Innovation, Sciences et Développement économique Canada
Office de la Propriété Intellectuelle du Canada

Innovation, Science and Economic Development Canada
Canadian Intellectual Property Office

CA 2844134 C 2020/02/25

(11)(21) **2 844 134**

(12) BREVET CANADIEN
CANADIAN PATENT
(13) **C**

(86) **Date de dépôt PCT/PCT Filing Date**: 2012/08/02
(87) **Date publication PCT/PCT Publication Date**: 2013/02/07
(45) **Date de délivrance/Issue Date**: 2020/02/25
(85) **Entrée phase nationale/National Entry**: 2014/02/04
(86) **N° demande PCT/PCT Application No.**: EP 2012/003289
(87) **N° publication PCT/PCT Publication No.**: 2013/017278
(30) **Priorité/Priority**: 2011/08/04 (DE10 2011 109 368.4)

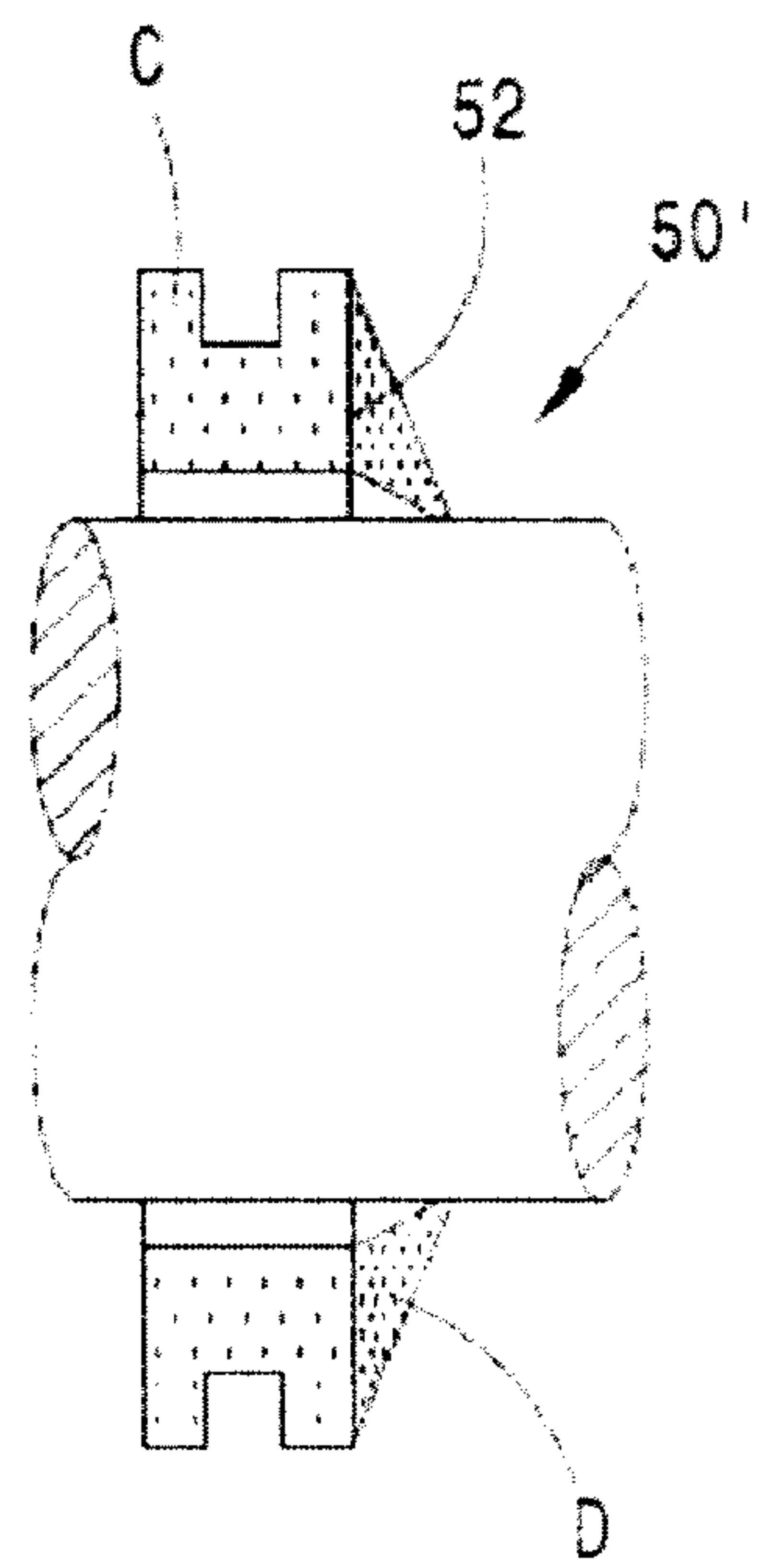
(51) **Cl.Int./Int.Cl.** *B29C 64/112* (2017.01)

(72) **Inventeurs/Inventors**:
KRAIBUHLER, HERBERT, DE;
DUFFNER, EBERHARD, DE

(73) **Propriétaire/Owner**:
ARBURG GMBH + CO. KG, DE

(74) **Agent**: BENOIT & COTE INC.

(54) Titre : PROCEDE DE FABRICATION D'UN OBJET TRIDIMENSIONNEL EN MATIERE DURCISSABLE AINSI QU'OBJET FABRIQUE AU MOYEN DE CE PROCEDE
(54) Title: METHOD FOR PRODUCING A THREE-DIMENSIONAL OBJECT FROM COMPACTABLE MATERIAL AND THE OBJECT PRODUCED THEREBY



(57) Abrégé/Abstract:
A method for producing a three-dimensional object through generative building in a direct build sequence from solidifiable material that occurs in its natural state as a fluid or which can be liquefied. To that end, a plurality of material components are discharged

(57) Abrégé(suite)/Abstract(continued):
through a plurality of alternately programmable discharge units and form, as a result of the discharge, adjoined various parts of the object (50, 50'), the geometric relationships attained during discharge already corresponding to the object (50, 50'). Because the material components (C, D) form among each other either limitless merging edge areas (51) or non-connecting, close running edge areas of the various material components, a method and hence a produced object can be provided, at which limits and border areas are formed between various material components "as from one section", even with complex geometries.

(12) NACH DEM VERTRAG ÜBER DIE INTERNATIONALE ZUSAMMENARBEIT AUF DEM GEBIET DES PATENTWESENS (PCT) VERÖFFENTLICHTE INTERNATIONALE ANMELDUNG

(19) Weltorganisation für geistiges Eigentum
Internationales Büro

(43) Internationales Veröffentlichungsdatum
7. Februar 2013 (07.02.2013)

WIPO | PCT

(10) Internationale Veröffentlichungsnummer
WO 2013/017278 A1

(51) Internationale Patentklassifikation: *B29C 67/00* (2006.01)

(21) Internationales Aktenzeichen: PCT/EP2012/003289

(22) Internationales Anmeldedatum: 2. August 2012 (02.08.2012)

(25) Einreichungssprache: Deutsch

(26) Veröffentlichungssprache: Deutsch

(30) Angaben zur Priorität: 10 2011 109 368.4 4. August 2011 (04.08.2011) DE

(71) Anmelder *(für alle Bestimmungsstaaten mit Ausnahme von US)*: **ARBURG GMBH + CO. KG** [DE/DE]; Arthur-Hehl-Strasse, 72290 Lossburg (DE).

(72) Erfinder; und
(75) Erfinder/Anmelder *(nur für US)*: **KRAIBÜHLER, Herbert** [DE/DE]; Unterbrändi 28, 72290 Lossburg (DE). **DUFFNER, Eberhard** [DE/DE]; Fichtenstrasse 2, 72181 Starzach (DE).

(74) Anwälte: **REINHARDT, Harry** et al.; Reinhardt & Pohlmann Partnerschaft, Grünstrasse 1, 75172 Pforzheim (DE).

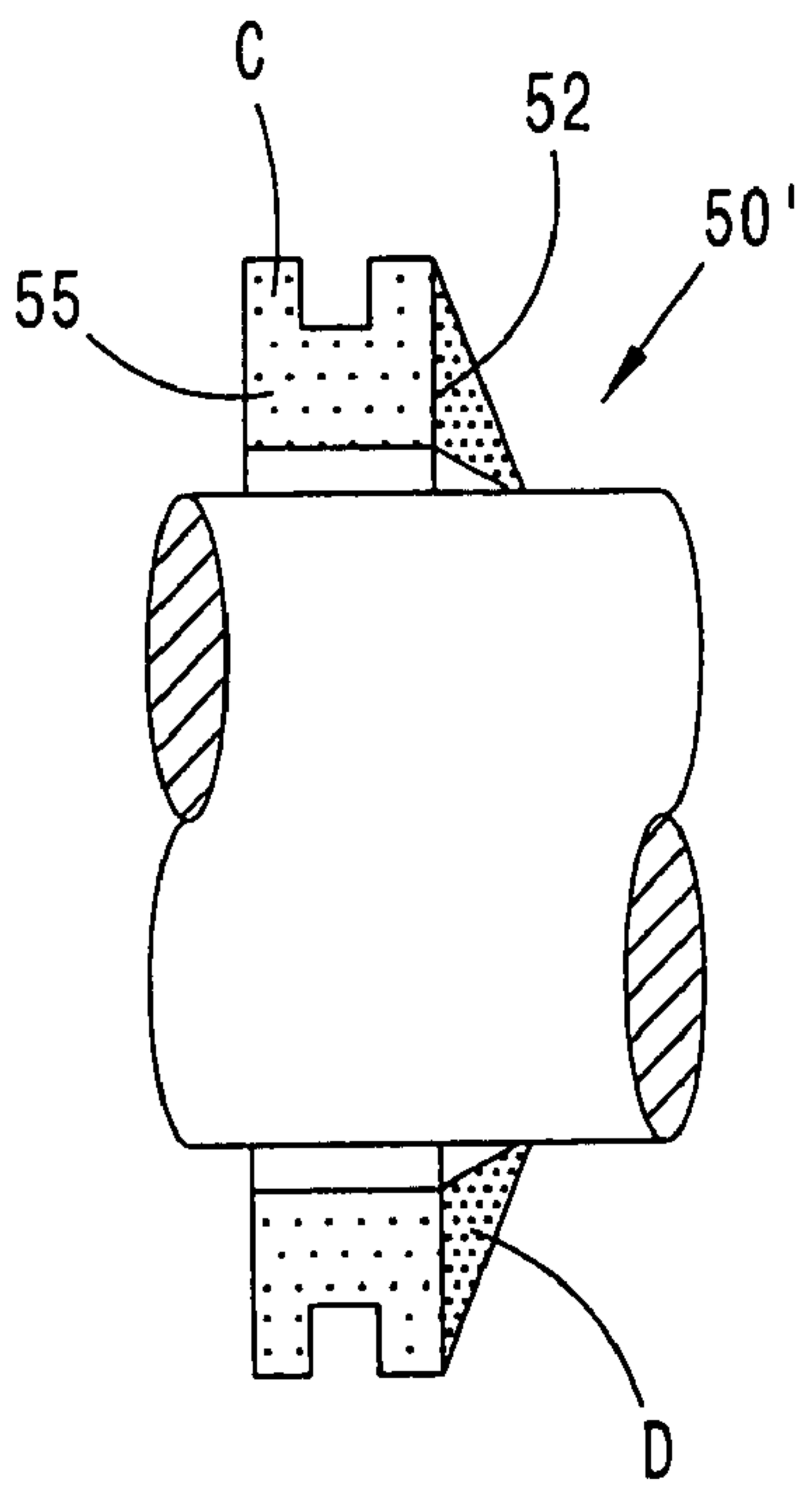
(81) Bestimmungsstaaten *(soweit nicht anders angegeben, für jede verfügbare nationale Schutzrechtsart)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

[Fortsetzung auf der nächsten Seite]

(54) Title: METHOD FOR PRODUCING A THREE-DIMENSIONAL OBJECT FROM COMPACTABLE MATERIAL AND THE OBJECT PRODUCED THEREBY

(54) Bezeichnung : VERFAHREN ZUR HERSTELLUNG EINES DREIDIMENSIONALEN GEGENSTANDES AUS VERFESTIGBAREM MATERIAL SOWIE DAMIT HERGESTELLTER GEGENSTAND

FIG.2



(57) Abstract: A method for producing a three-dimensional object through generative building in a direct build sequence from solidifiable material that occurs in its natural state as a fluid or which can be liquefied. To that end, a plurality of material components are discharged through a plurality of alternately programmable discharge units and form, as a result of the discharge, adjoined various parts of the object (50, 50'), the geometric relationships attained during discharge already corresponding to the object (50, 50'). Because the material components (C, D) form among each other either limitless merging edge areas (51) or non-connecting, close running edge areas of the various material components, a method and hence a produced object can be provided, at which limits and border areas are formed between various material components "as from one section", even with complex geometries.

(57) Zusammenfassung: Ein Verfahren dient zur Herstellung eines dreidimensionalen Gegenstandes durch generativen Aufbau in direkter Aufbaufolge aus verfestigbarem Material, das entweder im Ausgangszustand in einer fluiden Phase vorliegt oder verflüssigt werden kann. Dazu werden mehrere Materialkomponenten über mehrere Austragseinheiten programmierbar wechselnd ausgetragen und bilden durch das Austragen aneinandergefügt verschiedene Teile des Gegenstandes (50, 50') aus, wobei die beim Ausbringen erhaltenen geometrischen Verhältnisse bereits dem Gegenstand (50, 50') entsprechen.

[Fortsetzung auf der nächsten Seite]

WO 2013/017278 A1

WO 2013/017278 A1

(84) Bestimmungsstaaten *(soweit nicht anders angegeben, für jede verfügbare regionale Schutzrechtsart)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), eurasisches (AM, AZ, BY, KG, KZ, RU, TJ, TM), europäisches (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Veröffentlicht:

— *mit internationalem Recherchenbericht (Artikel 21 Absatz 3)*

Dadurch, dass die Materialkomponenten (C, D) untereinander entweder grenzenlos ineinander übergehende Randbereiche (51) oder nicht verbindend aneinander liegende Grenzbereiche der verschiedenen Materialkomponenten bilden, können ein Verfahren und ein damit hergestellten Gegenstand zur Verfügung gestellt werden, bei denen Grenz- und Randbereiche zwischen verschiedenen Materialkomponenten "wie aus einem Stück" auch bei komplexen Geometrien gebildet sind.

Method for Producing a Three-Dimensional Object from Compactable Material and the Object Produced thereby

Description

Relation to Related Applications

The present application claims the priority of German patent application 10 2011 109 368.4 filed on 04 August 2011.

Field of the Invention

The invention relates to a method for producing a three-dimensional object from a solidifiable material according to the preamble of claim 1 and also to an object produced therewith according to the preamble of claim 10.

Prior Art

In plastic part production, parts are produced by injection molding or extrusion in large batch sizes and series using molds. The advantage of plastic injection molding in particular rests especially on the highly precise production of complex part geometries, wherein the versatility of operation of the injection molding process covers the requirements for an inexpensive and economical production of plastic parts in an optimum manner. However, plastic injection molding reaches its limitations when materials that are not compatible with one another have to be processed or, in the case of positive-locking connections in particular, problems arise with removal from the mold.

At the same time, there is an ever-increasing demand for plastic parts in a unit number of one and small batch sizes such as pattern parts, for example, with the requirement of provision in a very short period as well as properties that are similar to those of injection molded parts. For the production of such parts there are production processes that are widely known by the term prototyping and rapid manufacturing. The production of such parts, in most cases, is based on generation of the geometry from 3D data without tools, i.e. without molds. These geometries are produced in a wide variety of shapes by appropriate means such as melting powder layers by the application of heat, e.g. by means of lasers, generative systems such as printing processes in a different connecting shape of the powder parts or also in the so-called melt extrusion process. In particular, the powder processes also reach their limitations when multiple different material components have to be processed next to one another.

A device, wherein a plasticising unit known in injection molding technology is coupled to a pressurisable material storage device for a liquid phase of a material, is known from EP 1 886 793 A1. To generate an object on an object support, this material is discharged in the form of drops there through a discharge opening. Because of the adhesion forces of the material a high pressure and high melting temperatures are necessary for the material, especially as the drop must have a size of 0.01 to 0.05 mm^3 to obtain an appropriate surface quality. Different parts of the object are already joined to one another as a result of the discharging of the drops. The geometric proportions obtained during discharge are substantially retained during the production process and already correspond to the object. It is already proposed there, paragraphs [0016] and [0035], to discharge dif-ferent material components by means of multiple discharge units so that they mix with one another at the impact point without separating. The aim in this case is a mixing of material. Boundary regions of different materials or the use of reactive multicomponents can thus be realised efficiently.

A laser sintering process, in which metal powder layers are welded to one another by heat application by means of lasers, is known from DE 692 06 357 T2. The supply of energy necessary for this enables the object and its geometry to be formed only after discharge of the material. The materials are welded or alloyed. This influences the final external geometry of the object. In the process a layered structure of a metal part is formed by selectively assembling layers by welding and by applying by plasma spraying virtually as a second component a very brittle auxiliary layer for the assembly process that serves as support structure for overhangs and also in order to minimise delays. After a layer is applied, this is milled in order to have a defined geometry plane for the next layer. In this welding process alloying materials can be fused together so that the boundary layer comprises an alloy of both materials.

Disclosure of the Invention

Starting from this prior art, the object of the present invention is to provide a method and an object produced therewith, in which boundary and edge regions are formed "as if from one piece" between different material components even in the case of complex geometries.

This solution enables direct edge layer regions to be generated with comparable firm connection with one another, as is otherwise only possible with the use of one material component, e.g. in the injection molding process. Fusing edge layers, which either merge into one another without boundaries and form a connecting structure, but which are nevertheless not joined and can form adjoining boundary regions, or also intermediate layers, as necessary, which can be activated later as a movable connection, are formed in quick alternation in the transition regions between different material components.

No combination of the plastic chains is formed in the boundary layer even in the case of compatible materials. Instead, a van der Waals electron bonding of the ends of the plastic chains of the individual materials can occur. Moreover, no microscopic mixing of the molecules occurs because of the relatively poor flowability of the plastic molecules. Therefore, in the plastics technology sense the boundary layer is not a compound but a boundary layer. This applies all the more in the case of incompatible materials, since this is then a matter of "point-microscopic positive-locking" of the connection.

Where necessary, it is also possible to use a material component so that it is configured as a support that can be detached later after the production of the object. As a result, overhangs can be generated on the object without any problem, while at the same time corresponding surfaces of the finished object can be produced by keeping to boundary regions or by the formation of intermediate layers. This enables production down to a unit number of one of objects that, on the one hand, have material properties that are better than those of injection molded parts, where necessary, but on the other hand, also have such complex geometries that they can be produced only with high expenditure with the injection molding process, if at all.

The use of appropriate intermediate layers, which are either detachable upon movement of the adjoining parts and/or form a sliding connection, also allows objects with complex geometries with undercuts such as e.g. universal joints or ball joints to be produced according to this method.

Further advantages are evident from the sub-claims and the following description.

Brief Description of the Figures

The invention is explained in more detail below on the basis of exemplary embodiments represented in the Figures.

Figure 1	shows an object produced from two material components with an edge region joining the two material components in a non-positive-locking manner;
Figure 2	shows a further object produced according to the method of the invention, on which a second material component is molded e.g. as a seal;
Figures 3a, 3b	show a ball and socket joint produced according to the method directly after production and in the state of use after after-treatment of an intermediate layer;
Figure 4	shows a device for producing an object by means of multiple material components.

Detailed Description of Preferred Exemplary Embodiments

The invention will now be explained in more detail in an exemplary manner with reference to the attached drawings. However, the exemplary embodiments are only examples that are not meant to restrict the inventive concept to a specific arrangement. Before the invention is described in detail, it should be noted that it is not restricted to the respective structural parts of the device or the respective method steps, since these structural parts and methods can vary. The terms used here are merely intended to describe particular embodiments and are not used for restriction. Moreover, when the singular or indefinite article is used in the description or in the claims, this also relates to the plural of these elements unless the overall context clearly indicates something different.

The Figures show different objects that are produced in accordance with the method. The method serves to produce a three-dimensional object such as rapid-prototype parts with the multicomponent process, wherein the object is produced in direct construction sequence using additive or generative construction. In this case, an additive or generative construction is understood to be a gradual construction generating the structural part, e.g. line by line or layer by layer of an object. In an extreme case this relates to construction drop by drop. In this case, "direct construction sequence" is understood to mean that the object is constructed point by point, irrespective of which material component must currently be output.

The solidifiable material, from which the three-dimensional object 50, 50' or the ball and socket joint 60 according to Figures 3a, 3b as object is produced, is present either in the starting state in a fluid phase or can be liquefied. The solidifiable material is a plasticised material such as silicone, for example, or a plasticizable material such as plastic or also materials in powder form, wherein substantially what matters is that the solidifiable material is present either in the starting state in a fluid phase or can be liquefied. The material can also be a material that is reversibly meltable under heat application and is therefore recyclable. In principle, all materials such as resins, thermoplastics, silicones and other support materials that allow an additive or generative construction are conceivable. Since a plasticising unit known in injection molding technology is preferably used for processing the solidifiable material as plasticised or plasticizable material, a standard commercially available material or a material used during injection molding can be used to produce the parts. A special extra material is therefore not necessary.

The discharge of the solidifiable material can occur either sequentially in the form of drops from a discharge opening of at least one timed or clocked discharge unit 12', as is known, for example, from EP 1 886 793 A1. However, a discharge in strands from a discharge unit can also occur, wherein combinations of both discharge methods are possible for faster part formation. Multiple discharge units, but at least multiple material storage devices, are preferably provided that alternately discharge drops as the smallest discharge quantity in a programmable manner. Different parts of the object 50, 50' are thus already joined to one another as a result of the discharge. Thus, the geometric proportions already corresponding to the object 50, 50' are preferably already formed during the discharge of the material in particular the drops.

The discharge unit 12' according to Figure 4 is actually known from EP 1 886 793 A1 By discharging drops from the discharge unit 12' the object 50 is created layer by layer on an object support 13, which is movable on a construction table 113 in the three spatial directions.

A fibre element, which is embedded into the solidifiable material at the point of impact, can be additionally supplied, where required, by means of a fibre feed device controlled by a fibre control device. The discharge unit 12' connects to a material storage device 18, 18' for each material component and material processed by a processing unit is fed under pressure to the material storage device by means of a pressure generating unit. By means of the preferably timed outlet the drops are generated and transported in a construction area for construction of the object 50, 50'. The discharge unit 12' is preferably a part of a plasticising unit, which is actually known in principle in injection molding technology and which at the same time also comprises the pressurisable material storage device for incorporating the fluid phase. The pressure on the fluid phase in the material storage device generates the drops by direct coupling.

Multiple material components A, B or C, D are discharged by means of multiple discharge units 12' and at least from multiple material storage devices 18, 18'. The material components respectively form parts of the object 50, 50' to be produced, as is clearly shown in Figures 1, 2. Since the construction occurs in direct construction sequence, in the case of multiple discharge units a different material for the construction of the object can be discharged in any desired sequence, i.e. layer for layer or line for line and down to droplet by droplet. This discharge can change in a programmable manner, i.e. depending on the program settings and thus on the geometry of the object, different materials can be placed alternately next to one another down to the smallest discharge quantity of a drop and thus drop by drop. Thus, in Figure 1, for example, edge regions 51 that virtually fuse together and merge into one another without boundaries are formed between the different material components A, B. This leads to a connecting structure such as only results when using only one material or one material component in a single process. Thus, in relation to the drop size a kind of positive-locking connection such as e.g. an interlocking connection occurs. However, it is also possible to form boundary regions 52 between the different material components that abut one another without joining. Figure 2 shows the molding of a seal composed of a softer material component D, for example, onto a further harder material component C, for example. Thus, materials, which as a result of van der Waals forces or because of reactive properties cannot otherwise be processed with one another, i.e. are not compatible, can also be placed next to one another.

The whole can be achieved, for example, by two discharge units synchronised with one another discharging the material components in any desired sequence. There can be an optimisation of this process, for example, in the synchronous production of multiple parts at a geometric spacing, in which the travel movement paths of the discharge units are minimised. In principle, it is recommended that the outlets of the two discharge units or the material storage devices 18, 18' lie closely next to one another, so that little time passes possibly for a travel movement during the change of material components. Thus, fusing edge layers can be formed in the edge region in very quick alternation.

A material component forming an intermediate layer 53 and configured as a separable connection between the materials adjoining the intermediate layer 53 can also be discharged in the edge region 51 or boundary region 52. Figure 3a shows a corresponding configuration for the case of the production of a ball and socket joint 60. The intermediate layer 53 is still recognisable in Figure 3a, whereas in Figure 3b it is replaced by a gap 54. As the structure forming the parts of ball 61 and socket 62 the material of the intermediate layer 53 can form a sliding connection and, as required, can also be used as a sliding means in the ball and socket joint. Thus, upon movement the intermediate layer 53 either disintegrates completely or remains as sliding means. It can be useful here to configure the boundary regions to abut one another without joining in order to obtain a geometrically closed surface of the parts that are later movable into one another. However, a connecting structure can also be configured to hold the sliding means in place. This shows what possibilities are made available to a person skilled in the art completely as required with this method. With this method a predetermined spacing or a clearance between the parts of the object adjoining the intermediate layer 53 is settable by means of the intermediate layer, i.e. the spacing can be changed in a programmable manner, where necessary, even from part to part, which is only possible with extremely high expenditure, for example, in the injection molding process.

Therefore, in principle, an object, in which multiple adjoining parts composed of different material components are present, is produced with the method or can be produced therewith. After the production the parts are joined to one another by a structure composed of different material components connecting them, wherein a structure results practically as in a production from one material. However, the material component can also be used so that it is discharged as a support for the further material components that is detachable after production of the object. In this case the boundary regions 52 are configured so that as good a surface quality of the object as possible results "behind" the support, wherein this geometry is already formed during discharge of the material. Thus, overhangs can also be easily formed on the object to be produced.

It is clearly understood that the material components do not have to be compatible with one another and can still be placed next to one another, as is possible, for example, with corresponding van der Waals forces. Use is also possible, for example, with different material properties such as in use of a material component that is hard in the state of use, for example, and a soft material component. In particular, the production of permanent connections but also the production of toothing or other non-positive and positive-locking connections are conceivable.

It is clearly understood that this description can be subject to a wide variety of modifications, changes and adaptations, which move into the realm of equivalents to the attached claims.

List of Reference Numerals

12'	discharge unit
13	object support
18, 18'	material storage device
50, 50'	object
51	edge region
52	boundary region
53	intermediate layer
54	gap
60	ball and socket joint
61	ball
62	socket
113	construction table
A, B, C, D	material components

Claims

1. A method for producing a three-dimensional object in direct construction sequence by additive construction from solidifiable material which can be liquefied,

   wherein in the direct construction sequence multiple material components are alternately discharged in a programmable manner by means of multiple discharge units under pressure from a material storage device, are placed alternately next to one another from drop to drop and configure different parts of the object already joined to one another as a result of the discharge,

   wherein the discharge unit is part of a plasticizing unit known per se in injection molding technology, which at the same time comprises the pressurizable material storage device for introducing the fluid phase, wherein the pressure in the material storage device generates the droplets in direct coupling,

   wherein the geometric proportions obtained during discharge already correspond to the geometry of the object in the final state, and

   wherein the material components form edge regions which merge with one another and melt together without boundaries as a connecting structure of different material components.

2. A method according to claim 1, wherein the droplets join together in a positive-locking manner.

3. A method according to claim 1 or 2, wherein a material component forming an intermediate layer is discharged in the edge region and is configured as a releasable connection between the materials adjoining the intermediate layer.

4. A method according to claim 3, wherein a predetermined spacing or a clearance between the parts of the object adjoining the intermediate layer is set by means of the intermediate layer.

5. A method according to any one of claims 1 to 4, wherein a material component is discharged as a support for the at least one further material component, which can be detached after production of the object.

6. A method according to any one of claims 1 to 5, wherein material components are placed side by side, which due to Van der Waals forces or due to reactive properties are otherwise not processable with each other, not compatible with each other, or both thereof.

7. An object, produced by a method according to any one of claims 1 to 6, comprising multiple adjoining parts, wherein after production the parts have a structure connecting them consisting of different material components fused together.

8. An object according to claim 7, wherein the structure connecting the parts forms a sliding connection or is an intermediate layer, which adjoins the parts and is detachable upon movement.

9. An object according to claim 8, wherein the intermediate layer forms a predetermined spacing or a clearance between the parts of the object adjoining the intermediate layer.

FIG.1

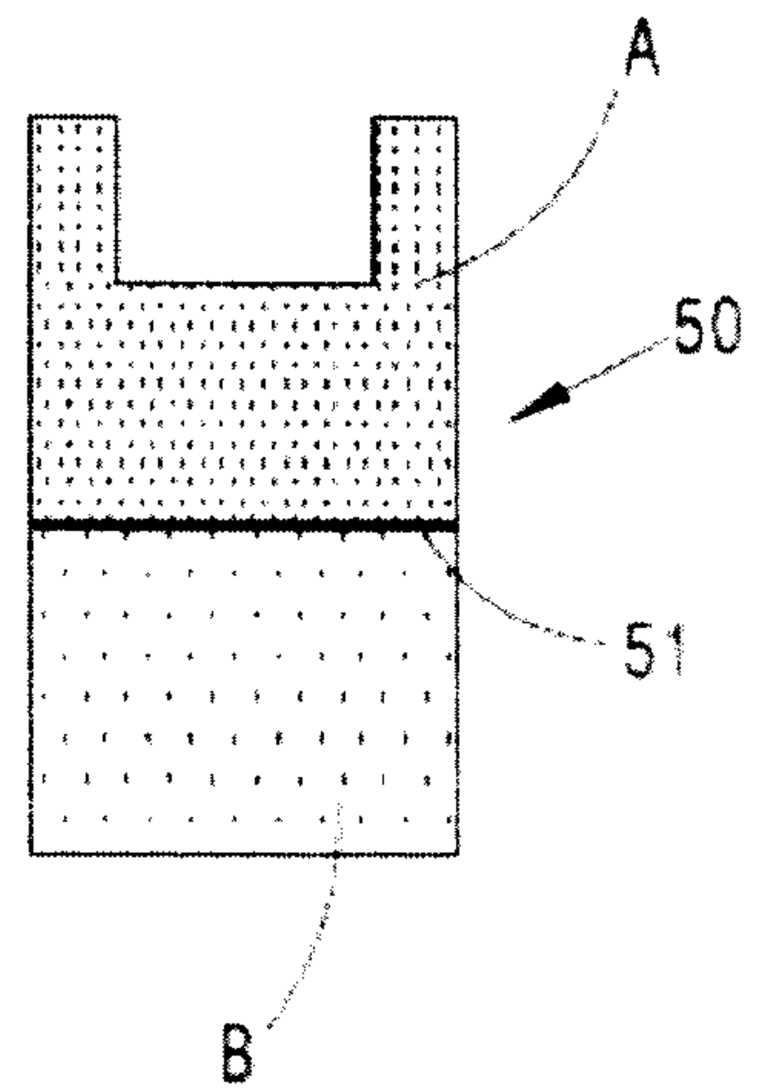


FIG.2

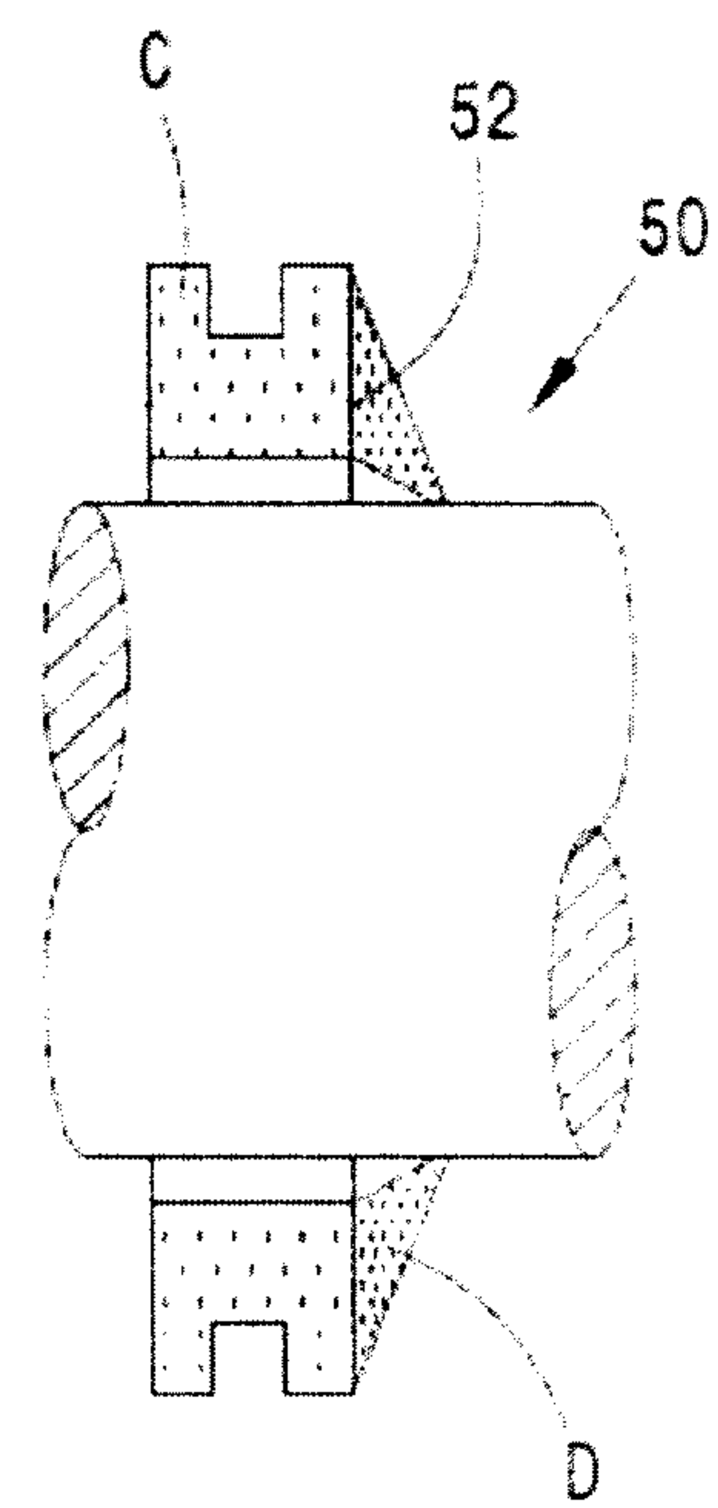


FIG.3a

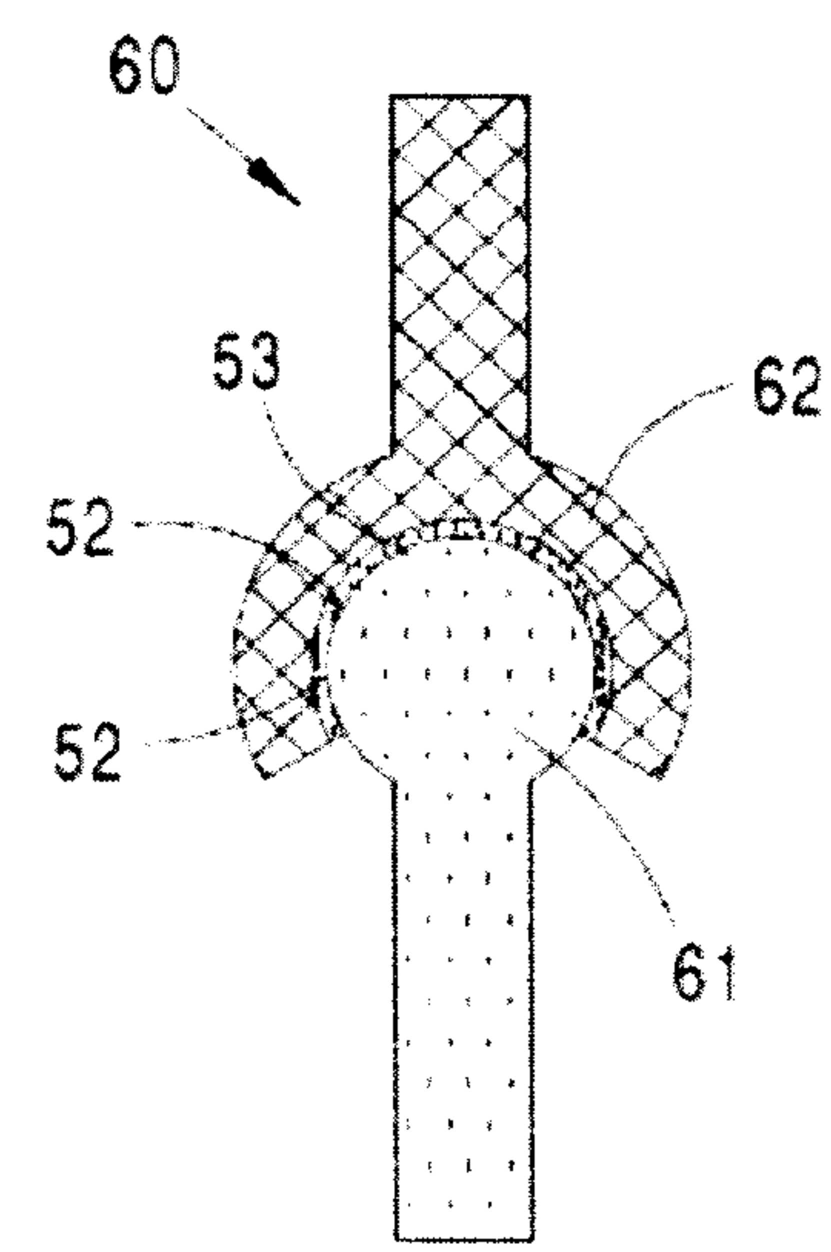


FIG.3b

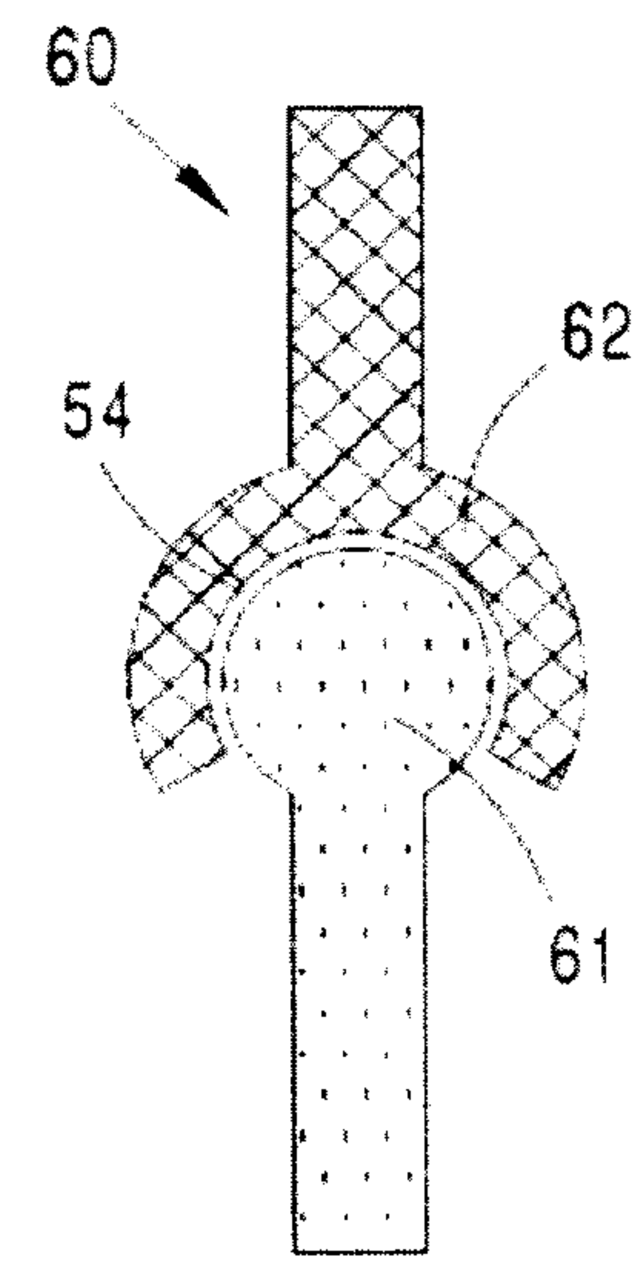


FIG.4

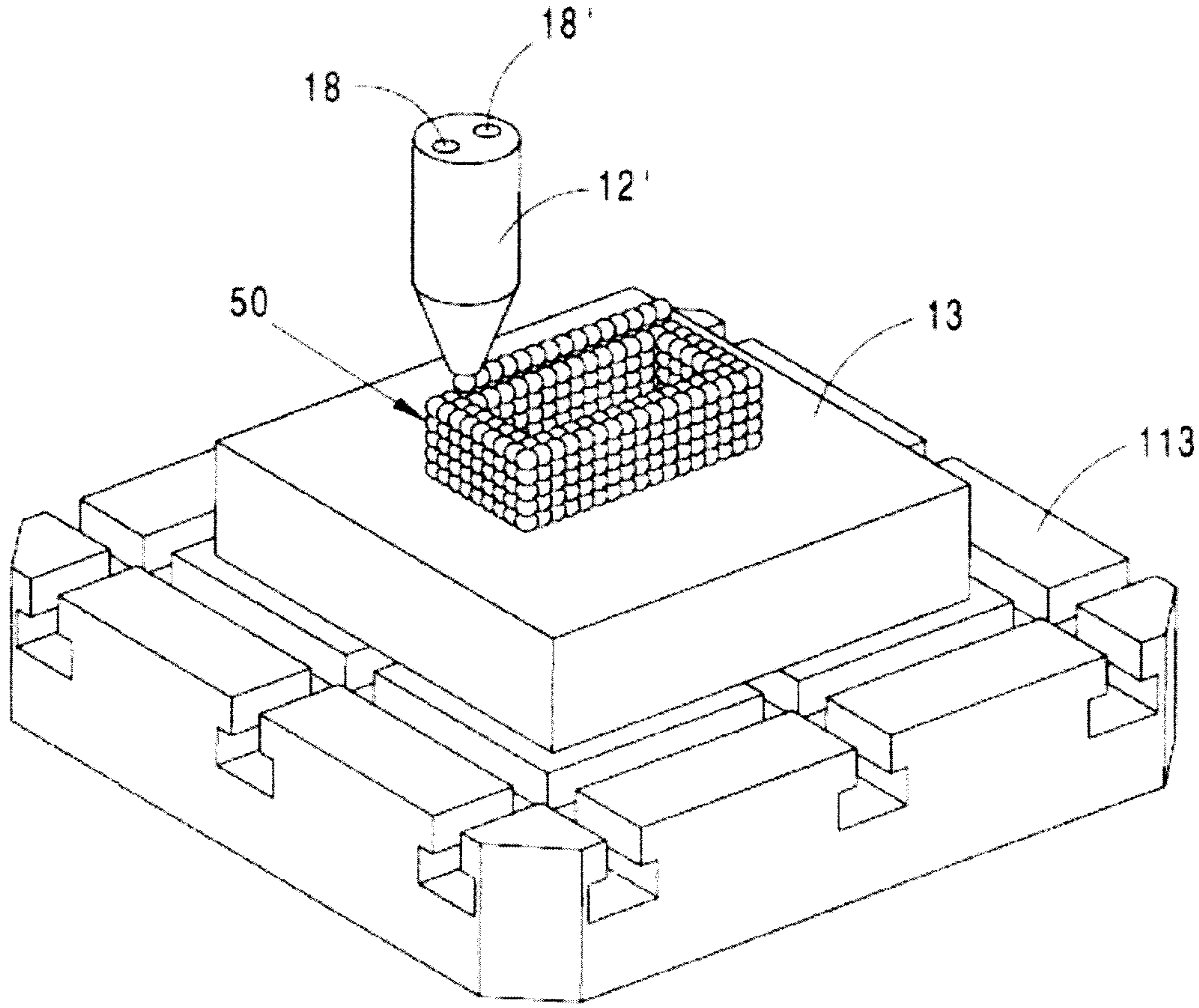


FIG.2