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(54) Title: MEDICAL DEVICE AND SMOOTH COATING THEREFOR

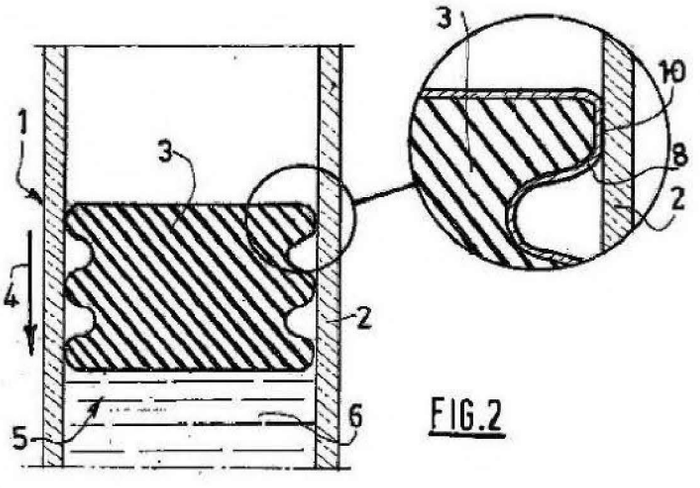
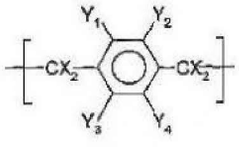


FIG.2

(57) Abstract: The invention relates to a medical device (1) comprising at least one first part (2; 3) coated with a coating (8) having a composition comprising at least one polymer material comprising polymer chains having the following repeat unit Formula (I): in which X represents a halogen, for example F, or a hydrogen, and in which Y_1, Y_2, Y_3, Y_4 each independently represent a halogen, for example Cl, or a hydrogen, characterized in that the outer surface of said coating (8) has a mean roughness Ra of less than 2.5 µm. The invention also relates to a part (2; 3) for a medical device (1) intended to cooperate with another part (3; 2) and provided with such a coating (8).



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Medical device and smooth coating therefor

The present invention relates in general to a medical device, for example a syringe, comprising at least one smooth coated part, , for example a container and/or a piston, said parts being able to move one relative to the other, for example translationally and/or rotationally, when the medical device is operated.

In this application, the term distal means the part furthest from the user's hand, and the term proximal means the part closest to the user's hand. Likewise, in this application, the term "distal direction" means the direction of administration, i.e., towards the patient, and the term "proximal direction" means direction opposite to the direction of administration, i.e., away from the patient.

Furthermore, the container is intended to accommodate a medical product in the liquid, gaseous, fluid, pasty or lyophilized phase, which may have a variable viscosity and is therefore able to flow, particularly because of the pressure exerted as a result of the movement of the piston relative to the container. The piston is preferably made at least partially from a viscoelastic material so as to ensure tightness in the region of contact between the container and the piston. At the same time, the volume of the medical product contained in the medical device varies, for example decreases, according to the relative movement between the two parts of the medical device.

The present invention also relates to a part for a medical device, this part being intended to cooperate with a complementary part by moving relative to said complementary part when the medical device is operated, said part being provided with a coating.

In order to improve the slip between said parts, it has been proposed for the entirety of the developed surface of one of the parts to be coated with a coating consisting of at least one polymer material, whether this is a true polymer or a copolymer, comprising polymer chains including repeats of one or more chemical units:

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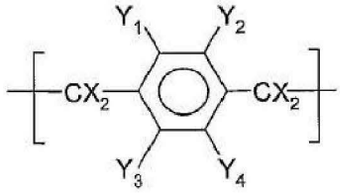


in which X represents a halogen, for example F, or a hydrogen,

and in which Y_1, Y_2, Y_3, Y_4 each independently represent a halogen, for example Cl, or a hydrogen.

For example, the polymer material is chosen from the group consisting of poly(p-xylylene) polymers, which may or may not be substituted, and in particular, poly(p-xylylene), poly(p-meta-chloroxylylene), poly(p-ortho-chloro/meta-chloroxylylene) and poly(p-difluoroxylylene). The latter four polymer materials are manufactured and sold by UNION CARBIDE CORPORATION, or by SPECIALTY COATING SYSTEMS, under the names Parylene N, Parylene C, Parylene D and Parylene AF_4, respectively.

For information regarding the synthesis of these particular polymer materials, particularly using chemical vapour polymerization (CVP), on their various properties and on their main uses or applications, reference may usefully be made to the following documents, the respective contents of which are incorporated as required into this description: US 3,288,728, US 3,342,754, US 3,379,803, US 3,472,795, US 4,225,647, US 3,300,332 and US 6,270,872.

These polymer materials have various properties, for example imperviousness to gases, for example oxygen, and to dry-lubricating liquids, for example water, which make them particularly attractive for use in numerous biomedical applications, particularly for certain medical devices.

Unlike a conventional polymer material, a polymer material of the poly(p-xylylene) type is not employed by injection, dissolving or suspending in a solvent, but is used by depositing it onto the part by a direct dry vacuum deposition process using the following protocol:

(a) use is made of a polymerization intermediate of the polymer material, in this instance of a cyclic dimer form of the aforementioned chemical unit, in solid and divided form,

(b) the dimer is vaporized under vacuum (1 mm of mercury for example) and at approximately 150°C for example,

(c) the vaporized dimer is then pyrolized, still under vacuum but at a higher temperature, for example at 650°C, in order to obtain the reactive monomer form corresponding to the aforementioned dimer and to the aforementioned chemical unit, and

(d) the reactive monomer is deposited directly on the entire accessible developed surface of the part, both internal and external, and polymerized at ambient temperature under a low vacuum, in a method akin to the vacuum deposition of a thin metal layer, so as to obtain a continuous coating of (substituted or unsubstituted) poly(p-xylylene) of relatively uniform thickness, completely (with no discontinuity) covering the part of the medical device.

Various equipment and corresponding operating procedures are nowadays available on the market for the purposes of obtaining a poly(p-xylylene) coating and, by way of example, reference may be made to the equipment sold by COMELEC SA, CH-2301 La Chaux de Fonds, Switzerland, or alternatively to the PDS 2010 Labcoter 2 equipment sold by SPECIALTY COATING SYSTEMS.

The coating thus obtained, made of relatively crystalline polymer, adheres to the part directly or indirectly. Because of its slip characteristics, the coating facilitates the relative movement between the two parts of the medical device. In addition, the elastic behaviour of the coating allows it in a resilient manner to accommodate the deformations and stresses imposed on the part provided with it, for example the piston, as it slides in the container. Thus, tightness in the region of contact between the piston and the container can be guaranteed to be maintained.

Adhesion between the coating and the part may be direct, particularly by means of chemical bonds formed at the time of deposition and polymerization of the reactive monomer, between said part and the polymer material, or indirect, by way of a tie layer or primer layer applied beforehand to the surface that is to be coated, if appropriate after that surface has been cleaned or prepared.

The medical devices as previously defined and discussed therefore require substantial improvements, in respect of the following requirements, which are sometimes contradictory, as far as the coating is concerned.

The viscoelastic material of which the piston of a medical device such as a syringe may be made is generally an elastomeric material which alters, in particular degrades chemically over time. This possible degradation is sometimes initiated by the processes used to sterilize the medical devices containing them, for example bringing them into contact with ionizing radiation. Such degradation alters the surface properties of the elastomeric material and may cause inadequate interactions with the medical product potentially present in the medical device. Such degradation may also affect other surface properties of the elastomeric material, for example the adhesion or friction with respect to one of the other parts of the medical device. Over time, that is to say as soon as the medical device has been filled with the medical product, and in particular when it is used or operated, it is therefore necessary for a coating to effectively isolate the region of contact between on one hand a first part of the device made of such a viscoelastic material and on the other hand the medical product or a second part of the device, intended to cooperate with said first part, so that the surface characteristics, including the coefficient of friction, of the region of contact between the two parts of the medical device, can be maintained over time, even after prolonged storage, regardless from the fact that the properties of said viscoelastic material may have been adversely affected over time.

Additionally, it is necessary for such a coating to show surface characteristics enabling gliding between the two parts intended to cooperate together and also tightness between these two parts at the contact region.

It is therefore an object of the present invention to provide a roughness of coating for at least one part of a medical device, said roughness allowing on one hand the medical product potentially present in the medical device to be preserved and on the other hand to reconcile the gliding function between two complementary parts with the maintaining of tightness in the contact region of said parts, static tightness over time and dynamic tightness when using the medical device, whether the coating be provided on a first part such as a piston, on a second part such as a container or on an intermediate part located between said first and second parts.

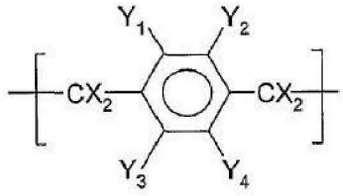
According to the present invention, it has to these ends been found that the mean roughness Ra, that is to say the surface finish, of the coating of a first coated part in the contact region needs to be equal or less than 2.5 μm,

preferably less than 2 μm and more preferably less than 1.5 μm, for example in the order of 1.0 μm.

Such a roughness is important in giving the coating the desired performance and function, independently of the thickness of the coating.

In the present application, the roughness Ra is measured according the following method : roughness measurements done in triplicate are performed by using a profiler Wyko NT 1100 (Veeco Instruments Inc. Tucson USA) on scans 370 μm x 240 μm with a VSI mode (Vertical Scanning Interferometry). The calibration of the apparatus is performed following the procedure WI 7.6-20 using measuring instruments traceable to the National Institute of Standards and Technology (NIST).

A first aspect of the present invention is a medical device comprising at least one first part coated with a coating having a composition comprising at least one polymer material comprising polymer chains having the following repeat unit:



in which X represents a halogen, for example F, or a hydrogen,

and in which Y_1, Y_2, Y_3, Y_4 each independently represent a halogen, for example Cl, or a hydrogen,

characterized in that the outer surface of said coating has a mean roughness Ra of less than 2.5 μm.

The medical device of the invention with at least one part coated with a coating having such a roughness allows the medical product intended to be present in the medical device to be preserved.

In embodiments of the invention, said mean roughness Ra is less than 2 μm, preferably less than 1.5 μm and, for example, of the order of 1.0 μm.

In embodiments of the invention, said one first part is chosen among a piston, the internal surface of a container intended to receive a medical

product, or an intermediate part located between a piston and the internal surface of a container intended to receive a medical product.

In embodiments of the invention, the medical device further comprises at least one second part being intended to move relative to said first part in a sliding relationship when said medical device is operated, said first and second parts defining between them a contact region.

A roughness Ra equal or less than 2.5 µm for the outer surface of the coating of the medical device of the invention allows a smooth gliding of a first coated part, like a piston, relative to a second part, like a container.

The medical device of the invention allows to have decreased activation, sustainable and final forces for moving a first part relative to a second part, for example for moving a piston within the container in which it is lodged, without having to add a lubricant and while preserving the tightness at the contact region between said two parts. For example, in a medical device such as a syringe, the piston must be able to be moved relative to the container or syringe body, through a gliding movement, while at the same time ensuring the tightness with said container, so that all of the product to be administered escapes only via the distal end of the container and does not leak out of said container via the piston at the proximal end of the container. The medical device of the invention, thanks to a specific coating having a specific roughness range at the contact region between the piston and the container, allows the successful completion of these two relatively incompatible requirements.

Moreover, with the medical device of the invention, it is possible to decrease the total amount of lubricant, for example silicone oil, that is necessary in such a medical device.

In consequence, the medical device of the invention allows to limit the risk of interaction between a lubricant, for example silicone oil, and the therapeutic molecules potentially stored in the container of the medical device prior to delivery to a patient.

In embodiments of the invention, one of said first and second parts consists of a viscoelastic material designed to encourage tightness at said contact region.

In embodiments of the invention, said first part is a piston and said second part is the internal surface of a container intended to receive a medical product or an intermediate part located between said piston and the internal

surface of a container intended to receive a medical product, said piston being movable within said container when said medical device is operated.

In embodiments of the invention, said first part is an intermediate part located between a piston and the internal surface of a container intended to receive a medical product, and said second part is a piston or the internal surface of a container intended to receive a medical product, said piston being movable within said container when said medical device is operated.

In embodiments of the invention, said first part is the internal surface of a container intended to receive a medical product, and said second part is a piston or an intermediate part located between a piston and the internal surface of a container intended to receive a medical product, said piston being movable within said container when said medical device is operated.

In embodiments of the invention, said second part is further coated with said coating at least in the contact region.

In embodiments of the invention, said coating is continuous and elastic.

In embodiments of the invention, said polymer material is chosen from the group consisting of poly(p-xylylene), poly(p-meta-chloroxylylene), poly(p-ortho-chloro/meta-chloroxylylene) and poly(p-difluoroxylylene).

For example, said polymer material consists of poly(p-meta-chloroxylylene).

In embodiments of the invention, said coating has a mean thickness ranging from 2 to 10 μm, preferably, ranging from 3 to 10 μm, and more preferably ranging from 3 to 5 μm.

Such a thickness has the advantage of ensuring that, regardless of the profile, shape or surface characteristics of the coated part, at the end of the process of depositing/polymerizing the polymer material, the coating covers the entirety of the part over the desired region, namely at least the region corresponding to the contact region, with no discontinuity, and does so durably.

In embodiments of the invention, said contact region further includes a lubricant other than said coating.

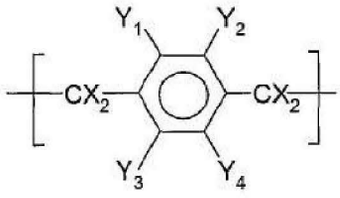
In embodiments of the invention, said coating provided on said container and/or on said piston and/or on said intermediate part is at least partially covered with said lubricant.

In embodiments of the invention, said piston or said container or said intermediate part, not provided with said coating, is at least partially covered with said lubricant.

In embodiments of the invention, said lubricant contains silicone.

In embodiments of the invention, the medical device includes an injection device.

A further aspect of the invention is a part for a medical device, the part being intended to cooperate in relative movement with respect to a complementary part in order to operate said medical device, said part comprising a coating consisting of at least one polymer material comprising polymer chains consisting of the following repeat unit:



in which X represents a halogen, for example F, or a hydrogen,
and in which Y_1, Y_2, Y_3, Y_4 each independently represent a halogen, for example Cl, or a hydrogen,
said coating having a outer surface intended to move relative to said complementary part,
characterized in that said outer surface of said coating has a mean roughness Ra of less than 2.5 μm.

Preferably, said outer surface has a mean roughness Ra of less than 2 μm, preferably less than 1.5 μm and, for example, of the order of 1.0 μm.

Said coating may be continuous and elastic.

Preferably, said polymer material is chosen from the group consisting of poly(p-xylylene), poly(p-meta-chloroxylylene), poly(p-ortho-chloro/meta-chloroxylylene), and poly(p-difluoroxylylene). Preferably, said polymer material consists of poly(p-meta-chloroxylene).

In an embodiment of the invention, the mean thickness of said coating ranges from 2 to 10 μm, preferably from 3 to 10 μm, and more preferably from 3 to 5 μm.

In an embodiment of the invention, said part comprises at least one of

- a container intended to accommodate a medical product, and/or
- a piston intended to be moved with respect to said container, and/or
- an intermediate part located between said container and said piston.

The present invention is now described with reference to the attached drawings in which:

- Figure 1 depicts, schematically and in cross section, a portion of a medical device considered by the present invention and according to a first embodiment thereof,
- Figure 2 depicts, again schematically and in cross section, a portion of a medical device according to a second embodiment of the invention.

With reference to Figures 1 and 2, a medical device 1 considered by the present invention, for example a syringe, comprises at least one first coated part. As will appear from the description that follows, in figures 1 and 2, the first coated part is the piston of a syringe.

In an embodiment of the invention not shown, the medical device is a vial, intended to receive a medical product, and that may be closed by a plug. In such a case, the first coated part may be either the plug or the internal surface of the vial.

With reference to figures 1 and 2, the medical device 1 comprises a first and a second parts 2 and 3, one being complementary to the other, for example a piston 3 housed in a container 2, the piston 3 and the internal surface of the container 2 being in contact with one another via a contact region 10. The piston 3 and the container 2 are able to move one with respect to the other in a predetermined gliding movement 4, for example translationally and/or rotationally. The container 2 is intended to accommodate a medical product 6 in the liquid, gaseous or fluid phase, the volume of said product 6 varying according to the movement of the piston 3 with respect to the container 2. In particular, for administering the product 6, the piston 3 is caused to move distally along arrow 4 of figure 1 in order to push the product 6 out of the container 2. The piston 3 is designed to deform in order to tighten the contact region 10. For example on figure 2, at least part of the developed surface of the piston 3, which corresponds to the contact region 10, is provided with a coating 8 which is continuous, intrinsically elastic and firmly secured to the piston 3.

According to Figure 1, in a first embodiment, the piston 3 comprises an intermediate part, under the form of an independent seal 9 housed in a groove 11 made in the piston 3, which is made of viscoelastic material, for example of elastomer, encouraging deformation of the piston 3 and therefore tightening the contact region 10. The seal 9 is also made out of a viscoelastic material, for example an elastomer, in order to ensure tightness at the contact region 10. With reference to Figure 1, the seal 9 is provided with a coating 8.

According to Figure 2, in a second embodiment, the piston 3 is made in its entirety of a viscoelastic material, for example an elastomer.

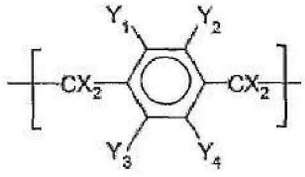
Irrespective of the embodiment considered, the contact region 10 between the internal surface of the container 2 and the piston 3 also determines a region of gliding contact between the piston 3 and the container 2.

According to the invention, and with reference to Figure 2, the internal surface of the container 2 and the piston 3 determine a contact region 10 which is provided with a coating 8. On the example shown on this figure, the coating 8 is provided on the piston 3. According to another embodiment which has not been depicted, the coating 8 is provided on the internal surface on the container 2. According to other alternative forms of embodiment which have not been depicted, the coating 8 may be formed of two individual coatings, one provided on the internal surface of the container 2 and one on the piston 3. According to another embodiment which has not been depicted, the coating 8 is provided on one or on the two faces of an intermediate part, such as the seal 9 shown on figure 1, located between the piston 3 and the container 2.

The coating 8 of the medical device 1 of the invention encourages the gliding of the piston 3 relative to the container 2 at the time of administration of the product 6. Moreover, the coating 8 also ensures static and dynamic tightness at the contact region 10 of the two complementary parts, namely the piston 3 and the container 2. In particular, before use of the medical device 1, for example during storage, the coating 8 ensures the static tightness between the piston 3 and the container 2 by preventing the leakage of the product 6 at the contact region 10 between the piston 3 and the internal surface of the container 2. When the medical device 1 is in use, the coating 8 ensures the dynamic tightness between the piston 3 and the internal surface of the container 2 by preventing the leakage of the product 6 at the contact region 10

between the piston 3 and the container 2 while the piston 3 is moving relative to the container 2.

According to the invention, the coating 8 consists of at least one polymer material comprising polymer chains consisting of the following repeat unit:



in which X represents a halogen, for example F, or a hydrogen, and in which Y_1, Y_2, Y_3 and Y_4 each independently represent a halogen, for example Cl, or a hydrogen. This coating 8 according to the invention is obtained by dry vacuum deposition/polymerization at ambient temperature, as described above.

The outer surface of the coating 8 has a mean roughness of less than 2.5 µm, preferably of less than 2 µm, more preferably of less than 1.5 µm, for example of the order of 1.0 µm.

During the CVP deposition/polymerization process, it is possible to control the surface finish, namely the contact or outer surface, of the coating 8. For example, when coating pistons by the CVP process, the person skilled in the art knows that it is possible to control the surface finish, namely the roughness obtained, by intermingling the pistons 3 with one another during the CVP process, on the one hand, and by intermingling them with inserted elements (inert parts) mixed in with the pistons 3 while they are being intermingled.

In the present application, the roughness Ra is measured according the following method : roughness measurements done in triplicate are performed by using a profiler Wyko NT 1100 (Veeco Instruments Inc. Tucson USA) on scans 370 µm x 240 µm with a VSI mode (Vertical Scanning Interferometry). The calibration of the apparatus is performed following the procedure WI 7.6-20 using measuring instruments traceable to the National Institute of Standards and Technology (NIST).

A roughness of less than 2.5 µm, measured as described hereinabove, for the outer surface of a coating 8 of a medical device 1 of the

invention allows a smooth gliding of a such coated part, like a piston 3, relative to a complementary part, like a container 2.

The coating 8 according to the invention has for example a thickness ranging from 2 to 10 μm. Hence, when the contact region 10 is provided with two individual coatings 8, one provided on the internal surface of the container 2 and one on the piston 3, the thickness of the coating 8 of the medical device will therefore be the sum of the thicknesses of each individual coating 8.

Starting with the appropriate dimer, and using equipment as identified hereinabove, the person skilled in the art will know how to deposit and control a predetermined thickness of the polymer material adopted, particularly by varying the time for which the part that is to be coated is exposed to the reactive monomer form of the poly(p-xylylene) chosen. Furthermore, a person skilled in the art knows that the rate of deposition/ polymerization is directly proportional to the square of the reactive monomer concentration, and inversely proportional to the absolute temperature of the part exposed to the monomer, this information allowing him to modify and control the thickness of the coating deposited on the part.

The present invention considers various substrates or viscoelastic materials to be appropriate to the deposition of a coating 8 as previously defined, these being various natural or synthetic elastomers: silicones, nitrile-based elastomers, natural or synthetic rubber, fluorocarbon elastomers, polyurethanes. As a preference, the invention will devote itself to bromobutyl and chlorobutyl synthetic elastomers.

By way of example, the mean thickness of the coating 8 ranges from 2 to 10 μm and preferably from 3 to 10 μm and, more preferably still, from 3 to 5 μm.

Such a specific thickness range allows a smooth gliding of two complementary parts relative to each other while ensuring tightness at the contact region between said two complementary parts.

As stated above, the polymer material is preferably chosen from the group consisting of poly(p-xylylene), poly(p-meta-chloroxylylene), poly(p-ortho-chloro/meta-chloroxylylene) and poly(p-difluoroxylylene). As a preference, the polymer material consists of poly(p-meta-chloroxylylene).

By implementing the invention, it is possible, to a significant extent, to limit or even eliminate the amount of lubricant other than the aforementioned

polymer material, for example silicone oil, customarily used at the contact region 10 of sliding contact between the piston 3 and the container 2.

The present invention will now be illustrated with the following examples.

Example 1 :

The following test protocol is performed on a medical device 1 of the syringe type, according to the second embodiment depicted in Figure 2 of the present application.

The container 2 is a glass syringe body accommodating a piston 3 able to move translationally along arrow 4 of figure 2 inside the container 2. The piston 3 is made of a viscoelastic material such as bromobutyl rubber commercially available at West Company, or chlorobutyl rubber commercially available at West Company.

Various medical devices, or container-piston systems, were tested: some with non coated pistons, others with coated pistons. The coated pistons 3 were coated with a coating 8 as previously defined, in which the polymer material is poly(p-meta-chloroxylylene) (Parylene C). Regarding the coated pistons, several surface finishes or roughnesses of the outer surface of coating 8 were tested, as summarized in Table 1 below.

Table 1 : configurations of pistons A, B1 and C

Piston reference	Viscoelastic substrate	Coating	Coating thickness	Surface finish
A (comparative)	Bromobutyl rubber	No	—	Smooth Ra = 0.7 µm Rt = 11.4 µm
B1 (invention)	Bromobutyl rubber	Yes	3 µm	Smooth Ra = 0.9 µm Rt =12.0 µm
B2 (comparative)	Bromobutyl rubber	Yes	3 µm	Rough Ra = 3.1 µm Rt = 24.0 µm
C (comparative)	Chlorobutyl rubber	No	—	Smooth Ra = 0.7 µm Rt = 11.0 µm

The surface finishes of the coatings of the coated pistons were examined by enlarging them using a scanning electron microscope, observed on a scale of 10 to 20 µm.

The roughness measurements were made using a profiler Wyko NT 1100 (Veeco Instruments Inc. Tucson USA) over an analysis area measuring 370 µm x 240 µm with a VSI mode. Ra represents the mean roughness (the arithmetic mean of the various values of a roughness profile) and is expressed in µm. Rt represents the maximum peak-to valley height in a roughness profile and is expressed in µm.

Tests (Activation Gliding Force tests) were performed to determine the necessary forces for moving each piston with respect to the container in which it is housed. These tests were performed using a LLOYD-CB190 tensile testing machine dynamometer using NEXYGEN operating software, according to two test protocols outlined briefly below.

Activation Gliding Force (AGF) tests were applied on containers filled with 1 mL of demineralised water and each plugged with one piston to be tested (coated or uncoated). Each container-piston system was tested 32 times

in order to ensure the reproducibility and to validate the results. To prepare the 32 syringes for a system, and particularly to insert the piston in the container, a Gröninger machine was used.

These gliding tests made it possible to establish the value of various friction forces referenced B, S and F, respectively:

- the friction force B is the force required, under static conditions, to break the contact at the contact region 10 between the piston 3 and the container 2,

- the friction force S is the force required, under dynamic conditions, for moving the piston 3 in the container 2. The friction force S is measured half way of the piston travel. In order to measure the friction force S, the container 2 was used filled with water,

- and the friction force F is the force required, again in dynamic mode, to move the piston 3 when it reaches the end of its travel in the container 2. Just as when measuring the friction force S, the friction force F is measured with a container 2 empty of medical product 6 but initially filled with water.

In order to study the evolution of the interface, namely the contact region, between the piston and the container, samples undergo an accelerated aging in a climatic room. The conditions of the Heraeus climatic room were a temperature of 40°C and a humidity rate of 75%. The systems under assessment were placed in the climatic room during 1, 3 and 6 months.

The results obtained were as follows:

1. Piston surface finish

Surface observations were performed on pistons A, B1, B2 and C prior to any functional test.

It was observed that piston A, which had no coating according to the invention, had a relatively rough surface finish with peaks and troughs. The coating 8 of the invention on piston B1 had relatively smooth and uniform surface finishes, and the coating on the comparative piston B2 had a relatively rough surface finish with various irregularities.

During the CVP deposition/polymerization process, it was possible to control the surface finish of the coating obtained by intermingling the pistons 3

with one another during the CVP process, on the one hand, and by intermingling them with inserted elements (inert parts) mixed in with the pistons 3 while they were being intermingled.

2. Gliding test

Pistons B1 (according to the invention) and B2 (comparative) with their coatings were fitted and assembled in a glass container 2, such as a syringe body, coated on its internal surface with a layer of silicone at a rate of 4 μg per $cm^2 \pm 1$. No lubricant of the silicone type was added to the pistons B1 and B2. The syringes 2 thus assembled were placed in an ageing chamber for one month at 40°C with a relative humidity RH of 75%.

The friction forces B, S and F were measured by the protocol described before, using the aforementioned equipment, at a rate of travel of 380 mm/min. Each measurement of the friction force B, S and F was repeated 30 times. The results obtained are collected in Table 2 below. The bracketed values correspond to the standard deviation.

Table 2 : Activation Gliding Forces, Pistons B1 and B2, 1 month ageing

Silicone/internal surface of syringe		4 μg/cm²	4 μg/cm²	4 μg/cm²
Force (N)		B	S	F
Piston	B1 (invention)	3.0 (0.4)	3.4 (0.5)	2.8 (0.6)
	B2 (comparative)	2.6 (0.3)	4.3 (0.8)	4.3 (0.8)

The results obtained show that, for the same thickness of coating 8, namely 3 μm, the friction forces S and F are lower for piston B1 for which the coating has a "smooth" surface finish and a relatively low roughness value (Ra = 0.9 μm, see Table 1) than they are for comparative piston B2, the surface finish of the coating 8 of which is "rough" and has a roughness value higher (Ra = 3.1 μm, see Table 1) than that of the piston B1.

In conclusion, it is possible to affirm that, for a given thickness, a coating 8 with a relatively smooth surface finish according to the invention is

preferable in order to limit the friction and optimize the sliding of the piston 3 in the container 2.

Example 2

The pistons A, B1, B2 and C of example 1 were coated by spraying respectively various quantities, respectively 5 µg/cm^2, 15 µg/cm^2 and 50 µg/cm^2, of a silicone-based lubricant (with a viscosity of 1000 cst) and were assembled in containers 2 themselves coated on their internal surface with a 50 µg/cm^2 coating of silicone. The silicone amount was measured prior to any AGF test. This measurement was done in order to quantify the silicone amount in the system, i.e. silicone on the piston and silicone on the internal surface of the container and thus, define the low limit for the silicone amount acceptable for functional testing (AGF test).

- The same experimental protocol as that defined hereinabove was used, with an ageing period of one month in an ageing chamber at 40°C with a relative humidity RH of 75% for pistons A, B1 and C.

The results are collected in the following table 4.

Table 4 : Activation Gliding Forces, pistons A, B1, C, 1 month ageing

Silicone/internal surface of container		50 µg/cm²			50 µg/cm²			50 µg/cm²		
Silicone/piston		5 µg/cm²			15 µg/cm²			50 µg/cm²		
Force (N)		B	S	F	B	S	F	B	S	F
Piston	$A_{T=0}$	6.1 (0.6)	1.1 (0.5)	7.0 (3.1)	6.0 (0.8)	0.9 (0.3)	6.9 (3.0)	6.0 (0.7)	0.8 (0.2)	6.5 (2.7)
	$A_{T=1}$	9.1 (0.6)	2.0 (1.0)	5.0 (2.1)	9.3 (2.1)	2.8 (1.0)	4.5 (1.3)	9.0 (0.5)	2.2 (1.0)	4.1 (1.6)
	$B1_{T=0}$	2.1 (0.1)	1.2 (0.3)	2.5 (1.1)	2.1 (0.1)	1.2 (0.3)	2.1 (1.2)	2.0 (0.1)	1.2 (0.3)	2.1 (1.0)
	$B1_{T=1}$	2.3 (0.2)	1.2 (0.3)	2.3 (0.5)	2.3 (0.1)	1.2 (0.2)	1.2 (0.4)	2.3 (0.2)	1.2 (0.1)	1.9 (0.4)
	$C_{T=0}$	3.8 (0.5)	0.8 (0.3)	2.5 (1.1)	3.6 (0.5)	0.8 (0.4)	4.2 (2.2)	3.6 (0.4)	0.8 (0.3)	3.3 (1.8)
	$C_{T=1}$	5.0 (0.9)	1.0 (0.3)	3.2 (1.5)	4.7 (0.7)	1.1 (0.3)	3.5 (1.4)	4.8 (0.8)	1.0 (0.2)	2.7 (1.2)

According to Table 4, it can be observed that the friction forces B and F are reduced by as much as a factor of 3 for piston B1 according to the invention, compared with pistons A and C, and that this is true independently of the amount of silicone carried on the pistons. It is therefore possible, thanks to the invention, to reduce significantly the amount of silicone carried in the medical device 1, and to do so without adversely affecting the sliding of the piston 3 with respect to the syringe body 2 or container. In addition, it can be observed that friction forces S, B and F of piston B1 are roughly constant despite ageing over the time, which is not the case for pistons A and C.

Example 3

The test protocol of Example 2 was repeated with pistons A, B1, B2 and C, with various levels of lubrication thereof, these levels being expressed by weight of silicone employed. The results obtained are given in Table 5 below.

Table 5 : Activation Gliding Forces, Pistons A, B1 and C

Silicone/internal surface of container		4 µg/cm²			4 µg/cm²			4 µcm²		
Silicone/piston		5 µg/cm²			15 µg/cm²			50 µg/cm²		
Force (N)		B	S	F	B	S	F	B	S	F
Piston	$A_{T=0}$	6.6 (0.6)	5.8 (1.0)	4.7 (1.0)	7.2 (0.5)	6.9 (1.9)	4.7 (1.9)	6.6 (0.8)	6.5 (1.5)	4.0 (1.5)
	$A_{T=1}$	12.0 (2.3)	8.4 (2.0)	3.2 (1.3)	11.0 (0.8)	8.0 (1.9)	3.3 (1.0)	10.7 (1.2)	6.7 (1.5)	3.6 (1.7)
	$B1_{T=0}$	2.2 (0.2)	2.7 (0.4)	2.7 (0.4)	2.2 (0.2)	3.0 (0.6)	3.0 (0.6)	2.1 (0.1)	2.6 (0.5)	2.6 (0.5)
	$B1_{T=1}$	2.8 (0.3)	4.3 (1.2)	4.3 (1.2)	2.6 (0.6)	3.3 (0.3)	3.3 (0.3)	2.5 (0.2)	3.4 (0.3)	3.4 (0.3)
	$C_{T=0}$	4.7 (0.4)	6.5 (0.6)	4.6 (0.6)	4.2 (0.3)	6.0 (0.7)	4.2 (0.7)	3.9 (0.5)	5.2 (0.7)	4.0 (0.7)
	$C_{T=1}$	8.4 (0.6)	8.3 (1.9)	4.1 (1.6)	7.5 (0.6)	8.3 (1.4)	4.8 (2.2)	7.8 (1.1)	6.2 (1.0)	3.7 (1.5)

As Table 5 shows, with the smooth Parylen C coating according to the invention (piston B1), the friction forces B, S and F are always below 4 N, regardless of the amount of silicone coating added onto the piston. The results obtained with a piston having no coating (piston C) are markedly inferior. After one month of ageing, the friction forces B and S increase, in the case of comparative pistons A and C, whereas they remain practically unchanged and below 4 N in the case of inventive piston B1.

Example 4

The protocol of Example 2 was repeated using a different syringe body or container 2, which was not coated with an internal film of silicone oil. By contrast, a silicone oil was used on the pistons 3 prior to assembly or fitting.

The results according to Table 6 were then obtained.

Table 6

Silicone/internal surface of syringe		0 µg/cm²			0 µg/cm²		
Silicone/piston		15 µg/cm²			50 µg/cm²		
Force (N)		B	S	F	B	S	F
Piston	$A_{T=1}$	29.3 (2.7)	32.0 (6.3)	56.6 (8.1)	31.8 (2.6)	13.0 (1.9)	20.3 (4.5)
	$B1_{T=1}$	9.5 (1.1)	8.8 (1.1)	15.2 (1.5)	9.0 (1.0)	7.0 (1.0)	9.0 (1.0)

As can be seen from Table 6, it seems difficult to make the pistons A move inside the syringe body 2. However, thanks to the coating 8 according to the invention, in the case of piston B1, all the friction forces B, S and F are reduced in comparison to piston A, by about a factor of 4 in the case of an additional silicone coating of 15 µg/cm^2 of silicone, and about a factor of 2 in the case of an additional silicone coating of 50 µg/cm^2 of silicone.

Example 5

The protocol of Example 2 was repeated for both of the following scenarios:

Scenario 1: a silicone lubricant was deposited and baked onto the internal surface of the syringe body 2, at a rate of 40 µg for a surface area of 10 cm^2, but no silicone was used or sprayed on the pistons 3.

Scenario 2: a silicone lubricant was sprayed onto the internal surface of the syringe body 2 at a rate of 500 µg for a surface area of 10 cm^2, but no silicone was used or sprayed on the pistons 3. The results obtained are collated in Table 7 below.

Table 7

		Scenario 1			Scenario 2		
Silicone/internal surface of syringe		4 µg/cm²	4 µg/cm²	4 µg/cm²	50 µg/cm²	50 µg/cm²	50 µg/cm²
Silicone/piston		---	---	---	---	---	---
Force (N)		B	S	F	B	S	F
Piston	$A_{T=0}$	6.6 (0.3)	6.9 (1.4)	4.0 (1.4)	5.5 (0.5)	1.2 (0.3)	4.0 (2.0)
	$A_{T=1}$	15.7 (2.9)	5.3 (2.6)	6.1 (4.2)	8.6 (1.1)	1.6 (0.7)	5.6 (4.1)
	$B1_{T=0}$	2.1 (0.1)	2.5 (0.3)	2.6 (0.3)	1.9 (0.2)	1.3 (0.3)	2.1 (0.7)
	$B1_{T=1}$	3.0 (0.4)	3.4 (0.5)	2.8 (0.6)	2.2 (0.2)	1.4 (0.3)	2.4 (0.6)
	$C_{T=0}$	3.9 (0.6)	6.6 (2.5)	3.9 (2.5)	4.2 (0.6)	1.0 (0.4)	4.7 (2.9)
	$C_{T=1}$	14.4 (2.2)	4.8 (2.1)	3.6 (1.1)	5.4 (1.2)	1.3 (0.5)	4.3 (2.8)
	$A_{T=3}$	17.2 (6.1)	4.3 (2.4)	2.9 (1.2)	10.0 (1.0)	1.5 (0.3)	4.0 (3.0)
	$A_{T=5}$	20.5 (4.0)	6.1 (3.0)	3.0 (1.0)	15.1 (1.4)	2.5 (1.5)	3.0 (2.0)

With pistons A and C, the friction forces B, S and F were relatively high, something which does not appear to be acceptable for a medical device. Conversely, with piston B1 which is provided with the coating 8 of the invention, the friction forces B and F were entirely compatible with the way in which a medical device 1 is used.

After one month of ageing, the friction forces B, S and F for pistons A and C had increased appreciably, especially the friction forces B. Conversely, the friction forces B, S and F of pistons B1 had increased very little.

Using the invention, it therefore appears to be possible, thanks to the coating 8 according to the invention, to eliminate the use of silicone oil on rubber pistons 3 in medical devices 1.

Additional tests similar to the tests described above demonstrated that the optimum mean thickness for the coating 8 for the medical device 1 of the invention ranges between 2 and 10 µm and preferably from 3 to 10 µm and, more preferably still, from 3 to 5 µm.

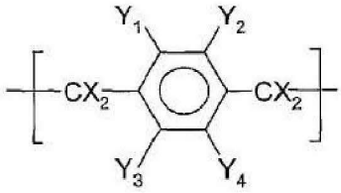
In an alternative form of embodiment that has not been illustrated, the coating according to the invention is on the container rather than on the

piston. In this configuration, the piston may be provided with a coating of silicone to face the coating at the contact region.

In general, the container 2 according to the invention may be made of any kind of material - glass, plastic, polymer. When the container 2 is intended to receive the coating, for certain materials such as glass, an adhesion-promoting layer that encourages the coating to bond with the container 2 will be provided.

CLAIMS

1. Medical device (1) comprising at least one first part (2; 3) coated with a coating (8) having a composition comprising at least one polymer material comprising polymer chains having the following repeat unit:



in which X represents a halogen, for example F, or a hydrogen,
and in which Y_1, Y_2, Y_3, Y_4 each independently represent a halogen, for example Cl, or a hydrogen,

characterized in that the outer surface of said coating (8) has a mean roughness Ra of less than 2.5 μm.

2. Medical device (1) according to claim 1, characterized in that said mean roughness Ra is less than 2 μm, preferably less than 1.5 μm and, for example, of the order of 1.0 μm.

3. Medical device (1) according to claim 1 or 2, characterized in that said one first part is chosen among a piston (3), the internal surface of a container (2) intended to receive a medical product (6), or an intermediate part (9) located between a piston (3) and the internal surface of a container (2) intended to receive a medical product (6).

4. Medical device (1) according to one of claims 1 to 3, characterized in that it further comprises at least one second part (2; 3; 9) being intended to move relative to said first part (2; 3; 9) in a sliding relationship when said medical device(1) is operated, said first and second parts (2; 3; 9) defining between them a contact region (10).

5. Medical device (1) according to the preceding claim, characterized in that one of said first and second parts (2; 3; 9) consists of a viscoelastic material designed to encourage tightness at said contact region (10).

6. Medical device (1) according to one of claims 4 or 5, characterized in that said first part is a piston (3) and said second part is the internal surface of a container (2) intended to receive a medical product (6), or

an intermediate part (9) located between said piston (3) and the internal surface of a container (2) intended to receive a medical product (6), said piston (3) being movable within said container (2) when said medical device (1) is operated.

7. Medical device (1) according to one of claims 4 or 5, characterized in that said first part is an intermediate part (9) located between a piston (3) and the internal surface of a container (2) intended to receive a medical product (6), and said second part is a piston (3) or the internal surface of a container (2) intended to receive a medical product (6), said piston (3) being movable within said container (2) when said medical device (1) is operated.

8. Medical device (1) according to one of claims 4 or 5, characterized in that said first part is the internal surface of a container (2) intended to receive a medical product (6), and said second part is a piston (3) or an intermediate part (9) located between a piston (3) and the internal surface of a container (2) intended to receive a medical product (6), said piston (3) being movable within said container (2) when said medical device (1) is operated.

9. Medical device (1) according to one of claims 4 to 8, characterized in that said second part (2; 3; 9) is further coated with said coating (8) at least in the contact region.

10. Medical device (1) according to one of claims 1 to 9, characterized in that said coating (8) is continuous and elastic.

11. Medical device (1) according to one of claims 1 to 10, characterized in that said polymer material is chosen from the group consisting of poly(p-xylylene), poly(p-meta-chloroxylylene), poly(p-ortho-chloro/meta-chloroxylylene) and poly(p-difluoroxylylene).

12. Medical device (1) according to the preceding claim, characterized in that said polymer material consists of poly(p-meta-chloroxylylene).

13. Medical device (1) according to one of claims 1 to 12, characterized in that said coating (8) has a mean thickness ranging from 2 to 10 μm, preferably, ranging from 3 to 10 μm, and more preferably ranging from 3 to 5 μm.

14. Medical device (1) according to one of claims 1 to 13, characterized in that said contact region (10) further includes a lubricant other than said coating (8).

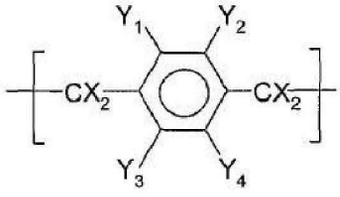
15. Medical device (1) according to one of claims 6 to 8 and claim 14, characterized in that said coating (8) provided on said container (2) and/or on said piston (3) and/or on said intermediate part (9) is at least partially covered with said lubricant.

16. Medical device (1) according to one of claims 6 to 8 and 14, characterized in that said piston (3) or said container (2) or said intermediate part (9), not provided with said coating (8), is at least partially covered with said lubricant.

17. Medical device (1) according to one of claims 14 to 16, characterized in that said lubricant contains silicone.

18. Medical device (1) according to one of claims 1 to 17, characterized in that it includes an injection device.

19. Part (2; 3) for a medical device (1), the part (2; 3) being intended to cooperate in relative movement with respect to a complementary part (3, 2) in order to operate said medical device (1), said part (2; 3) comprising, a coating (8) consisting of at least one polymer material comprising polymer chains consisting of the following repeat unit:



in which X represents a halogen, for example F, or a hydrogen,
and in which Y_1, Y_2, Y_3, Y_4 each independently represent a halogen, for example Cl, or a hydrogen,
said coating (8) having a outer surface intended to move relative to said complementary part (3, 2),
characterized in that said outer surface of said coating (8) has a mean roughness Ra equal or less than 2.5 μm.

20. Part (2, 3) according to claim 19, characterized in that said outer surface has a mean roughness Ra equal or less than 2 μm, preferably less than 1.5 μm and, for example, of the order of 1.0 μm.

21. Part (2; 3) according to Claim 19, characterized in that said coating (8) is continuous and elastic.

22. Part (2; 3) according to Claim 19, characterized in that said polymer material is chosen from the group consisting of poly(p-xylylene), poly(p-meta-chloroxylylene), poly(p-ortho-chloro/meta-chloroxylylene), and poly(p-difluoroxylylene).

23. Part (2, 3) according to Claim 22, characterized in that said polymer material consists of poly(p-meta-chloroxylene).

24. Part (2; 3) according to Claim 19, characterized in that the mean thickness of said coating (8) ranges from 2 to 10 μm, preferably from 3 to 10 μm, and more preferably from 3 to 5 μm.

25. Part (2, 3) according to Claim 19, characterized in that it comprises at least one of

- a container (2) intended to accommodate a medical product (6), and/or
- a piston (3) intended to be moved with respect to said container (2), and/or
- an intermediate part (9) located between said container (2) and said piston (3).

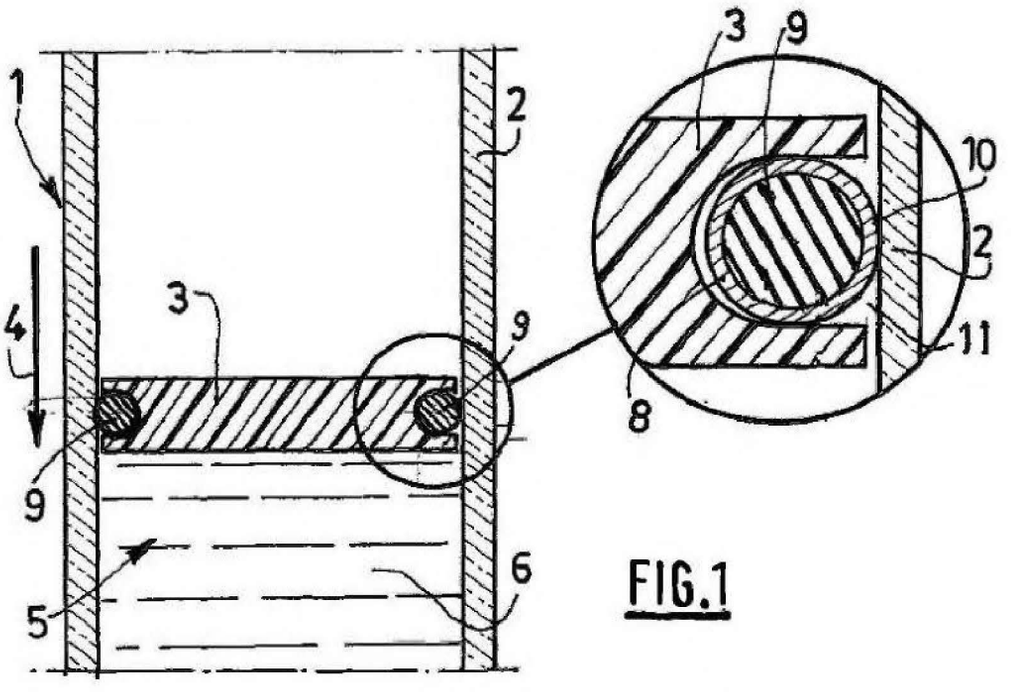


FIG.1

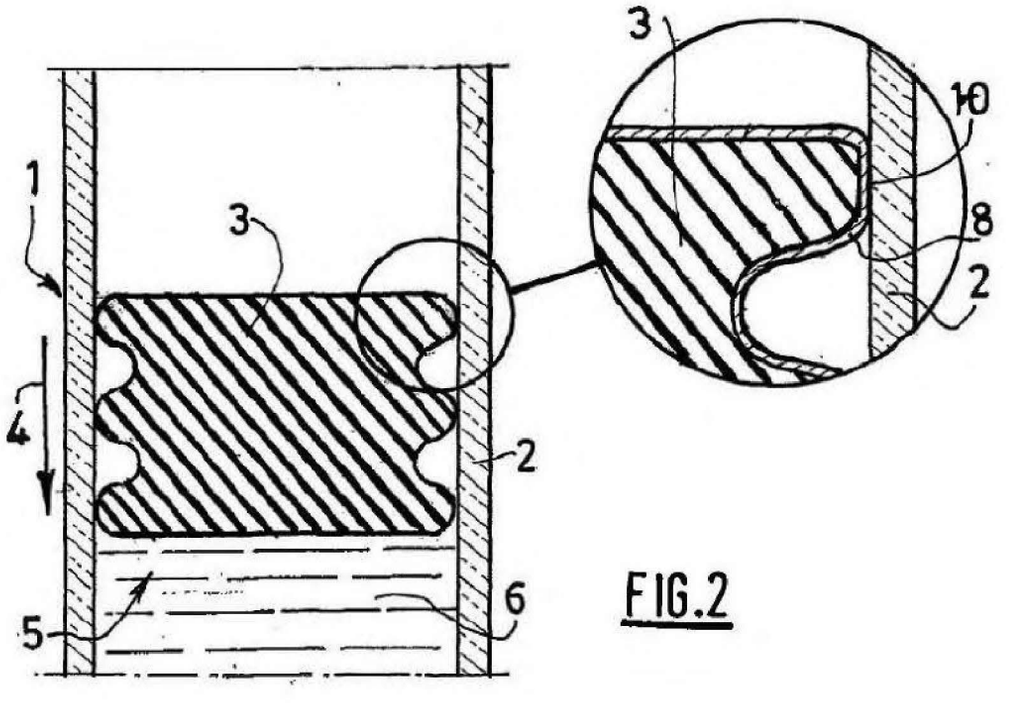


FIG.2

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2007/003435

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61M5/315 A61J1/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61M A61J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, CHEM ABS Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005/010175 A1 (BEEDON DANIEL E [US] ET AL) 13 January 2005 (2005-01-13) cited in the application paragraphs [0006], [0039], [0040]	1-25
X	DATABASE WPI Week 200547 Derwent Publications Ltd., London, GB; AN 2005-461897 XP002481769 & JP 2005 160888 A (TERUMO CORP) 23 June 2005 (2005-06-23) abstract	1-25

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 May 2008	16/06/2008

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Mazet, Jean-François

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2007/003435

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	U.GÖCHEL ET AL.: "Surface Film Formation by Chemical Vapor Deposition of Di-p-xylylene : Ellipson, Atomic Force Microscopy and X-ray Studies" LANGMUIR, vol. 16, no. 6, 2000, pages 2887-2892, XP002481916 abstract page 2890; figures 5,6	1-25

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2007/003435

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2005010175 A1	13-01-2005	NONE	
JP 2005160888 A	23-06-2005	NONE	