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Albertus; c/o High Tech Campus 7, 5656 AE Eindhoven (NL).

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(74) Agent: VAN DIJKEN, Albert et al.; High Tech Campus 7, 5656 AE Eindhoven (NL).

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(71) Applicant: SIGNIFY HOLDING B.V. [NL/NL]; High Tech Campus 48, 5656 AE Eindhoven (NL).

(72) Inventors: HIKMET, Rifat, Ata, Mustafa; c/o High Tech Campus 7, 5656 AE Eindhoven (NL). VAN HAL, Paulus,

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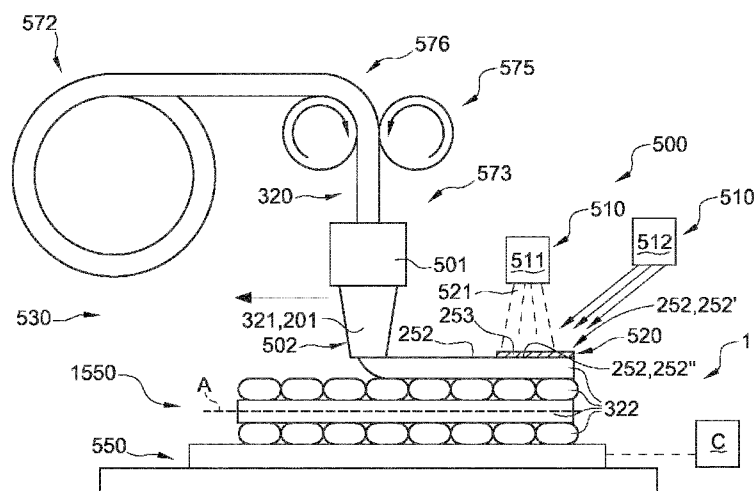


FIG. 2A

(57) Abstract: The invention provides a method for producing a 3D item (1) by means of fused deposition modelling, the method comprising (i) a 3D printing stage comprising layer-wise depositing an extrudate (321) comprising 3D printable material (201), to provide the 3D item (1) comprising 3D printed material (202), wherein the 3D item (1) comprises a plurality of layers (322) of 3D printed material (202), wherein the 3D item (1) has an item surface (252) defined by at least part of the 3D printed material (202), and (ii) a coating stage comprising applying one or more starting materials (521) to at least a surface part (253) of the item surface (252) to form a polymeric coating (520) on the surface part (253), wherein the one or more starting materials (521) comprise two or more reactive materials (524) that are reactable with each other, and wherein the coating stage comprises reacting the two or more reactive materials (524) on the surface part (253) to provide the polymeric coating (520).

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FDM PRINTED MATERIAL RESISTANT TO SOLVENT INDUCED CRACKING

FIELD OF THE INVENTION

The invention relates to a method for manufacturing a 3D (printed) item and to a software product for executing such method. The invention also relates to the 3D (printed) item obtainable with such method. Further, the invention relates to a lighting device
5 including such 3D (printed) item. Yet further, the invention also relates to a 3D printer, such as for use in such method.

BACKGROUND OF THE INVENTION

The use of a post-treatment stage in 3D printing is known in the art.
10 WO2016124432A1, for instance, describes a method for manufacturing a 3D item, wherein the 3D item comprises an outer layer and a support structure with cavities, wherein the outer layer at least partly encloses the support structure, and wherein the method comprises: (a) a 3D printing stage comprising 3D printing with fused deposition modeling (FDM) 3D printable material the outer layer and the support structure and at least partly filling the
15 cavities with a filler material; and (b) a post-treatment stage comprising post treating at least part of the outer layer (210) for reducing surface roughness, wherein the post-treatment stage comprises one or more of (a) heating at least part of the outer layer, (b) solvent dissolving at least part of the outer layer, and (c) coating at least part of the outer layer, and wherein the thus obtainable outer layer and the support structure differ in one or more of (a) chemical
20 composition, (b) density, and (c) surface texture.

WO2012058278 discloses a three-dimensional fabrication apparatus having an extruder assembly for dispensing a polymer in a layer-by-layer process to form a three-dimensional object on a build platform. The fabrication apparatus also has a print head and an ink delivery system for dispensing ink on the three-dimensional object during the build
25 process. The ink is used to form an ink layer that may include dyes or pigments so that the three-dimensional object may be a colored three-dimensional object.

WO2018095753 discloses a method for 3D printing a 3D item. The method comprises the steps of providing a 3D printable material and printing, during a printing stage, the 3D printable material to provide the 3D item. The 3D printable material comprises a

thermoplastic material. The 3D item has an item surface, and the method further comprises the step of providing a powder coating on at least part of the item surface during a coating stage.

5 SUMMARY OF THE INVENTION

Within the next 10-20 years, digital fabrication will increasingly transform the nature of global manufacturing. One of the aspects of digital fabrication is 3D printing. Currently, many different techniques have been developed in order to produce various 3D printed objects using various materials such as ceramics, metals and polymers. 3D printing
10 can also be used in producing molds which can then be used for replicating objects.

For the purpose of making molds, the use of polyjet technique has been suggested. This technique makes use of layer by layer deposition of photo-polymerisable material which is cured after each deposition to form a solid structure. While this technique produces smooth surfaces the photo curable materials are not very stable and they also have
15 relatively low thermal conductivity to be useful for injection molding applications.

The most widely used additive manufacturing technology is the process known as Fused Deposition Modeling (FDM). Fused deposition modeling (FDM) is an additive manufacturing technology commonly used for modeling, prototyping, and production applications. FDM works on an "additive" principle by laying down material in
20 layers; a plastic filament or metal wire is unwound from a coil and supplies material to produce a part. Possibly, (for thermoplastics for example) the filament is melted and extruded before being laid down. FDM is a rapid prototyping technology. Other terms for FDM are "fused filament fabrication" (FFF) or "filament 3D printing" (FDP), which are considered to be equivalent to FDM. In general, FDM printers use a thermoplastic filament, which is
25 heated to its melting point and then extruded, layer by layer, (or in fact filament after filament) to create a three-dimensional object. FDM printers are relatively fast and can be used for printing complicated object.

FDM printers are relatively fast, low cost and can be used for printing complicated 3D objects. Such printers are used in printing various shapes using various
30 polymers. The technique is also being further developed in the production of LED luminaires and lighting solutions.

Fused Deposition Modelling (FDM) is one of the most frequently used techniques used in producing objects based on additive manufacturing (3-D printing). FDM works on an "additive" principle by laying down plastic material in layers.

Surprisingly, it was found that upon subjecting 3D printed objects of e.g. polycarbonate (PC) to every day cleansing liquids the objects became cracked. This is a behavior which is not observed by injection molded PC.

It is theorized that the observed effect is a result of the printing process during which and after cooling down the print stress gets built-up into the structures. When e.g. amorphous thermoplastic polymers, such as polycarbonate or polystyrene, are used in combination with structure having relatively low wall thicknesses like those such as the ones used in luminaires, during cleaning with cleaning fluids they rapidly form cracks, especially along the printing layers between the ribs.

Hence, it is an aspect of the invention to provide an alternative 3D printing method and/or 3D (printed) item which preferably further at least partly obviate(s) one or more of above-described drawbacks. The present invention may have as object to overcome or ameliorate at least one of the disadvantages of the prior art, or to provide a useful alternative.

Amongst others, it is herein suggested - in embodiments - to apply a protective coating from e.g. a separate spray nozzle during or after the printing the object. For this purpose, a crosslinkable layer can be used. The coating layer(s) may in embodiments especially be formed by a two-component system which may instantaneously react during deposition to form a crosslinked film reducing the chance of cracking during the deposition process.

Hence, in a first aspect the invention provides a method for producing a 3D item by means of fused deposition modelling, wherein the method comprises: (i) a 3D printing stage comprising layer-wise depositing an extrudate comprising 3D printable material, to provide the 3D item comprising 3D printed material, wherein the 3D item comprises a plurality of layers of 3D printed material, wherein the 3D item has an item surface defined by at least part of the 3D printed material, and (ii) a coating stage comprising applying one or more starting materials to at least a surface part of the item surface to form a polymeric coating on the surface part. The one or more starting materials comprise two or more reactive materials. The two or more reactive materials are reactable with each other. The coating stage comprises reacting the two or more reactive materials (on the surface part) to provide the polymeric coating. For instance, the two or more reactive material may comprise unsaturated polymeric materials and molecules that form crosslinking molecules between the (unsaturated) polymeric materials, such as an epoxide crosslinking agent. Especially, the polymeric coating comprises crosslinked material. Hence, especially, the one

or more starting materials comprise crosslinkable material. The method may further comprise applying one or more starting materials comprising crosslinkable material to at least a surface part of the item surface, and crosslinking the crosslinkable material.

With such method, a 3D printed item may be provided that, even when
5 forming cracks, may be protected by the coating from intrusion of liquids such as cleaning liquids. The coating may fill possible cracks or may keep the surface of the item closed even when cracks would be formed under the coating. The coating is recognizable as coating, and may in embodiments consist of another material than the 3D printed (or 3D printable) material and/or may differ in that the 3D printed material is (essentially) not crosslinked
10 whereas the coating may comprise crosslinked material. Hence, the 3D printable material may comprise (polymeric) material that is essentially non-crosslinkable.

As indicated above, the method is especially used for producing a 3D item by means of fused deposition modelling (FDM). The method comprises two stages, a 3D printing stage and a coating stage, wherein the latter is in general later than the former,
15 though there may be some overlap in time in other embodiments (see also below). The method may also comprise one or more further stages, like a heating stage (e.g. for smoothening the surface). Other stages may also be available. Preceding to the 3D printing stage, and/or between the 3D printing stage and the coating stage, and/or after the coating stage, in embodiments there may be one or more further stages.

20 Further, the term “stage” may also refer to a sequence of stages, such as e.g. a sequence of printing stages wherein in between one or more functional components or other components are integrated in or arranged on the thus obtained 3D printed material. Hence, the term “coating stage” may refer to a coating stage wherein a multi-layer coating is provided. This may e.g. be done during a plurality of coating stages (or, a coating stage
25 wherein a plurality of layers is provided to provide a multi-layer polymeric coating).

The 3D printing stage comprises layer-wise depositing an extrudate comprising 3D printable material, and a shell comprising a shell material, to provide the 3D item comprising 3D printed material. Hence, the 3D printing process especially provides the 3D item which comprises a plurality of layers of 3D printed material, which are especially
30 formed due to the layer-wise deposition.

In embodiments, the extrudate may comprise a core-shell extrudate. In other embodiments, the extrudate comprises a single material. When at least part of the 3D printable material is deposited, the coating may be applied to part of the 3D printed material. This is indicated as “wherein the 3D item has an item surface defined by at least part of the

3D printed material, and (ii) a coating stage comprising applying one or more starting materials to at least a surface part of the item surface to form a polymeric coating on the surface part”.

The thus obtained 3D item has an item surface defined by at least part of the 3D printed material. Especially, this item surface is defined by the shell material when the extrudate comprises a core-shell extrudate.

As indicated above, part of the item surface, which is indicated as surface part, is provided with a polymeric coating. The polymeric coating may comprise one or more of the herein indicated material. However, as indicated above at least part of the polymeric material of the polymeric coating differs in chemical composition of the polymeric material of the 3D printed material and/or the at least part of the polymeric material of the polymeric coating, whereas the polymeric material of the 3D printable material may not be crosslinked.

Actually, this part of the item surface is now translated to a new item surface which may be defined by the surface of the polymeric coating. From the context it is clear when with the terms “item surface” or “surface part” is meant the surface or part of the 3D item without polymeric coating (if such surface is available) or whether it refers to the surface or surface part, respectively, which is formed by the surface of the polymeric coating. The latter may also be indicated as primary surface or primary surface part, respectively; the former may be indicated as secondary surface secondary surface part, respectively.

In the coating stage, a material is applied to the 3D printed material that can form the polymeric coating. In embodiments, this may be monomeric material that is polymerized on the surface part. Alternatively or additionally, the material that is applied to the surface part comprises crosslinkable polymer material that is crosslinked on the surface part. Crosslinking can be done with technologies known in the art. The material that is applied to the surface part, which is herein indicated as one or more starting materials, may essentially not be crosslinked before application to the surface part. The term “surface part” may also refer to a plurality of surface parts. In embodiments, the entire (outer) surface of the 3D item may be provided with the polymeric coating.

Hence, the 3D item has an item surface defined by at least part of the 3D printed material. To at least the surface part of the item surface one or more starting materials are applied, to form a polymeric coating on the surface part. For instance, these starting materials may be polymerized to form the polymeric coating.

As indicated above, the term “coating stage” may also include a stage wherein a plurality of coating is applied, such as to provide a polymeric multi-layer coating. As

indicated above, the coating may be applied to layers that essentially consist of a single material, or may be applied to shells of core-shell layers.

As indicated above, the method comprises depositing during a printing stage 3D printable material. Herein, the term “3D printable material” refers to the material to be deposited or printed, and the term “3D printed material” refers to the material that is obtained after deposition. These materials may be essentially the same, as the 3D printable material may especially refer to the material in a printer head or extruder at elevated temperature and the 3D printed material refers to the same material, but in a later stage when deposited. The 3D printable material is printed as a filament and deposited as such. The 3D printable material may be provided as filament or may be formed into a filament. Hence, whatever starting materials are applied, a filament comprising 3D printable material is provided by the printer head and 3D printed. The term “extrudate” may be used to define the 3D printable material downstream of the printer head, but not yet deposited. The latter is indicated as “3D printed material”. In fact, the extrudate comprises 3D printable material, as the material is not yet deposited. Upon deposition of the 3D printable material or extrudate, the material is thus indicated as 3D printed material. Essentially, the materials are the same material, as the thermoplastic material upstream of the printer head, downstream of the printer head, and when deposited, is essentially the same material.

Herein, the term “3D printable material” may also be indicated as “printable material. The term “polymeric material” may in embodiments refer to a blend of different polymers, but may in embodiments also refer to essentially a single polymer type with different polymer chain lengths. Hence, the terms “polymeric material” or “polymer” may refer to a single type of polymers but may also refer to a plurality of different polymers. The term “printable material” may refer to a single type of printable material but may also refer to a plurality of different printable materials. The term “printed material” may refer to a single type of printed material but may also refer to a plurality of different printed materials.

Hence, the term “3D printable material” may also refer to a combination of two or more materials. In general, these (polymeric) materials have a glass transition temperature T_g and/or a melting temperature T_m . The 3D printable material will be heated by the 3D printer before it leaves the nozzle to a temperature of at least the glass transition temperature, and in general at least the melting temperature. Hence, in a specific embodiment the 3D printable material comprises a thermoplastic polymer having a glass transition temperature (T_g) and/or a melting point (T_m), and the printer head action comprises heating the 3D printable material above the glass transition and if it is a semi-crystalline polymer

above the melting temperature. In yet another embodiment, the 3D printable material comprises a (thermoplastic) polymer having a melting point (T_m), and the printer head action comprises heating the 3D printable material to be deposited on the receiver item to a temperature of at least the melting point. The glass transition temperature is in general not the same thing as the melting temperature. Melting is a transition which occurs in crystalline polymers. Melting happens when the polymer chains fall out of their crystal structures, and become a disordered liquid. The glass transition is a transition which happens to amorphous polymers; that is, polymers whose chains are not arranged in ordered crystals, but are just strewn around in any fashion, even though they are in the solid state. Polymers can be amorphous, essentially having a glass transition temperature and not a melting temperature or can be (semi) crystalline, in general having both a glass transition temperature and a melting temperature, with in general the latter being larger than the former. The glass temperature may e.g. be determined with differential scanning calorimetry. The melting point or melting temperature can also be determined with differential scanning calorimetry.

As indicated above, the invention thus provides a method comprising providing a filament of 3D printable material and printing during a printing stage said 3D printable material on a substrate, to provide said 3D item.

Materials that may especially qualify as 3D printable materials may be selected from the group consisting of metals, glasses, thermoplastic polymers, silicones, etc. Especially, the 3D printable material comprises a (thermoplastic) polymer selected from the group consisting of ABS (acrylonitrile butadiene styrene), Nylon (or polyamide), Acetate (or cellulose), PLA (poly lactic acid), terephthalate (such as PET polyethylene terephthalate), Acrylic (polymethylacrylate, Perspex, polymethylmethacrylate, PMMA), Polypropylene (or polypropene), Polycarbonate (PC), Polystyrene (PS), PE (such as expanded- high impact- Polythene (or polyethene), Low density (LDPE) High density (HDPE)), PVC (polyvinyl chloride) Polychloroethene, such as thermoplastic elastomer based on copolyester elastomers, polyurethane elastomers, polyamide elastomers polyolefine based elastomers, styrene based elastomers, etc.. Optionally, the 3D printable material comprises a 3D printable material selected from the group consisting of Urea formaldehyde, Polyester resin, Epoxy resin, Melamine formaldehyde, thermoplastic elastomer, etc.. Optionally, the 3D printable material comprises a 3D printable material selected from the group consisting of a polysulfone. Elastomers, especially thermoplastic elastomers, are especially interesting as they are flexible and may help obtaining relatively more flexible filaments comprising the thermally conductive material. A thermoplastic elastomer may comprise one or more of styrenic block

copolymers (TPS (TPE-s)), thermoplastic polyolefin elastomers (TPO (TPE-o)), thermoplastic vulcanizates (TPV (TPE-v or TPV)), thermoplastic polyurethanes (TPU (TPU)), thermoplastic copolyesters (TPC (TPE-E)), and thermoplastic polyamides (TPA (TPE-A)).

- 5 Suitable thermoplastic materials, such as also mentioned in WO2017/040893, may include one or more of polyacetals (e.g., polyoxyethylene and polyoxymethylene), poly(C₁₋₆ alkyl)acrylates, polyacrylamides, polyamides, (e.g., aliphatic polyamides, polyphthalamides, and polyaramides), polyamideimides, polyanhydrides, polyarylates, polyarylene ethers (e.g., polyphenylene ethers), polyarylene sulfides (e.g., polyphenylene
- 10 sulfides), polyarylsulfones (e.g., polyphenylene sulfones), polybenzothiazoles, polybenzoxazoles, polycarbonates (including polycarbonate copolymers such as polycarbonate-siloxanes, polycarbonate-esters, and polycarbonate-ester-siloxanes), polyesters (e.g., polycarbonates, polyethylene terephthalates, polyethylene naphtholates, polybutylene terephthalates, polyarylates), and polyester copolymers such as polyester-ethers),
- 15 polyetheretherketones, polyetherimides (including copolymers such as polyetherimide-siloxane copolymers), polyetherketoneketones, polyetherketones, polyethersulfones, polyimides (including copolymers such as polyimide-siloxane copolymers), poly(C₁₋₆ alkyl)methacrylates, polymethacrylamides, polynorbornenes (including copolymers containing norbornenyl units), polyolefins (e.g., polyethylenes, polypropylenes,
- 20 polytetrafluoroethylenes, and their copolymers, for example ethylene- α -olefin copolymers), polyoxadiazoles, polyoxymethylenes, polyphthalides, polysilazanes, polysiloxanes, polystyrenes (including copolymers such as acrylonitrile-butadiene-styrene (ABS) and methyl methacrylate-butadiene-styrene (MBS)), polysulfides, polysulfonamides, polysulfonates, polysulfones, polythioesters, polytriazines, polyureas, polyurethanes,
- 25 polyvinyl alcohols, polyvinyl esters, polyvinyl ethers, polyvinyl halides, polyvinyl ketones, polyvinyl thioethers, polyvinylidene fluorides, or the like, or a combination comprising at least one of the foregoing thermoplastic polymers. Embodiments of polyamides may include, but are not limited to, synthetic linear polyamides, e.g., Nylon-6,6; Nylon-6,9; Nylon-6,10; Nylon-6,12; Nylon-11; Nylon-12 and Nylon-4,6, preferably Nylon 6 and Nylon 6,6, or a
- 30 combination comprising at least one of the foregoing. Polyurethanes that can be used include aliphatic, cycloaliphatic, aromatic, and polycyclic polyurethanes, including those described above. Also useful are poly(C₁₋₆ alkyl)acrylates and poly(C₁₋₆ alkyl)methacrylates, which include, for instance, polymers of methyl acrylate, ethyl acrylate, acrylamide, methacrylic acid, methyl methacrylate, n-butyl acrylate, and ethyl acrylate, etc. In embodiments, a

polyolefine may include one or more of polyethylene, polypropylene, polybutylene, polymethylpentene (and co-polymers thereof), polynorbornene (and co-polymers thereof), poly 1-butene, poly(3-methylbutene), poly(4-methylpentene) and copolymers of ethylene with propylene, 1-butene, 1-hexene, 1-octene, 1-decene, 4-methyl-1-pentene and 1-octadecene.

The term 3D printable material is further also elucidated below, but especially refers to a thermoplastic material, optionally including additives, to a volume percentage of at maximum about 60%, especially at maximum about 30 vol.%, such as at maximum 20 vol.% (of the additives relative to the total volume of the thermoplastic material and additives).

The printable material may thus in embodiments comprise two phases. The printable material may comprise a phase of printable polymeric material, especially thermoplastic material (see also below), which phase is especially an essentially continuous phase. In this continuous phase of thermoplastic material polymer additives such as one or more of antioxidant, heat stabilizer, light stabilizer, ultraviolet light stabilizer, ultraviolet light absorbing additive, near infrared light absorbing additive, infrared light absorbing additive, plasticizer, lubricant, release agent, antistatic agent, anti-fog agent, antimicrobial agent, colorant, laser marking additive, surface effect additive, radiation stabilizer, flame retardant, anti-drip agent may be present. The additive may have useful properties selected from optical properties, mechanical properties, electrical properties, thermal properties, and mechanical properties (see also above).

The printable material in embodiments may comprise particulate material, i.e. particles embedded in the printable polymeric material, which particles form a substantially discontinuous phase. The number of particles in the total mixture is especially not larger than 60 vol.%, relative to the total volume of the printable material (including the (anisotropically conductive) particles) especially in applications for reducing thermal expansion coefficient. For optical and surface related effect number of particles in the total mixture is equal to or less than 20 vol.%, such as up to 10 vol.%, relative to the total volume of the printable material (including the particles). Hence, the 3D printable material especially refers to a continuous phase of essentially thermoplastic material, wherein other materials, such as particles, may be embedded. Likewise, the 3D printed material especially refers to a continuous phase of essentially thermoplastic material, wherein other materials, such as particles, are embedded. The particles may comprise one or more additives as defined above. Hence, in embodiments the 3D printable materials may comprises particulate additives.

The printable material is printed on a receiver item. Especially, the receiver item can be the building platform or can be comprised by the building platform. The receiver item can also be heated during 3D printing. However, the receiver item may also be cooled during 3D printing.

5 The phrase “printing on a receiver item” and similar phrases include amongst others directly printing on the receiver item, or printing on a coating on the receiver item, or printing on 3D printed material earlier printed on the receiver item. The term “receiver item” may refer to a printing platform, a print bed, a substrate, a support, a build plate, or a building platform, etc.. Instead of the term “receiver item” also the term “substrate” may be used. The
10 phrase “printing on a receiver item” and similar phrases include amongst others *also* printing on a separate substrate on or comprised by a printing platform, a print bed, a support, a build plate, or a building platform, etc.. Therefore, the phrase “printing on a substrate” and similar phrases include amongst others directly printing on the substrate, or printing on a coating on the substrate or printing on 3D printed material earlier printed on the substrate. Here below,
15 further the term substrate is used, which may refer to a printing platform, a print bed, a substrate, a support, a build plate, or a building platform, etc., or a separate substrate thereon or comprised thereby.

 Layer by layer printable material is deposited, by which the 3D printed item is generated (during the printing stage). The 3D printed item may show a characteristic ribbed
20 structures (originating from the deposited filaments). However, it may also be possible that after a printing stage, a further stage is executed, such as a finalization stage. This stage may include removing the printed item from the receiver item and/or one or more post processing actions. One or more post processing actions may be executed before removing the printed item from the receiver item and/or one more post processing actions may be executed after
25 removing the printed item from the receiver item. Post processing may include e.g. one or more of polishing, coating, adding a functional component, etc.. Post-processing may include smoothening the ribbed structures, which may lead to an essentially smooth surface.

 Different routes may be chosen to apply the coating to the 3D printed material.

 In embodiments, the one or more starting materials comprise a crosslinkable
30 material, and the coating stage comprises crosslinking the crosslinkable material (on the surface part) to provide the polymeric coating. Hence, the one or more starting material may comprise a crosslinkable material and a crosslinker, which upon activation starts (or enhances) crosslink formation of the one or more starting materials (on the surface part), such as upon one or more of UV radiation and heat.

Especially, the term “crosslinking” and similar terms relate to the process of forming a chemical bond to join two polymer chains together. The term, curing, refers to the crosslinking of thermosetting resins, such as unsaturated polyester and epoxy resins. Hence, in embodiments the one or more starting materials comprise a curable material (that is cured to form the polymeric coating).

As will be clear from the above, the term “one or more starting materials” may especially refer to two or more starting materials, as in general the polymeric coating will be based on two or more different starting materials.

In specific embodiments, the polymeric coating comprises one or more of a crosslinked polyurethane polymer, a crosslinked epoxide polymer, a crosslinked siloxane polymer, and a crosslinked acrylate polymer. Especially such type of coating may provide the desired protection, such as against cleaning agents. However, the polymeric coating may also have other (protective) functions. Hence, the one or more starting materials comprise one or more materials to form one or more of a crosslinked polyurethane polymer, a crosslinked epoxide polymer, a crosslinked siloxane polymer, and a crosslinked acrylate polymer. Hence, the one or more starting materials may comprise one or more materials to form a crosslinked polyurethane polymer. Alternatively or additionally, the one or more starting materials may comprise one or more materials to form a crosslinked epoxide polymer. Alternatively or additionally, the one or more starting materials may comprise one or more materials to form a crosslinked siloxane polymer. Alternatively or additionally, the one or more starting materials may comprise one or more materials to form a crosslinked acrylate polymer.

The polymeric coating may be obtained in different ways (“application methods”). Some chemistry has been described above. The application of the one or more starting materials is described below.

In embodiments, the method may comprise spraying one or more of the one or more starting materials to the surface part. In embodiments, wherein two or more starting materials are applied, two or more of these, especially all, may be sprayed. However, also different methods of application of one or more of the two or more starting materials may be applied. Hence, in embodiments a 3D printer may be used including an additional spray nozzle.

Alternatively or additionally, in embodiments the method may comprise coating one or more of the one or more starting materials to the surface part. The term coating in the context of this embodiment especially refers to application with a physical device that may contact the 3D printed material, such as with a brush. In embodiments,

wherein two or more starting materials are applied, two or more of these, especially all, may be coated. However, also different methods of application of one or more of the two or more starting materials may be applied. Hence, in embodiments a 3D printer may be used including an additional coating applicator.

5 Alternatively or additionally, in embodiments the method may comprise dip-coating one or more of the one or more starting materials to the surface part. In embodiments, wherein two or more starting materials are applied, two or more of these, especially all, may be dip-coated. However, also different methods of application of one or more of the two or more starting materials may be applied. Hence, in embodiments a 3D printer may be used
10 including an additional dip-coating system.

 Alternatively or additionally, in embodiments the method may comprise printing or jetting one or more of the one or more starting materials to the surface part. For printing, a further printer head may be applied. The term “jetting” especially refers to using e.g. an ink-jet type of device, to jet the one or more starting materials on the surface part. In
15 embodiments, wherein two or more starting materials are applied, two or more of these, especially all, may be printed or jetted. However, also different methods of application of one or more of the two or more starting materials may be applied. Hence, in embodiments a 3D printer may be used including an additional printer head and/or jet device.

 As indicated above, more than one different type of application methods of
20 two or more starting materials may be applied when two or more starting materials are used to form the coating. In embodiments, one starting material may be dip-coated, and another starting material may be sprayed.

 Other methods, such as via vapor deposition, may also be applied.

 In embodiments, one of the starting materials comprises a curable material and
25 another material comprises a molecule used for forming crosslinks. In embodiments, the different starting materials may be applied with the same application method. In other embodiments, the different starting materials may be applied with different application methods.

 In specific embodiments, the 3D printable material and the 3D printed material
30 comprise one or more of polycarbonate (PC), polyethylene (PE), high-density polyethylene (HDPE), polypropylene (PP), polyoxymethylene (POM), polyethylene naphthalate (PEN), styrene-acrylonitrile resin (SAN), polysulfone (PSU), polyphenylene sulfide (PPS), and semi-crystalline polyethylene terephthalate (PET), acrylonitrile butadiene styrene (ABS), poly(methyl methacrylate) (PMMA), polystyrene (PS), and styrene acrylic copolymers

(SMMA), wherein in specific embodiments the polymeric coating differs from the 3D printed material in at least one or more of (i) the 3D printed material not being crosslinked and the polymeric coating being crosslinked, and (ii) the 3D printed material and the polymeric coating comprising different polymers. These combinations may be especially suitable combinations of 3D printable material (and thus 3D printed material), and coating material.

Therefore, in specific embodiments the method may further comprise application of a fused deposition modeling 3D printer, comprising (a) the printer nozzle, and (b) a substrate, wherein the fused deposition modeling 3D printer is configured to provide the 3D printable material to the substrate.

Further, the invention relates to a software product that can be used to execute the method described herein. Hence, in yet a further aspect the invention also provides a software product when running on a computer is capable of bringing about the method as described herein. The computer may be functionally coupled to a fused deposition modeling 3D printer or may be comprised by such fused deposition modeling 3D printer, such as e.g. described herein.

The herein described method provides 3D printed items. Hence, the invention also provides in a further aspect a 3D printed item obtainable with the herein described method. In a further aspect a 3D printed item obtainable with the herein described method. Especially, the invention provides a 3D item comprising 3D printed material, wherein the 3D item comprises a plurality of layers of 3D printed material, wherein the 3D item has an item surface, wherein a surface part of the item surface is defined by at least part of the 3D printed material and a polymeric coating on the at least part of the 3D printed material.

The term “item surface” may refer to the surface of the 3D printed material as well as to the 3D printed material with the polymeric coating thereon.

The thickness and height of the layers may e.g. in embodiments be selected from the range of 100 – 3000 μm , with the height in general being smaller than the width. The coating thickness may in embodiments e.g. be selected from the range of 5 – 2000 μm , especially up to about 1000 μm , such as 10-500 μm . In general, the (average) coating thickness will be smaller than the width of the layers. In view of the possible ribbed structure of the 3D item, the thickness may vary over the surface of the 3D item.

Some specific embodiments in relation to the 3D printing method described above not only relate to the method but also to the 3D printed item. Below, some specific embodiments in relation to the 3D printed item are discussed in more detail.

Hence, in specific embodiments (see also above), the polymeric coating comprises one or more of a crosslinked polyurethane polymer, a crosslinked epoxide polymer, a crosslinked siloxane polymer, and a crosslinked acrylate polymer.

In yet further specific embodiments, the 3D printed material comprises one or
5 more of polycarbonate (PC), polyethylene (PE), high-density polyethylene (HDPE),
polypropylene (PP), polyoxymethylene (POM), polyethylene naphthalate (PEN), styrene-
acrylonitrile resin (SAN), polysulfone (PSU), polyphenylene sulfide (PPS), and semi-
crystalline polyethylene terephthalate (PET), acrylonitrile butadiene styrene (ABS),
poly(methyl methacrylate) (PMMA), polystyrene (PS), and styrene acrylic copolymers
10 (SMMA). Especially, the polymeric coating may in embodiments differ from the 3D printed
material in at least one or more of (i) the 3D printed material not being crosslinked and the
polymeric coating being crosslinked, and (ii) the 3D printed material and the polymeric
coating comprising different polymers.

The 3D item as described herein, and as obtainable with the method as
15 described herein, may be substantially any kind of item. The 3D item herein is especially a
body, which may be partly hollow or which may be a massive body. The 3D item may be a
plate, a shaped article, etc., etc.. Specific examples of items that may be created with the
present invention and may be the result of the method described herein are e.g. an optical
(translucent) filter, a reflector, a light mixing chamber, a collimator, a compound parabolic
20 concentrator, etc..

The thus obtained 3D printed item may be functional per se. For instance, the
3D printed item may be a lens, a collimator, a reflector, etc.. The thus obtained 3D item may
(alternatively) be used for decorative or artistic purposes. The 3D printed item may include or
be provided with a functional component. The functional component may especially be
25 selected from the group consisting of an optical component, an electrical component, and a
magnetic component. The term “optical component” especially refers to a component having
an optical functionality, such as a lens, a mirror, a light source (like a LED), etc. The term
“electrical component” may e.g. refer to an integrated circuit, PCB, a battery, a driver, but
also a light source (as a light source may be considered an optical component and an
30 electrical component), etc. The term magnetic component may e.g. refer to a magnetic
connector, a coil, etc.. Alternatively or additionally, the functional component may comprise
a thermal component (e.g. configured to cool or to heat an electrical component). Hence, the
functional component may be configured to generate heat or to scavenge heat, etc..

As indicated above, the 3D printed item maybe used for different purposes.

Amongst others, the 3D printed item maybe used in lighting. Hence, in yet a further aspect the invention also provides a lighting device comprising the 3D item as defined herein.

Especially, the 3D item may be configured as one or more of at least part of a lighting device

5 housing, a wall of a lighting chamber, and an optical element. As a relative smooth surface may be provided, the 3D printed item may be used as mirror or lens, etc..

Returning to the 3D printing process, a specific 3D printer may be used to provide the 3D printed item described herein. Therefore, in yet a further aspect the invention also provides a fused deposition modeling 3D printer, comprising (a) a printer head

10 comprising a printer nozzle, and (b) a 3D printable material providing device configured to provide 3D printable material to the printer head, wherein the fused deposition modeling 3D printer is configured to provide said 3D printable material to a substrate, thereby providing a 3D item comprising 3D printed material, wherein the 3D item has an item surface, wherein the fused deposition modeling 3D printer further comprises (c) a coating system for applying
15 one or more starting materials to at least a surface part of the item surface to form a polymeric coating on the surface part, and in specific embodiments (d) a control system (C), wherein the control system (C) is configured to execute the method as defined herein. For instance, the control system may use the herein described software product to bring about the above describe method.

20 The 3D printable material providing device may provide a filament comprising 3D printable material to the printer head or may provide the 3D printable material as such, with the printer head creating the filament comprising 3D printable material. Hence, in embodiments the invention provides a fused deposition modeling 3D printer, comprising (a) a printer head comprising a printer nozzle, and (b) a filament providing device configured
25 to provide a filament comprising 3D printable material to the printer head, wherein the fused deposition modeling 3D printer is configured to provide said 3D printable material to the substrate, thereby providing a 3D item comprising 3D printed material, wherein the 3D item has an item surface, wherein the fused deposition modeling 3D printer further comprises (c) a coating system for applying one or more starting materials to at least a surface part of the
30 item surface to form a polymeric coating on the surface part, and (d) a control system (C), wherein the control system (C) is configured to execute the method as defined herein. For instance, the control system may use the herein described software product to bring about the above describe method.

As can be derived from the above, the coating system may especially be configured to apply one or more of the above indicated coating methods.

Instead of the term “fused deposition modeling (FDM) 3D printer” shortly the terms “3D printer”, “FDM printer” or “printer” may be used. The printer nozzle may also be indicated as “nozzle” or sometimes as “extruder nozzle”. Instead of the term “nozzle” also the terms “opening” or “nozzle opening” may be applied.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts, and in which:

Figs. 1a-1c schematically depict some general aspects of the 3D printer and of an embodiment of 3D printed material;

Figs. 2a-2c schematically depict some aspects; and

Fig. 3 schematically depicts an aspect of the invention.

The schematic drawings are not necessarily to scale.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Fig. 1a schematically depicts some aspects of the 3D printer. Reference 500 indicates a 3D printer. Reference 530 indicates the functional unit configured to 3D print, especially FDM 3D printing; this reference may also indicate the 3D printing stage unit. Here, only the printer head for providing 3D printed material, such as a FDM 3D printer head is schematically depicted. Reference 501 indicates the printer head. The 3D printer of the present invention may especially include a plurality of printer heads, though other embodiments are also possible. Reference 502 indicates a printer nozzle. The 3D printer of the present invention may especially include a plurality of printer nozzles, though other embodiments are also possible. Reference 321 indicates a filament of printable 3D printable material (such as indicated above). For the sake of clarity, not all features of the 3D printer have been depicted, only those that are of especial relevance for the present invention (see further also below).

The 3D printer 500 is configured to generate a 3D item 1 by layer-wise depositing on a receiver item 550, which may in embodiments at least temporarily be cooled, a plurality of filaments 321 wherein each filament 310 comprises 3D printable material 201,

such as having a melting point T_m . The 3D printable material 201 may be deposited on a substrate 1550 (during the printing stage).

The 3D printer 500 is configured to heat the filament material upstream of the printer nozzle 502. This may e.g. be done with a device comprising one or more of an
5 extrusion and/or heating function. Such device is indicated with reference 573, and is arranged upstream from the printer nozzle 502 (i.e. in time before the filament material leaves the printer nozzle 502). The printer head 501 may (thus) include a liquefier or heater. Reference 201 indicates printable material. When deposited, this material is indicated as (3D) printed material, which is indicated with reference 202.

10 Reference 572 indicates a spool or roller with material, especially in the form of a wire, which may be indicated as filament 320. The 3D printer 500 transforms this in a filament 321 downstream of the printer nozzle which becomes a layer 322 on the receiver item or on already deposited printed material. In general, the diameter of the filament 321 downstream of the nozzle is reduced relative to the diameter of the filament 322 upstream of
15 the printer head. Hence, the printer nozzle is sometimes (also) indicated as extruder nozzle. Arranging layer 322 by layer 322 and/or layer 322t on layer 322, a 3D item 1 may be formed. Reference 575 indicates the filament providing device, which here amongst others include the spool or roller and the driver wheels, indicated with reference 576.

Reference A indicates a longitudinal axis or filament axis.

20 Reference C schematically depicts a control system, such as especially a temperature control system configured to control the temperature of the receiver item 550. The control system C may include a heater which is able to heat the receiver item 550 to at least a temperature of 50 °C, but especially up to a range of about 350 °C, such as at least 200 °C.

25 Alternatively or additionally, in embodiments the receiver plate may also be moveable in one or two directions in the x-y plane (horizontal plane). Further, alternatively or additionally, in embodiments the receiver plate may also be rotatable about z axis (vertical). Hence, the control system may move the receiver plate in one or more of the x-direction, y-direction, and z-direction.

30 Alternatively, the printer can have a head can also rotate during printing. Such a printer has an advantage that the printed material cannot rotate during printing.

Layers are indicated with reference 322, and have a layer height H and a layer width W.

Note that the 3D printable material is not necessarily provided as filament 320 to the printer head. Further, the filament 320 may also be produced in the 3D printer 500 from pieces of 3D printable material.

Reference D indicates the diameter of the nozzle (through which the 3D printable material 201 is forced).

Fig. 1b schematically depicts in 3D in more detail the printing of the 3D item 1 under construction. Here, in this schematic drawing the ends of the filaments 321 in a single plane are not interconnected, though in reality this may in embodiments be the case.

Reference H indicates the height of a layer. Layers are indicated with reference 203. Here, the layers have an essentially circular cross-section. Often, however, they may be flattened, such as having an outer shape resembling a flat oval tube or flat oval duct (i.e. a circular shaped bar having a diameter that is compressed to have a smaller height than width, wherein the sides (defining the width) are (still) rounded).

Hence, Figs. 1a-1b schematically depict some aspects of a fused deposition modeling 3D printer 500, comprising (a) a first printer head 501 comprising a printer nozzle 502, (b) a filament providing device 575 configured to provide a filament 321 comprising 3D printable material 201 to the first printer head 501, and optionally (c) a receiver item 550. In Figs. 1a-1b, the first or second printable material or the first or second printed material are indicated with the general indications printable material 201 and printed material 202. Directly downstream of the nozzle 502, the filament 321 with 3D printable material becomes, when deposited, layer 322 with 3D printed material 202.

Fig. 1c schematically depicts a stack of 3D printed layers 322, each having a layer height H and a layer width W. Note that in embodiments the layer width and/or layer height may differ for two or more layers 322.

Reference 252 in Fig. 1c indicates the item surface of the 3D item (schematically depicted in Fig. 1c).

Referring to Figs. 1a-1c, the filament of 3D printable material that is deposited leads to a layer having a height H (and width W). Depositing layer 322 after layer 322, the 3D item 1 is generated.

Figs. 1a-1c show embodiments of amongst the method in general. Figs. 2a-2f schematically depict some aspects in more detail, wherein the core-shell 3D printing is further schematically elucidated.

Fig. 2a is essentially the same as Fig. 1a. However, some further details are shown. 3D printed item 1 has an item surface 252 defined by at least part of the 3D printed

material 202. The fused deposition modeling 3D printer 500 in this schematically depicted embodiment further comprises a coating system 510 for applying one or more starting materials 521 to at least a surface part 253 of the item surface 252 to form a polymeric coating 520 on the surface part 253. By way of example, the coating system 510 comprising a unit 511 for applying one or more starting materials 521, such as a spray unit. Further, the coating system 510 may comprise a crosslinking promotor system 512, such as e.g. a (UV) radiation unit, which may promote crosslinking of the one or more starting materials 521 on the item surface 252 to form the polymeric coating 520. The control system C may be configured to execute the method as defined herein.

Note that the item surface 252 may be the surface of the uncoated 3D item. However, on this item surface, also the polymeric coating 520 may be provided, whereby effectively the outer surface of the 3D item at that part of the 3D item is the surface of the polymeric coating 520. Hence, at the surface part 253 where the polymeric coating is provided, this part of the item surface is now translated to a new item surface which may be defined by the surface of the polymeric coating. The former item surface below the polymeric coating is herein also indicated as secondary surface 252''. The item surface where polymeric coating is available, and wherein the outer surface of the polymeric coating actually provides the item surface may be indicated as primary item surface 252'. Where no polymeric coating 250 is available, the item surface 252 is defined by the 3D printed material. Where the polymeric coating 520 is available, the item surface 252 (or primary item surface 252') is defined by the polymeric coating 250 and the 3D printed material 202 (as the polymeric coating is available on the 3D printed material 202). Likewise, the surface part 253 where the coating is available may be indicated as secondary surface part 253'', and the surface part defined by the outer surface of the polymeric coating on that surface part 253'' (i.e. secondary surface part 253'') may be indicated as primary surface part 253', see also Fig. 2b.

Fig. 2b schematically depicts an embodiment of a coating 520 on the 3D printed material. Due to the possibly ribbed surface, the thickness d1 of the coating 520 may vary. Optionally, preceding to the coating stage, the 3D printed item surface may be flattened.

Fig. 2c schematically depicts an embodiment wherein two starting materials 521 are applied, which are deposited to form a layer 520' which may be converted into the polymeric layer 520 due to crosslinking. However, other embodiments may also be possible.

Fig. 3 schematically depicts an embodiment of a lamp or luminaire, indicated with reference 2, which comprises a light source 10 for generating light 11. The lamp may comprise a housing or shade or other element, which may comprise or be the 3D printed item 1.

5 The term “substantially” herein, such as “substantially consists”, will be understood by the person skilled in the art. The term “substantially” may also include embodiments with “entirely”, “completely”, “all”, etc. Hence, in embodiments the adjective substantially may also be removed. Where applicable, the term “substantially” may also relate to 90% or higher, such as 95% or higher, especially 99% or higher, even more
10 especially 99.5% or higher, including 100%. The term “comprise” includes also embodiments wherein the term “comprises” means “consists of”. The term “and/or” especially relates to one or more of the items mentioned before and after “and/or”. For instance, a phrase “item 1 and/or item 2” and similar phrases may relate to one or more of item 1 and item 2. The term “comprising” may in an embodiment refer to “consisting of” but
15 may in another embodiment also refer to “containing at least the defined species and optionally one or more other species”.

Furthermore, the terms first, second, third and the like in the description and in the claims, are used for distinguishing between similar elements and not necessarily for describing a sequential or chronological order. It is to be understood that the terms so used
20 are interchangeable under appropriate circumstances and that the embodiments of the invention described herein are capable of operation in other sequences than described or illustrated herein.

The devices herein are amongst others described during operation. As will be clear to the person skilled in the art, the invention is not limited to methods of operation or
25 devices in operation.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. Use
30 of the verb “to comprise” and its conjugations does not exclude the presence of elements or steps other than those stated in a claim. The article “a” or “an” preceding an element does not exclude the presence of a plurality of such elements. The invention may be implemented by means of hardware comprising several distinct elements, and by means of a suitably programmed computer. In the device claim enumerating several means, several of these

means may be embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

5 The invention also provides a control system that may control the apparatus or device or system, or that may execute the herein described method or process. Yet further, the invention also provides a computer program product, when running on a computer which is functionally coupled to or comprised by the apparatus or device or system, controls one or more controllable elements of such apparatus or device or system.

10 The invention further applies to a device comprising one or more of the characterizing features described in the description and/or shown in the attached drawings. The invention further pertains to a method or process comprising one or more of the characterizing features described in the description and/or shown in the attached drawings.

15 The various aspects discussed in this patent can be combined in order to provide additional advantages. Further, the person skilled in the art will understand that embodiments can be combined, and that also more than two embodiments can be combined. Furthermore, some of the features can form the basis for one or more divisional applications.

It goes without saying that one or more of the first (printable or printed) material and second (printable or printed) material may contain fillers such as glass and fibers which do not have (to have) influence on the on T_g or T_m of the material(s).

CLAIMS:

1. A method for producing a 3D item (1) by means of fused deposition modelling, wherein the method comprises:
 - (i) a 3D printing stage comprising layer-wise depositing an extrudate (321) comprising 3D printable material (201), to provide the 3D item (1) comprising 3D printed material (202), wherein the 3D item (1) comprises a plurality of layers (322) of 3D printed material (202), wherein the 3D item (1) has an item surface (252) defined by at least part of the 3D printed material (202), and
 - (ii) a coating stage comprising applying one or more starting materials (521) to at least a surface part (253) of the item surface (252) to form a polymeric coating (520) on the surface part (253), wherein the one or more starting materials (521) comprise two or more reactive materials (524) that are reactable with each other, and wherein the coating stage comprises reacting the two or more reactive materials (524) on the surface part (253) to provide the polymeric coating (520).
2. The method according to claim 1, wherein the one or more starting materials (521) comprise a crosslinkable material (521), and wherein the coating stage comprises crosslinking the crosslinkable material (521) on the surface part (253) to provide the polymeric coating (520).
3. The method according to any one of the preceding claims, wherein the polymeric coating (520) comprises one or more of a crosslinked polyurethane polymer, a crosslinked epoxide polymer, a crosslinked siloxane polymer, and a crosslinked acrylate polymer.
4. The method according to any one of the preceding claims, comprising spraying one or more of the one or more starting materials (521) to the surface part (253).
5. The method according to any one of the preceding claims, comprising coating one or more of the one or more starting materials (521) to the surface part (253).

6. The method according to any one of the preceding claims, comprising dip-coating one or more of the one or more starting materials (521) to the surface part (253).
- 5 7. The method according to any one of the preceding claims, comprising printing or jetting one or more of the one or more starting materials (521) to the surface part (253).
8. The method according to any one of the preceding claims, wherein the 3D printable material (201) and the 3D printed material (202) comprise one or more of
10 polycarbonate (PC), polyethylene (PE), high-density polyethylene (HDPE), polypropylene (PP), polyoxymethylene (POM), polyethylene naphthalate (PEN), styrene-acrylonitrile resin (SAN), polysulfone (PSU), polyphenylene sulfide (PPS), and semi-crystalline polyethylene terephthalate (PET), acrylonitrile butadiene styrene (ABS), poly(methyl methacrylate) (PMMA), polystyrene (PS), and styrene acrylic copolymers (SMMA), wherein the polymeric
15 coating (520) differs from the 3D printed material (202) in at least one or more of (i) the 3D printed material (202) not being crosslinked and the polymeric coating (520) being crosslinked, and (ii) the 3D printed material (202) and the polymeric coating (520) comprising different polymers.
- 20 9. A 3D item (1) obtained by means of fused deposition modelling, wherein the 3D item (1) comprises a plurality of layers (322) of a 3D printed material (202), wherein the 3D item (1) has an item surface (252), wherein a surface part (253) of the item surface (252) is defined by at least part of the 3D printed material (202) and a polymeric coating (520) on the at least part of the 3D printed material (202), and wherein the polymeric coating (520) is
25 obtained by reacting two or more reactive materials (524) with each other.
10. The 3D item (1) according to claim 9, wherein the polymeric coating (520) comprises one or more of a crosslinked polyurethane polymer, a crosslinked epoxide polymer, a crosslinked siloxane polymer, and a crosslinked acrylate polymer.
- 30 11. The 3D item (1) according to any one of the preceding claims 9-10, wherein the 3D printed material (202) comprise one or more of polycarbonate (PC), polyethylene (PE), high-density polyethylene (HDPE), polypropylene (PP), polyoxymethylene (POM), polyethylene naphthalate (PEN), styrene-acrylonitrile resin (SAN), polysulfone (PSU),

polyphenylene sulfide (PPS), and semi-crystalline polyethylene terephthalate (PET), acrylonitrile butadiene styrene (ABS), poly(methyl methacrylate) (PMMA), polystyrene (PS), and styrene acrylic copolymers (SMMA), wherein the polymeric coating (520) differs from the 3D printed material (202) in at least one or more of (i) the 3D printed material (202) not being crosslinked and the polymeric coating (520) being crosslinked, and (ii) the 3D printed material (202) and the polymeric coating (520) comprising different polymers.

12. A lighting device (1000) comprising the 3D item (1) according to any one of the preceding claims 9-11, wherein the 3D item (1) is configured as one or more of at least part of a lighting device housing, a wall of a lighting chamber, and an optical element.

13. A software product when running on a computer is capable of bringing about the method as described in any one of the preceding claims 1-8.

14. A fused deposition modeling 3D printer (500), comprising (a) a printer head (501) comprising a printer nozzle (502), and (b) a 3D printable material providing device (575) configured to provide 3D printable material (201) to the printer head (501), wherein the fused deposition modeling 3D printer (500) is configured to provide said 3D printable material (201) to a substrate (1550), thereby providing a 3D item (1) comprising 3D printed material (202), wherein the 3D item (1) has an item surface (252), wherein the fused deposition modeling 3D printer (500) further comprises (c) a coating system (510) for applying one or more starting materials (521) to at least a surface part (253) of the item surface (252) to form a polymeric coating (520) on the surface part (253), and (d) a control system (C), wherein the control system (C) is configured to execute the method according to any one of the preceding claims 1-8.

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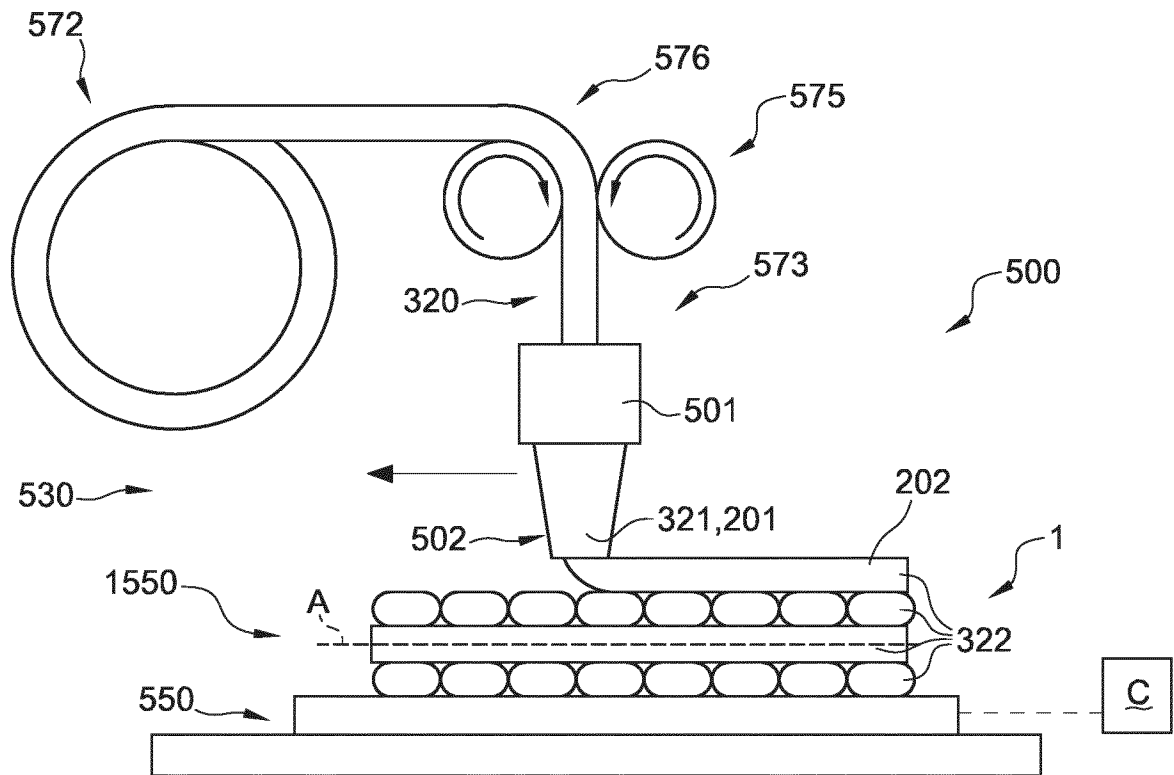


FIG. 1A

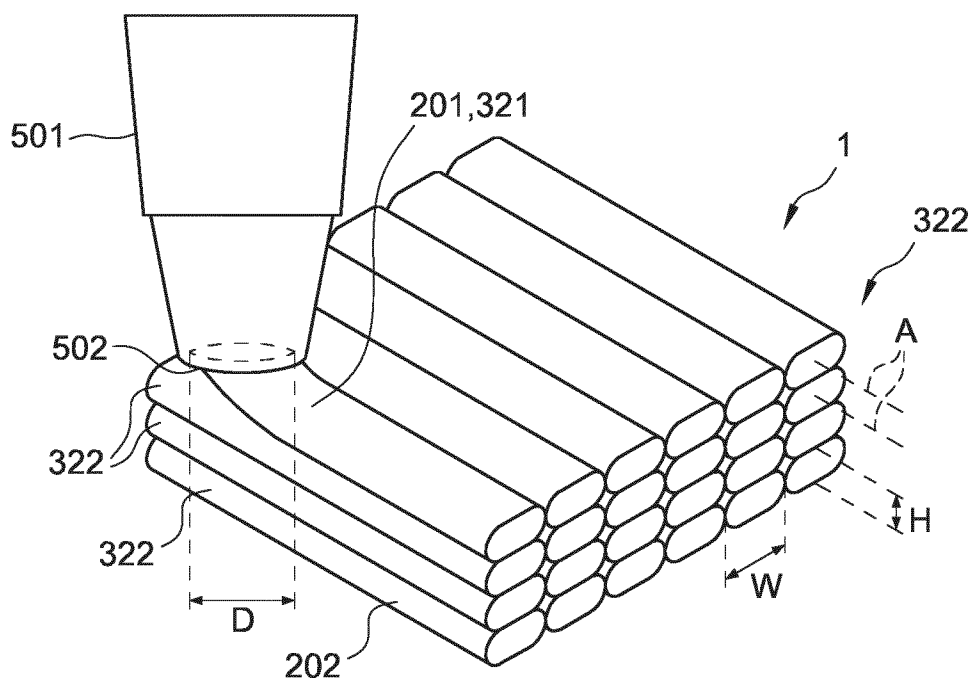


FIG. 1B

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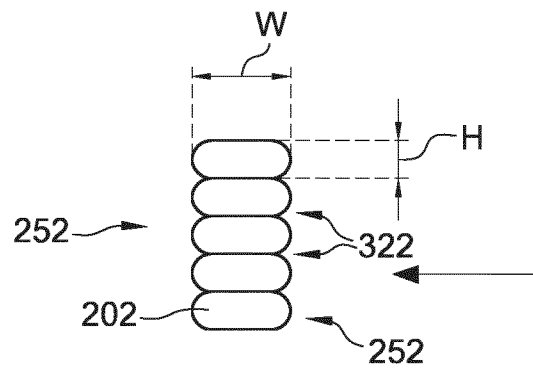


FIG. 1C

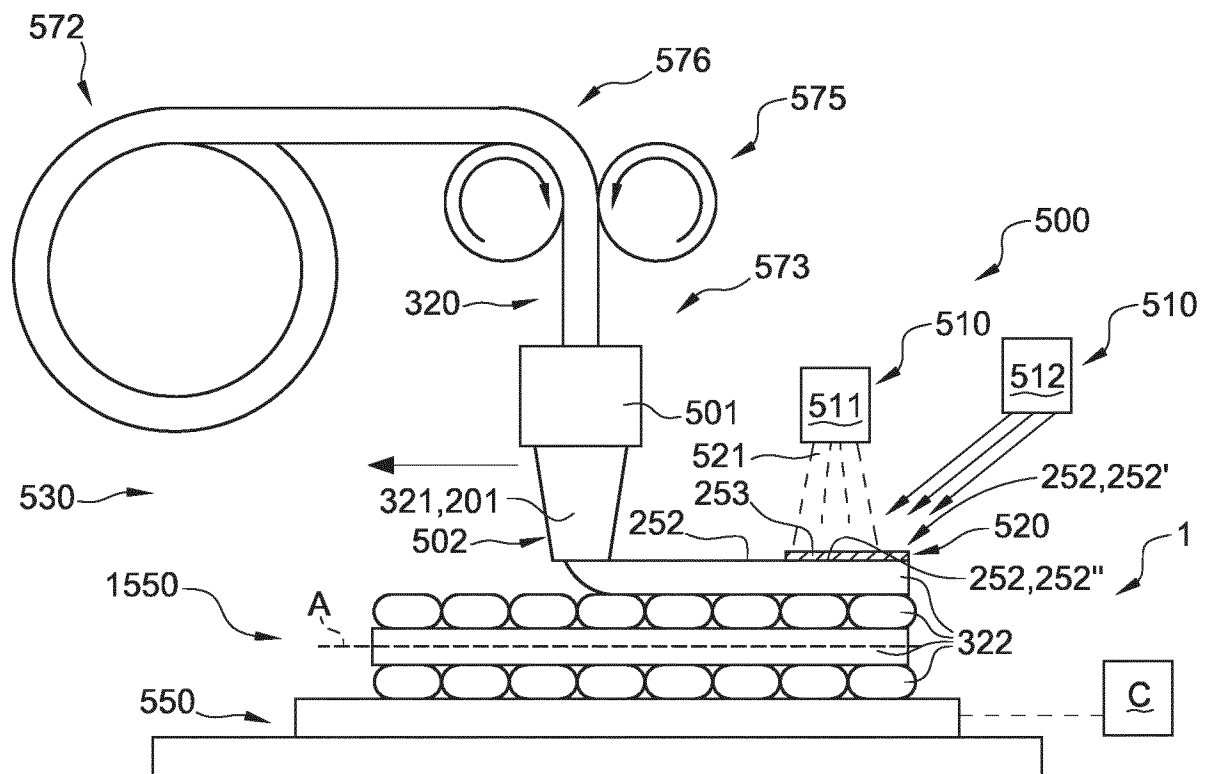


FIG. 2A

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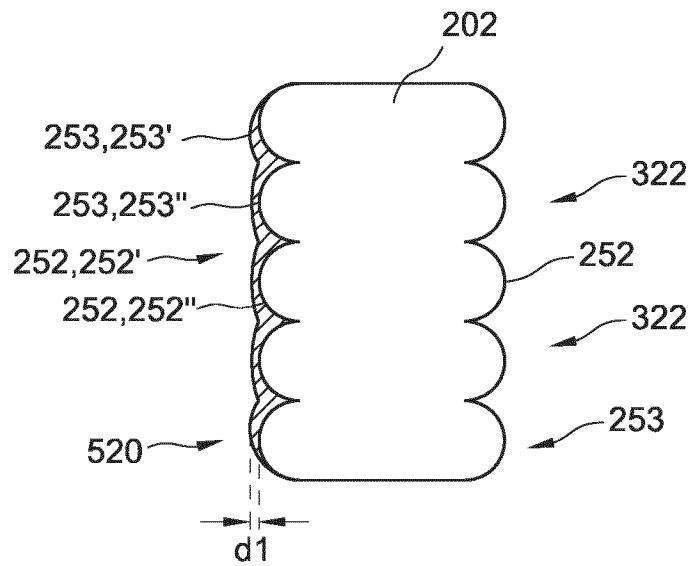


FIG. 2B

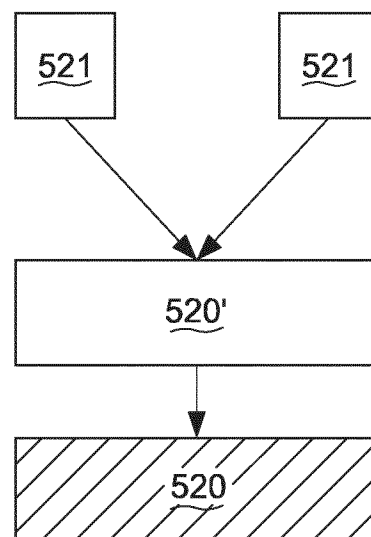


FIG. 2C

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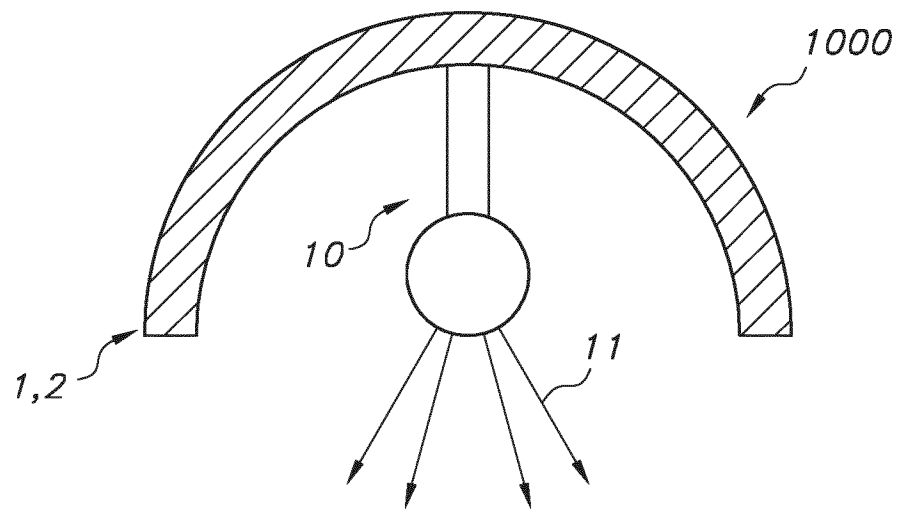


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/074602

A. CLASSIFICATION OF SUBJECT MATTER
INV. B29C64/118 B33Y10/00
ADD.

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)
B29C B33Y

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 practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2018/095753 A1 (PHILIPS LIGHTING HOLDING BV [NL]) 31 May 2018 (2018-05-31) page 8, lines 13-15; claims page 17, lines 24-31 page 4, lines 15-31 -----	1-14
A	WO 2012/058278 A2 (GILLER EUGENE [US]) 3 May 2012 (2012-05-03) paragraphs [0022], [0027], [0031], [0034], [0051] -----	1-14
A	US 2017/197341 A1 (WEINICK HOWARD LESLIE [US] ET AL) 13 July 2017 (2017-07-13) paragraphs [0028] - [0033] -----	1-14



Further documents are listed in the continuation of Box C.



See patent family annex.

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"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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Date of the actual completion of the international search

17 October 2019

Date of mailing of the international search report

25/10/2019

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Zattoni, Federico

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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