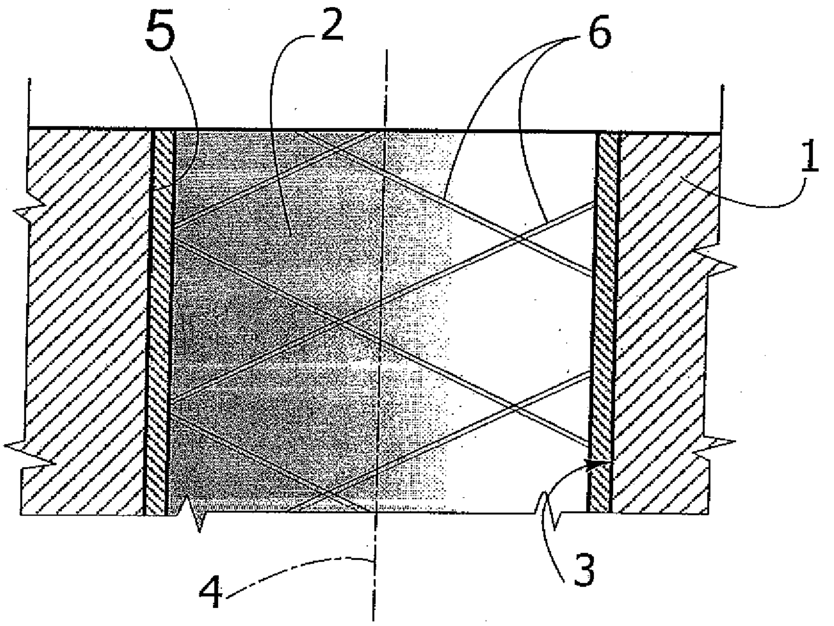


FIG. 2

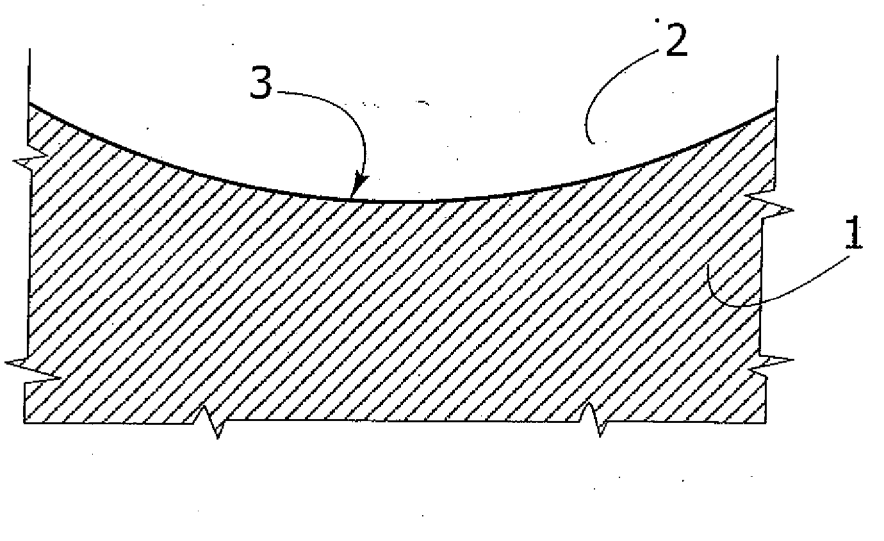


FIG. 3

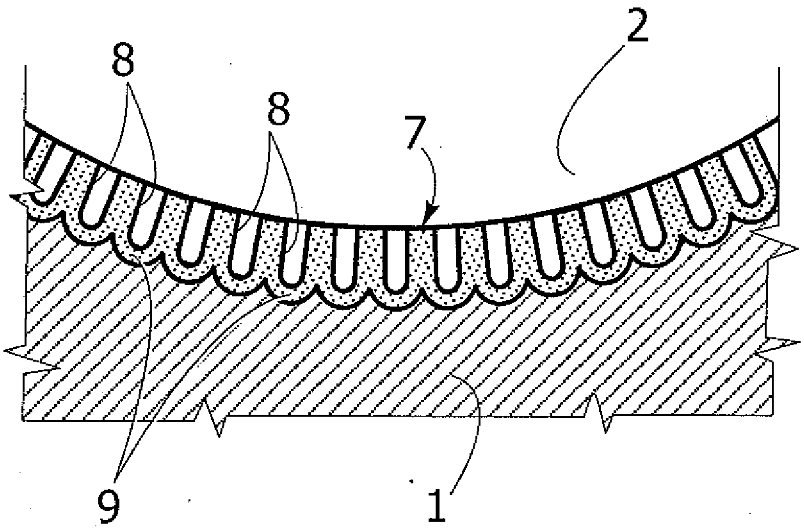


FIG. 4

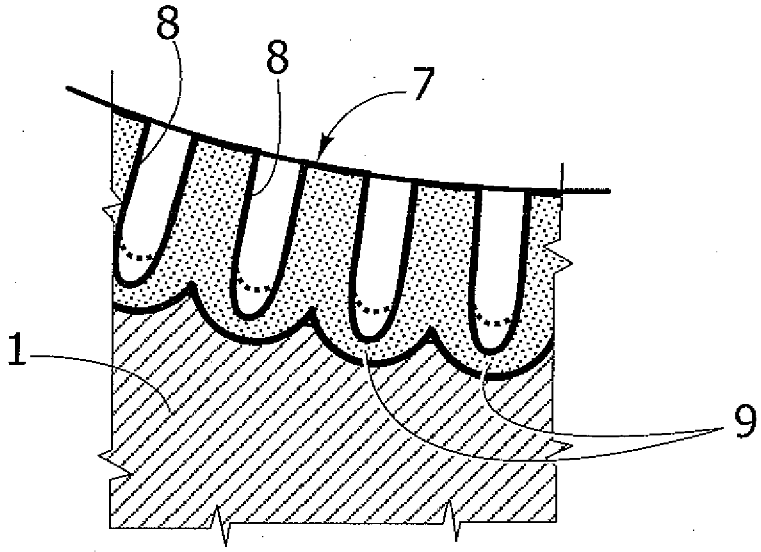


FIG. 5

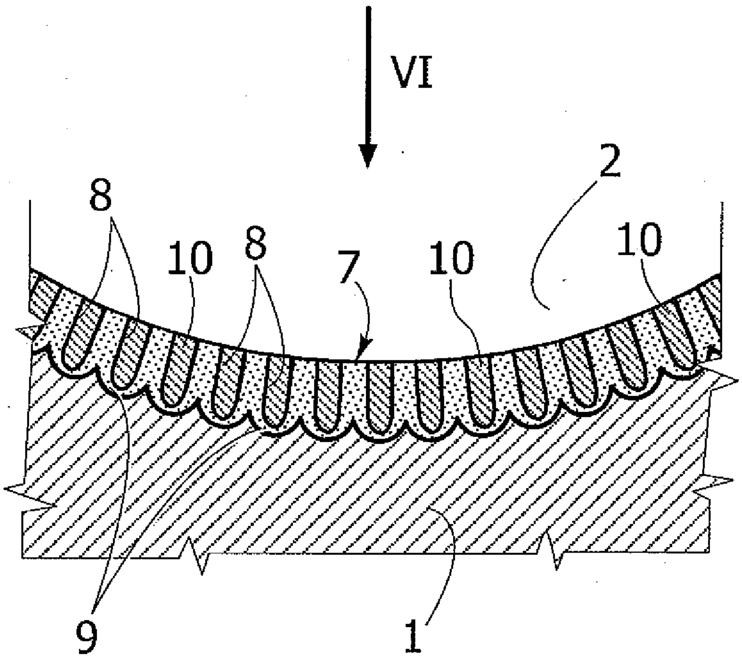


FIG. 6

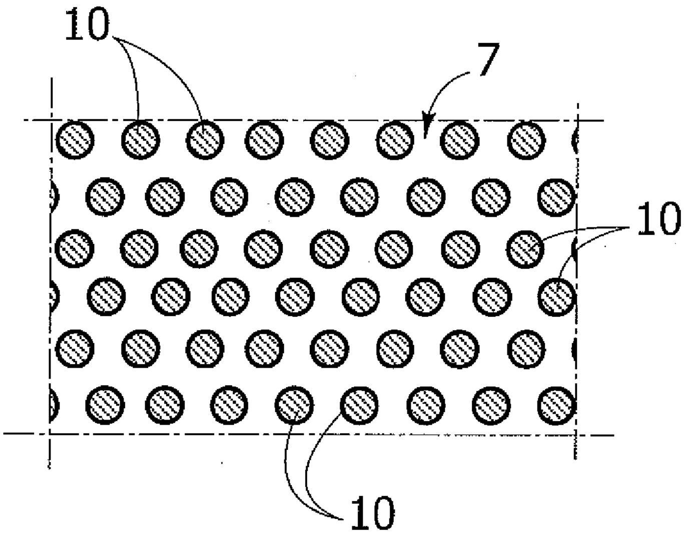
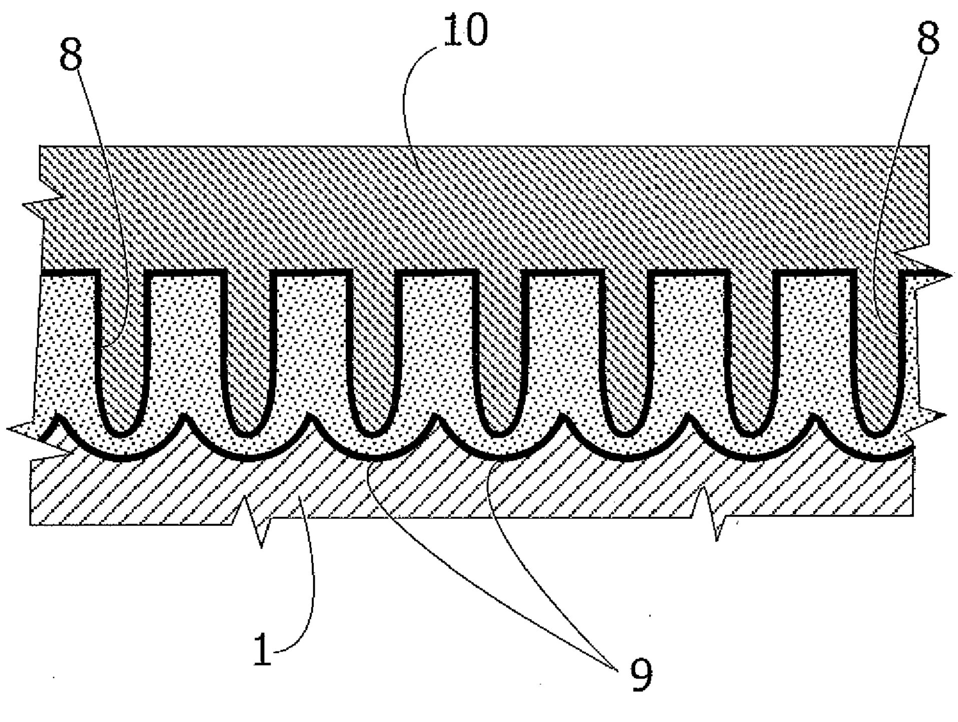


FIG. 7



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EUROPEAN SEARCH REPORT

Application Number
EP 07 42 5379

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	28 September 2007	Yates, John

CATEGORY OF CITED DOCUMENTS

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