(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) **World Intellectual Property Organization**
International Bureau

(43) **International Publication Date**
14 February 2019 (14.02.2019)

WIPO | PCT

(10) **International Publication Number**
WO 2019/031979 A1

(51) **International Patent Classification:**
B33Y 30/00 (2015.01) ***B29C 64/295*** (2017.01)
B33Y 40/00 (2015.01) ***B29C 64/371*** (2017.01)
B29C 64/153 (2017.01) ***B29C 64/227*** (2017.01)
B29C 64/214 (2017.01) ***B29C 64/268*** (2017.01)
B29C 64/30 (2017.01)

(21) **International Application Number:**
PCT/RU2017/000581

(22) **International Filing Date:**
08 August 2017 (08.08.2017)

(25) **Filing Language:** English

(26) **Publication Language:** English

(71) **Applicant: SIEMENS AKTIENGESELLSCHAFT** [DE/DE]; Werner-von-Siemens-Strasse, 1, 80333 München (DE).

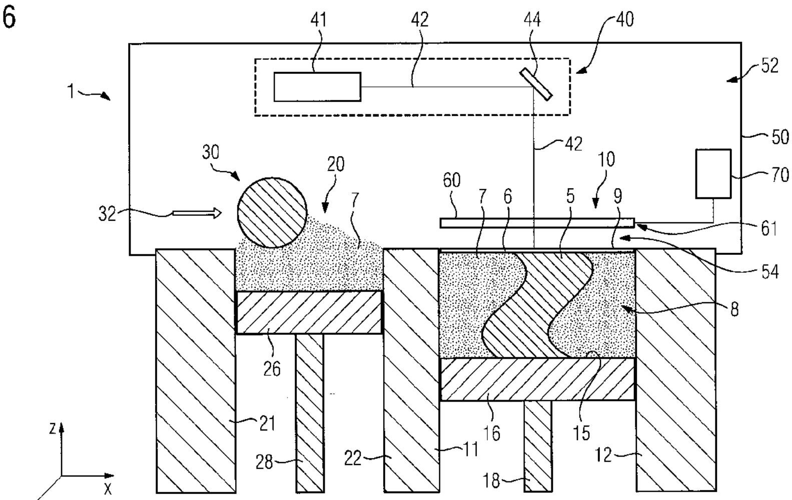
(72) **Inventors: NESTERENKO, Dmitry Leonidovich**; Karpinskogo, 33/1-301, St.Petersburg, 195273 (RU). **GRITCKEVICH, Mikhail Sergeevich**; bulvar Novatorov, 49-53, St.Petersburg, 198216 (RU).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: 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, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, 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.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ,

(54) **Title:** ADDITIVE MANUFACTURING APPARATUS WITH A HEAT SHIELD FOR CONTROLLING HEAT LOSSES FROM A POWDER BED

FIG 6



(57) **Abstract:** An additive manufacturing (AM) apparatus (1) including a part building module (10) having a build platform (16) to bound a powder bed (8), a build chamber (50), a powder supply module (20), a spreading mechanism (30), and a power beam arrangement (49). The AM apparatus (1) includes a heat shield (60) and a drive mechanism (70) for the heat shield (60). The heat shield (60) is changeable, by the drive mechanism (70), between a deployed position (61) and an idle position (62) realized by having different spatial orientations of the heat shield (60). When in the deployed position (61), the heat shield (60) is housed within the build chamber (50) and spatially oriented above a surface of the powder bed (8). The heat shield (60) in the deployed position (61) entraps heat lost from the surface of the powder bed (8), thereby reducing a temperature gradient.

WO 2019/031979 A1

[Continued on next page]

UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (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, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

ADDITIVE MANUFACTURING APPARATUS WITH A HEAT SHIELD FOR CONTROLLING HEAT LOSSES FROM A POWDER BED

The present invention relates to additive manufacturing (AM) and, in particular, to additive manufacturing apparatus having a heat shield for controlling heat losses from a powder bed.

Additive Manufacturing (AM), also known as Additive Layer Manufacturing (ALM), 3D printing, rapid prototyping or freeform fabrication, is a group of processes of joining additive materials, i.e. plastic, metal or ceramic, to make objects from 3D model data, usually building it up layer upon layer.

Additive manufacturing (AM) is a relatively new consolidation process that is able to produce a functional complex part, layer by layer, without moulds or dies. This process uses a powerful heat source in form of a power beam such as a laser beam or an electron beam to melt a controlled amount of additive material, for example metal in the form of metallic powder or wire, which is then deposited, initially, on a build platform of a part building module or a surface of a prefabricated workpiece placed on the build platform of the part building module. Subsequent layers are then built up upon each preceding layer. As opposed to conventional machining processes, this computer-aided manufacturing (CAM) technology builds complete functional parts or, alternatively, builds features on existing components i.e. on a workpiece, by adding material to the workpiece layer by layer rather than by removing it as is done in machining.

Additive manufacturing often starts by slicing a three dimensional representation, for example a CAD model, of a part to be manufactured into very thin layers, thereby creating a two dimensional image of each layer. As aforementioned the part to be manufactured may be a part that is built from beginning or may be a part that is to be built on a workpiece, for example during repairing of a chipped turbine blade the chipped turbine blade is the workpiece and the patch formed to fill or reform the chipped part is the part that is built on the workpiece. The workpiece is positioned on the build platform. To form each layer, popular laser additive manufacturing techniques such as selective laser melting (SLM) and selective laser sintering (SLS) involve mechanical pre-placement of a thin layer of metal powder of precise thickness on a surface of the workpiece and in adjoining horizontal surface above the build platform. Such pre-placement is achieved by using a mechanical wiper or by a powder spreading mechanism to sweep or spread a uniform layer of the powder or to screed the layer, after which an energy beam, such as a laser, is indexed across the powder layer, to selectively scan portions of the layer, according to the two dimensional pattern of solid material for the respective layer. After the indexing operation, i.e. the selective scanning is complete for the respective layer, the build platform, and, therefore, the horizontal plane of deposited material is lowered and the process is repeated until the three dimensional part is completely built on the workpiece as desired.

In order to protect the thin layers of fine metal particles from contaminants and from moisture pickup, the operation is usually performed under gases like nitrogen or an atmosphere of inert gas, e.g. argon. The inert gas is confined in a build chamber to form an inert gas environment or ambience. The build chamber also houses at least a part or a portion of the part build module and the build platform so that the additive manufacturing is carried out in the ambient gas environment.

Alternatively, when manufacturing the part from the beginning, no pre-placement of the workpiece on the build platform is required. A first layer of the part is manufactured by the additive manufacturing process in one of the layers, generally the first layer, of the powdered material spread on the build platform. Subsequent layers of the part are manufactured on top of the first layer of the part by the additive manufacturing process as aforementioned.

Nowadays the AM processes are widely used in aerospace and energy industries, medical applications, jewelry, etc. Selective Laser Melting (SLM) and Selective Laser Sintering (SLS), such as Direct metal laser sintering (DMLS), Direct metal laser melting (DMLM), are AM processes that use energy in the form of a high-power laser beam to create three-dimensional metal parts by fusing, or sintering in case of SLS, fine particles of thin powder layer together.

Although the SLM/SLS technologies become widely used in various applications, the SLM/SLS technologies have some limitations such as surface roughness, part accuracy, and the formation of layered residual stresses, which are reinforced by the high thermal gradients due to melting and solidification in a very short time. To control and vary the part properties and quality, the SLM/SLS technologies processing parameters, including laser power, laser scan speed, layer thickness, preheating and post-heating of the powdered bed, need to be varied and controlled.

During the SLM/SLS processes, high thermal gradients are present inside the parts because of the fast heating and cooling of the powdered material forming the part layer by layer. These thermal gradients lead to thermal stresses, which may cause residual stresses or even micro/macro cracks in the part that is built. To resolve these issues, preheating of the powdered bed, particularly of the layer of the powdered material that is to be melted or sintered, may be implemented, and thus during the building up of the part, the temperature differences within the powdered material will be lower, which results in lower thermal gradients. Preheating of the powder bed prior to the laser beam exposure provides beneficial effects during the SLM/SLS processes. Setting the temperature of the powder close to its melting point might save the energy induced by the laser and improve the wettability of the solid by the liquid phase i.e. of the underlying surface of the workpiece or of a layer formed in a previous step. In addition, preheating of the powder material reduces the thermal gradients and slows down the cooling rates within heat affected zone lowering susceptibility for residual stresses formation and cracking during solidification.

Additionally, reduction of the thermal gradients and slowing down of the cooling rates within heat affected zone is also achieved by post-heating associated with controlled cooling of the melted or sintered layer thereby also lowering susceptibility for residual stresses formation and cracking during solidification. Thus in general the rate of cooling of the melted or sintered layer is required to be slow, whether achieved with or without the pre/post heating of the powder bed, and particularly of the surface of the powder bed.

There are many pre/post heating techniques that are used in conventionally known AM systems – such as convectional heating of the powder bed using a heating element placed embedded within the build platform or by using Infrared heaters positioned above the powder bed. However, whether using the pre/post heating or not, none of the presently known AM techniques manage or regulate the cooling of the surface of the powder bed or of the melted or sintered portions of the surface of the powder bed that results from the convection flow of the gas forming the inert gas environment.

Fig 3 shows formation of convection currents within a build chamber 50 which confines an inert gas environment 52, also referred to as an ambient gas environment 52, in a conventionally known AM system 2. When a power beam 42 heats up a surface 9 of a layer 6 of a bed 8 of powdered material 7 during selective scanning and/or when a surface 9 of the layer 6 of the bed 8 of the powdered material 7 is heated up during pre/post heating of the bed 8, and particularly of the layer 6, the gas in vicinity of the surface 9, for example in a volume 53 within the build chamber 50, is heated up and becomes hotter relative to the gas present in parts or volumes within the build chamber 50, for example a volume 51 within the build chamber 50, that are away from the surface 9. As a result of the relative temperature difference between the gas in the volume 53 which is hotter and the gas in the volume 51 which is cooler, a convection flow is set up within the build chamber 50. The hotter gas from the vicinity of the surface 9, i.e. from the volume 53 rises up whereas the cooler gas from the other parts within the build chamber 50, i.e. from the volume 51 descends to replace the hotter gas in the volume 53. As a result, the surface 9 encounters cooler gas and is cooled resulting in establishment of the temperature gradient and also resulting in reduction of efficiency of pre/post heating, if used. Furthermore, some heat is also lost from the surface 9 of the bed 8 in form of radiations. Thus, there exists a need of a technique for regulating or controlling the heat losses from the surface 9 of the bed 8 of the powdered material 7 in form of convection flow established within the build chamber 50, and optionally also in form of radiations emitted from the surface 9 of the bed 8 within the build chamber 50.

Thus, an object of the present invention is to provide an additive manufacturing technique, in particular an additive manufacturing apparatus for controlling heat losses from powder bed.

The above object is achieved by an additive manufacturing apparatus according to claim 1 of the present technique. Advantageous embodiments of the present technique are provided in dependent claims.

The present technique presents an additive manufacturing apparatus. The additive manufacturing apparatus, hereinafter also referred to as the AM apparatus or simply as to the apparatus, includes a part building module, a build chamber, a powder supply module, a spreading mechanism, and a power beam arrangement. The part building module bounds a bed of powdered material. The part building module includes a build platform. The build platform receives the powdered material and supports the bed of powdered material. The build chamber defines a volume and confines an ambient gas environment within the volume. At least a part or a portion of the part building module is housed within the build chamber. The powder supply module provides the powdered material to the part building module. The spreading mechanism spreads the powdered material along a direction of spreading of the powdered material to form a layer of the powdered material on the build platform and/or on the bed of the powdered material. The layer thus formed is part of the bed of the powdered material or is the bed of the powdered material. The power beam arrangement emits a power beam and selectively scans portions of a surface of the layer of the bed by using the power beam to melt or sinter the selectively scanned portions.

According to the present technique, the AM apparatus further essentially includes a heat shield and a drive mechanism for the heat shield. The heat shield is moveable or changeable, by the drive mechanism, between two positions - a deployed position and an idle position. The drive mechanism may be, but not limited to, an electrical drive, a hydraulic drive, etc. A spatial orientation of the heat shield in the deployed position is distinct or different from a spatial orientation of the heat shield in the idle position. When in the deployed position, the heat shield is housed within the build chamber and spatially oriented above the surface of the layer of the bed of the powdered material. The bed of the powdered material is hereinafter also referred to as the powder bed. The heat shield in the deployed position functions to at least partially entrap any heat losses from the surface of the layer of the powder bed and/or from the selectively scanned portions of the surface of the layer of the powder bed. The heat is entrapped within a space between the heat shield in the deployed position and the surface of the layer of the powder bed.

The phrase 'above the surface' as used herein means over the surface or aloft the surface. The phrase 'above the surface' also includes over the surface or aloft the surface and without physically contacting the surface.

When selective scanning is performed at least parts of the surface of the powder bed is heated up which in turn heat up the ambient gas in the vicinity of the heated surface. The heat shield entraps the hot gas close to the heated surface, by at least stopping parts of the hot gas to move upwards within the build chamber and, thus, reducing the exchange with the relatively cold gas from upper parts of the building chamber, therefore, minimizing the heat losses of the scanned layer or the processed layer. The entrapment of the hot gas in the space between the heat shield in deployed position and the surface of the powder bed and at least partial obviation of entry of the relatively cooler gas from the upper parts of the build chamber into the space between the heat shield in deployed position and the surface of the powder bed decreases the temperature gradients. Furthermore, the heat shield in deployed position reflects and/or entraps at least a portion of any thermal radiations emitted from the surface of the powder bed or from the processed layer, i.e. from the layer of the powder bed that has been selectively scanned, towards the surface of the powder bed and thus resulting into heating of the selectively scanned layer, of the powder bed and of the additively manufactured part resulting from the selective scanning of the surface of the powder bed. This provides for passive pre/post heating which is known to be beneficial for additive manufacturing.

In the AM apparatus, when in the idle position the heat shield is spatially oriented by the drive mechanism such that the spreading of the powdered material by the spreading mechanism is not interfered or hindered by the heat shield or by any other structure or part from which the heat shield may be suspended. The drive mechanism may be positioned outside or inside the build chamber. When the drive mechanism is positioned inside the build chamber, the drive mechanism is positioned in such a way that the drive mechanism does not interfere or hinder the spreading of the powdered material by the spreading mechanism. Thus, action or function of the spreading mechanism is unhindered by the heat shield.

In an embodiment of the AM apparatus, the heat shield is a flat sheet shaped part and is configured to be parallelly disposed in the deployed position above the surface of the layer of the powder bed. In a related embodiment of the AM apparatus, in the deployed position the heat shield is configured to be at a distance between 10 mm and 100 mm from the surface of the layer of the powder bed. Hereinafter the surface of the layer of the powder bed is also referred to as the surface of the powder bed or simply to as the surface. One layer thickness is equal to a thickness of the layer spread on the build platform and/or on the powder bed. Furthermore in another related embodiment of the AM apparatus, the heat shield includes at least one, and preferably more, overhanging side. Each overhanging side emanates at an angle from the flat sheet shaped part of the heat shield. The overhanging side of the heat shield is disposed, in the deployed position of the heat shield, between the flat sheet shaped part of the heat shield and a plane of the surface of the powder bed. Thus, the space for entrapment of the heat is small compared to the volume defined by the build chamber which in turns keeps the heat closer to the surface of the powder bed, thereby increasing the efficiency of the additive manufacturing process performed by the AM apparatus of the present technique.

In another embodiment of the AM apparatus, the heat shield is changeable between the deployed position and the idle position by a translation movement, i.e. a rectilinear movement, along an axis perpendicular to the surface of the powder bed. Additionally, the AM apparatus includes at least one guide system, for example a guide rail, to guide the translation movement of the heat shield. Thus, the heat shield can be simply lowered or raised to attain the deployed position or the idle position. The translational movement is easy to realize and makes the manufacturing and/or assembling of the AM apparatus simple.

In another embodiment of the AM apparatus, in the deployed position and in the idle position the heat shield is spatially oriented parallel to the surface of the powder bed. In this embodiment the heat shield is changeable between the deployed position and the idle position by a rotational movement and/or translational movement of the heat shield parallel to the surface of the powder bed. Thus the heat shield can be swung or slid into the deployed position from the idle position, and vice versa. The swinging and sliding motions are easy to realize and makes the manufacturing and/or assembling of the AM apparatus simple.

In another embodiment of the AM apparatus, in the deployed position the heat shield is spatially oriented parallel to the surface of the powder bed, wherein in the idle position the heat shield is spatially oriented at an angle to the surface of the powder bed. In this embodiment the heat shield is changeable between the deployed position and the idle position by a pivotal movement of the heat shield. Optionally, the angle is 90 degree. Thus, the heat shield can be realized as a flap hinged or attached on one side only and can be moved between the deployed position and the idle position to cover and uncover above the surface of the powder bed by swinging or pivoting the heat shield around the hinged side. The pivoting motion is easy to realize and makes the manufacturing and/or assembling of the AM apparatus simple.

In another embodiment of the AM apparatus, the heat shield is at least partially permeable to the power beam. The power beam arrangement directs the power beam to the surface the powder bed through the heat shield in the deployed position in order to selectively scan portions of the surface of the powder bed. The heat shield may be formed of a material which is at least partially permeable to the laser, and preferably substantially or completely permeable to laser, which does not get overheated while transmitting the laser energy through the material, and which withstands the conventional heating by the surrounding gas without significant thermal expansion, for example clear glass. In an embodiment, a clear glass with high capacity is used for example Fused quartz, Sodium borosilicate glass and other thermal-resistant types of glass. In another embodiment, a colored glass shield is used. Since the colored glass transmits only the electromagnetic waves with the wavelength which corresponds to the glass' color, such glass does not get substantially heated while transmitting the laser with the relevant wavelength. With the heat shield in deployed position while selectively scanning portions of the surface of the powder bed, the heat losses from any parts of an immediately scanned area of the surface of the powder bed is entrapped by the heat shield. Moreover, since the heat shield is not required to be moved into idle position during selective scanning, and is required to be moved into the idle position only during spreading of the layer by the spreading mechanism, the operation of the AM apparatus of the present technique is simple.

In another embodiment, the AM apparatus includes a heating mechanism for heating the powder bed, particularly the layer of the powder bed, before and/or after the selective scanning, by the power beam arrangement, of the portions of the surface of the powder bed. The heating mechanism may comprise one of a heating element, an Infra-red heater, an energy beam pre-heating arrangement, an Induction heating arrangement, and a combination thereof. The pre/post heating of the powder bed is, thus, realized with the help of the heating mechanism. The heat shield by entrapping the heat lost from the surface of the powder bed enhances the pre/post heating efficiency.

The present technique is further described hereinafter with reference to illustrated embodiments shown in the accompanying drawing, in which:

FIG 1 schematically illustrates a top view of a conventionally known additive manufacturing system;

FIG 2 schematically illustrates a side view of the conventionally known additive manufacturing system of FIG 1;

FIG 3 schematically illustrates a part of a build chamber of the conventionally known additive manufacturing system of FIG 1 depicting convectional flow within the build chamber;

FIG 4 schematically illustrates a top view of an additive manufacturing apparatus having a heat shield, according to the present technique;

FIG 5 schematically illustrates a side view, as viewed from a direction perpendicular to a direction of spreading of the powdered material, of the additive manufacturing apparatus of FIG 4 with the heat shield in an idle position;

FIG 6 schematically illustrates the side view, same as FIG 5, of the additive manufacturing apparatus of FIG 4 with the heat shield in a deployed position;

FIG 7 schematically illustrates another side view, as viewed along the direction of spreading of the powdered material, of the additive manufacturing apparatus of FIG 4 with the heat shield in the idle position;

FIG 8 schematically illustrates the side view, same as FIG 7, of the additive manufacturing apparatus of FIG 4 with the heat shield in the deployed position;

FIG 9 schematically illustrates a part of a build chamber of the additive manufacturing apparatus of FIG 4 depicting an exemplary embodiment of the functioning of the heat shield when in the deployed position of FIG 8;

FIG 10 schematically illustrates spatial orientation of the heat shield when in the deployed position of FIG 8 with respect to a surface of the bed of powdered material;

FIG 11 schematically illustrates an exemplary embodiment of the heat shield as a flat sheet shaped part;

FIG 12 schematically illustrates another exemplary embodiment of the heat shield having two overhanging sides;

FIG 13 schematically illustrates another exemplary embodiment of the heat shield having four overhanging sides;

FIG 14 schematically illustrates spatial orientation of an exemplary embodiment of the heat shield having overhanging sides;

FIG 15 schematically illustrates an exemplary embodiment of spatial orientations of the heat shield in the idle and deployed positions and further depicts schemes of movement of the heat shield from the idle position to the deployed position and vice versa;

FIG 16 schematically illustrates another exemplary embodiment of spatial orientations of the heat shield in the idle and deployed positions and further depicts a scheme of movement of the heat shield from the idle position to the deployed position and vice versa;

FIG 17 schematically illustrates an exemplary embodiment of a side view of the additive manufacturing apparatus having a heating element for direct conductive heating;

FIG 18 schematically illustrates an exemplary embodiment of a side view of the additive manufacturing apparatus having an infra-red heater for infra-red heating;

FIG 19 schematically illustrates an exemplary embodiment of a side view of the additive manufacturing apparatus having an energy beam pre-heating arrangement for laser-beam heating;

FIG 20 schematically illustrates an exemplary embodiment of a side view of the additive manufacturing apparatus having an induction coil for induction heating; and

FIG 21 schematically illustrates an exemplary embodiment the induction coil of FIG 20.

Hereinafter, above-mentioned and other features of the present technique are described in details. Various embodiments are described with reference to the drawing, wherein like reference numerals are used to refer to like elements throughout. In the following description, for purpose of explanation, numerous specific details are set forth in order to provide a thorough understanding of one or more embodiments. It may be noted that the illustrated embodiments are intended to explain, and not to limit the invention. It may be evident that such embodiments may be practiced without these specific details.

It may be noted that in the present disclosure, the terms "first", "second", etc. are used herein only to facilitate discussion, and carry no particular temporal or chronological significance unless otherwise indicated.

The basic idea of the present technique is to entrap heat lost from a surface of a powder bed by using a heat shield positioned in the vicinity of the surface of the powder bed.

FIG 1 schematically illustrates a top view of a conventionally known additive manufacturing system 2 and FIG 2 schematically illustrates a side view of the conventionally known additive manufacturing system 1 of FIG 1.

The conventionally known additive manufacturing system 2, hereinafter also referred to as the AM system 2 or simply as the system 2, generally includes a part building module 10, within which a part is build by additive manufacturing (AM) for example by SLM or SLS processes. The part building module 10, hereinafter also referred to as the module 10, is a container for example a box shaped or barrel shaped container and having a top side of the container open. FIG 2 represents such a container having side walls 11,12,13,14 and a bottom surface 15. The side walls 11,12,13,14 and the bottom surface 15 together define a space in which the part is built. The part may be build with or without a prefabricated workpiece or substrate. The space receives a workpiece 5 when the part is built onto the workpiece 5 for example as a part or integral addition to the workpiece 5. The workpiece 5 is an object that is supposed to be worked on by the AM system 2 and built upon by addition of layer after layer by a suitable AM process by adding layer after layer of powdered material 7. The workpiece 5 may also be understood as portions or layers of the part that is to be built and that are already built by the AM process in previous cycles of layer scanning. The powder material 7 is provided by a powder storage module 20, also known as the feed cartridge 20, that stores the powdered material 7, hereinafter also referred to as the powder 7. The powder 7 in the feed cartridge 20 is stored in an open top container having side walls 21,22 and a bottom 26. The bottom 26 is placed on top of a piston 28 that makes the bottom 26 slide or move in Z direction, as represented by the coordinate system shown in FIG 2.

When the piston 28 moves upwards in the Z direction, i.e. in a direction 29, the powder 7 from the container 20 is raised above and outside the container 20. The powder 7 is then spread as top surface 9 of a bed 8 of the powder 7 in the module 10 by using a powder spreading mechanism 30, hereinafter also referred to as the spreading mechanism 30 or simply as the mechanism 30, which evenly spreads a thin layer of the powder 7 in the module 10. The layer is spread in a direction 32 shown in FIG 2. Reference numeral 33 in FIG 1 presents an axis along the direction 32. The opposing walls 11, 12 of the module 10 are generally perpendicularly disposed to the axis 33. Usually the layer spread has a thickness of few micrometers, for example between 20 μm and 100 μm.

The module 10 binds the bed 8 of powdered material 7 limiting the bed 8 by the side walls 11,12,13,14 and the bottom surface 15. The bed 8 of the powdered material 7 is hereinafter also referred to as the powder bed 8. The module 10 also includes a build platform 16. The bottom surface of the container of the module 10 is formed by the build platform 16, hereinafter also referred to as the platform 16. The platform 16 receives and supports the powder bed 8 and also the workpiece 5, if any, which is positioned on the platform 16 embedded within the powder bed 8. The platform 16 is placed on top of a piston 18 that makes the platform 16 slide or move in Z direction, as represented by the co-ordinate system shown in FIG 2.

When the piston 18 moves downward in the Z direction, i.e. in a direction 19, the powder bed 8, along with the workpiece 5 when present, is lowered thereby creating a space at surface 9 of the container of the module 10 to accommodate the layer that is spread by the spreading mechanism 30. The layer so spread by the spreading mechanism forms the surface 9 of the powder bed 8 and also covers a surface 55 of the workpiece 5, if present.

It may be noted that although in FIGs 1 and 2 only one feed cartridge 20 and associated powder spreading mechanism 30 have been depicted, in some of the AM systems 2 there may be two such feed cartridges 20 and associated powder spreading mechanisms 30, one on each side of the module 10, such as on side of the opposing walls 11 and 12.

The system 2 also includes a power beam arrangement 40, also referred to as an energy beam arrangement 40. The power beam arrangement 40 generally has an energy source 41 from which an energy beam 42, also known as a power beam 42, such as a Laser beam 42 or an electron beam 42 is generated, and a scanning mechanism 44 that directs the beam 42 to specific selected parts of the surface 9 of the powder bed 8 to melt or sinter the selectively scanned portions to form the layers of the part 5 or onto the workpiece 5, if present. The specific portions of the surface 9 to which the beam 42 is directed are referred to as selectively scanned. The selections of portions that are to be scanned by the beam 42 by action of scanning mechanism 44 are based on a 3D model, for example a CAD model, of the part that has to be built.

When the part is being built on a preformed substrate or on previously scanned and thereby built layers of the part, the portions of the surface 9 that are selectively scanned by the beam 42 are generally limited on top of the surface 55 and thus are able to melt or sinter and be added to the surface 55 of the substrate or on the previously scanned and built layers of the part i.e. on the surface 55 of the workpiece 5. Once added to the workpiece 5, the portions of the layer so added form part of the workpiece 5.

As depicted in FIG 2, the module 10, or at least a part of the module 10, is housed within a build chamber 50. The build chamber 50 confines a gas (not shown) that forms an inert gas environment 52, also known as an ambient gas environment 52, within the build chamber 50.

The module 10, the feed cartridge 20, the spreading mechanism 30, and the energy beam arrangement 40, and the build chamber 50 along with the ambient gas environment 52 are well known in the art of additive manufacturing thus not described herein in further details for the sake of brevity.

FIGs 4, 5, 6, 7, and 8 schematically illustrate different views of an exemplary embodiment of an additive manufacturing apparatus 1 in accordance with the present technique. The additive manufacturing apparatus 1 of the present technique hereinafter also referred to as the AM apparatus 1 or simply as the apparatus 1, includes the module 10, the powder supply module 20 or the feed cartridge 20, the powder spreading mechanism 30, the power beam arrangement 40 and the build chamber 50 along with the ambient gas environment 52 as explained in reference to FIG 1. Additionally, the apparatus 1 includes a heat shield 60, and a drive mechanism 70 for the heat shield 60. The heat shield 60 is moveable or changeable, by the drive mechanism 70, between two positions - a deployed position 61 and an idle position 62. The view of FIG 5 is from a direction perpendicular to the direction 32 when the heat shield 60 is in the idle position 62, and FIG 7 depicts apparatus 1 of FIG 5, i.e. when the heat shield 60 is in the idle position 62, when viewed along and opposite to the direction 32. Similarly, the view of FIG 6 is from the direction perpendicular to the direction 32 when the heat shield 60 is in the deployed position 61, and FIG 8 depicts apparatus 1 of FIG 6, i.e. when the heat shield 60 is in the deployed position 61, when viewed along and opposite to the direction 32.

The drive mechanism 70 may be, but not limited to, an electrical drive, a hydraulic drive, etc. and functions to move the heat shield 60 from one spatial orientation to another within the build chamber 50. As shown in FIGs 5 and 7 in comparison to FIGs 6 and 8, a spatial orientation of the heat shield 60 in the idle position 62 is distinct or different from a spatial orientation of the heat shield 60 in the deployed position 61. When in the deployed position 61, the heat shield 60 is housed within the build chamber 50 and spatially oriented above a surface 9 of a layer 6 of the bed 8 of the powdered material 7, which has been spread by the spreading mechanism 30. The heat shield 60 in the deployed position 61 functions to at least partially entrap any heat lost from the surface 9 of the layer 6 of the powder bed 8 and/or from the selectively scanned portions of the surface 9 of the layer 6 of the powder bed 8.

The phrase 'above the surface 9' as used herein means over the surface 9 or aloft the surface 9. The phrase 'above the surface 9' also includes over the surface 9 or aloft the surface 9 and without physically contacting the surface 9.

FIG 9, in combination with FIGs 6 and 8, shows a scheme for heat entrapment within a space 54 between the heat shield 60 in the deployed position 61 and the surface 9 of the layer 6 of the powder bed 8. The surface 9 of the layer 6 of the powder bed 8 is hereinafter also referred to as the surface 9 of the powder bed 8, or simply to as the surface 9.

As shown in FIG 9, when selective scanning is performed and/or when pre/post heating is performed at least some parts of the surface 9 are heated up which in turn heat up the ambient gas in the vicinity of the heated surface 9. The hot gas from the vicinity of the surface 9 tends to move upwards. The heat shield 60 in the deployed position 61 being close to the surface 9 and covering at least a part of an expanse or area of the surface 9, and preferably spreading aloft the entire expanse or the entire area of the surface 9 entraps the hot gas and keeps the hot gas so entrapped close to the heated surface 9. The heat shield 60 in the deployed position 61 at least stops parts of the hot gas to move upwards within the build chamber 50 and thus reducing the exchange of the hot gas with the relatively cold gas from upper parts of the building chamber 50, for example from the volume 51 of FIG 3. Therefore, presence of the heat shield 60 in the deployed position 61 reduces the heat losses of the scanned layer or the processed layer 6 or of a pre-heated layer 6. The entrapment of the hot gas in the space 54 between the heat shield 60 in deployed position 61 and the surface 9 and at least partial obviation of entry of the relatively cooler gas from the upper parts of the build chamber 50 into the space 54 decreases the temperature gradients in the scanned parts, i.e. sintered or melted parts, manufactured by the AM apparatus 1. Furthermore, the heat shield 60 in deployed position 61 reflects and/or entraps at least a portion of any thermal radiations emitted from the surface 9 back towards the surface 9 and thus resulting into heating of the surface 9. This provides for passive pre/post heating of the surface 9.

As shown in FIG 5 and 7, in the AM apparatus 1, when the spreading mechanism 30 is required to spread onto the powder bed 8 a new layer 6, the heat shield 60 is moved into the idle position 62 by the drive mechanism 70. The drive mechanism 70 spatially orients the heat shield 60 into the idle position 62 such that the spreading of the powdered material 7 by the spreading mechanism 30 is not interfered or hindered by the heat shield 60. Furthermore, the heat shield 60 and any other structure or part from which the heat shield 60 may be suspended, for example shield holders 68 are positioned such that the spreading of the powdered material 7 by the spreading mechanism 30 is not interfered or hindered by the heat shield 60. Furthermore, the drive mechanism 70 may be positioned outside or inside the build chamber 50. When the drive mechanism 70 is positioned inside the build chamber 50, the drive mechanism 70 is positioned in such a way that the drive mechanism 70 does not interfere or hinder the spreading of the powdered material 7 by the spreading mechanism 30. Thus action or function of the spreading mechanism 30 is unhindered by the heat shield 60 when in the idle position 62.

As shown in FIGs 6 and 8, once the action of spreading of the powdered material 7 into the layer 6 by the spreading mechanism 30 is completed for each layer 6, the drive mechanism 30 spatially orients the heat shield 60 into the deployed position 61 such that the heat shield 60 functions to entrap any heat lost from the surface 9. The heat shield 60 may be spatially oriented into the deployed position 61 during selective scanning of the surface 9 by the power beam 42 and/or before or after the selective scanning of the surface 9 by the power beam 42, i.e. during pre-heating or post-heating stages during the AM process. Once the selective scanning of the surface 9 by the power beam 42 is complete and/or the pre-heating or post-heating of the layer 6 is complete, the heat shield 60 is moved from the deployed position 61 by the drive mechanism 70 to the idle position 62 of the heat shield 60. Thus during the AM process performed by the AM apparatus 1, the heat shield 60 is moved by the drive mechanism 70 to and fro between the deployed position 61 and the idle position 62.

FIGs 10, 11, 12, 13 and 14 depict different structural forms of the heat shield 60 and its relative orientation with respect to the surface 9 in the deployed position 61 of the heat shield 60. As shown in FIG 11, in an exemplary embodiment of the AM apparatus 1, the heat shield 60 is a flat sheet shaped part 63. The flat sheet shaped part 63 preferably covers the surface 9, i.e. when viewed along an axis 4 perpendicular to surface 9 as shown in FIGs 8 and 10, and when viewed towards the surface 9 from the heat shield 60 in deployed position 61, the heat shield 60 is superimposed or overlaid or overcasted on the surface 9. In other words the dimensions of the heat shield 60 in XY axis as shown in FIG 6 are same as the dimensions of the surface 9 in the XY axis.

As shown in FIG 10, the flat sheet shaped part 63 is configured to be parallelly disposed in the deployed position 61 of the heat shield 60 above the surface 9. In an embodiment of the AM apparatus 1, the heat shield 60, in the deployed position 61 the heat shield 60 is at a distance 59 from the surface 9. The distance 59 may be, but not limited to, between 10 mm and 100 mm. In another embodiment, the distance 59 is 100 layer thickness and 10,000 layer thicknesses i.e. between 100 times and 10,000 times of one layer thickness, wherein one layer thickness is equal to a thickness 3 of the layer 6 spread on the build platform 16 and/or on the powder bed 8.

As shown in FIGs 12 and 13, in combination with FIG 14, in another related embodiment of the AM apparatus 1, the heat shield 60 besides the flat sheet shaped part 63 includes at least one, and preferably more, overhanging sides 64. FIG 12 shows two such overhanging sides 64 whereas FIG 13 shows four such overhanging sides 64. Each overhanging side 64 emanates at an angle 65 from the flat sheet shaped part 63 of the heat shield 60. The angle 65 may be 90 degrees. The overhanging sides 64 may be formed integrally in one part with the flat sheet shaped part 63 or may be formed as separate part and then affixed to the flat sheet shaped part 63. In the example of FIG 13, the heat shield 60 resembles a box shape with four sides formed of the overhanging sides 64 and the top formed of the flat sheet shaped part 63. The box shaped heat shield 60 is open at the side opposite to the flat sheet shaped part 63.

FIG 14 shows the spatial orientation of the heat shield 60, and particularly of the flat sheet shaped part 63 and of the overhanging sides 64. The overhanging sides 64 of the heat shield 60 are disposed, in the deployed position 61 of the heat shield 60, between the flat sheet shaped part 63 of the heat shield 60 and the surface 9 of the powder bed 8, or a plane 69 of the surface 9 of the powder bed 8. The overhanging sides 64 may be aloft over the surface 9 or over the plane 69 as shown in FIG 14 thereby forming a partially enclosed volume defining the space 54. Alternatively, the overhanging sides 64 may rest on the side walls 11,12,13,14 of the module 10 thereby forming a partially, when the overhanging sides 64 are not present on all sides of the flat sheet shaped part 63, or a completely enclosed volume, when the overhanging sides 64 are present on all sides of the flat sheet shaped part 63 for example as depicted in FIG 13, between the heat shield 60 and the side walls 11,12,13,14 and the surface 9.

Hereinafter different techniques or schemes for moving the heat shield 60, by the drive mechanism 70, to and fro between the idle position 62 and the deployed position 61 are explained with reference to FIGs 7 and 8, FIG 15 and FIG 16.

As shown in FIGs 7 and 8, in an embodiment of the AM apparatus 1, the heat shield 60 is changeable between the deployed position 61 and the idle position 62 by a translation movement, i.e. a rectilinear movement, along the axis 4 perpendicular to the surface 9 of the powder bed 8. In this embodiment of the AM apparatus 1, the AM apparatus 1 may include at least one guide system 72, for example a guide rail 72, to guide the translation movement of the heat shield 60. In FIGs 7 and 8, arrows marked with reference numeral 98 and 99 represent directions of movement of the heat shield 60, when moving the heat shield 60 from the idle position 62 towards the deployed position 61, and when moving the heat shield 60 from the deployed position 61 towards the idle position 62. The shield holders 68 may be attached to the guide rails 72 and be moved by the drive mechanism 70 in order to realize the movement of the heat shield 60 between the deployed position 61 and the idle position 62.

As shown in FIG 15, in another embodiment of the AM apparatus 1, in the deployed position 61 and in the idle position 62 the heat shield 60 is spatially oriented parallel to the surface 9 of the powder bed 8. In this embodiment the heat shield 60 is changeable between the deployed position 61 and the idle position 62 by rotational movements as shown by the arrows 98 and 99 that represent movement of the heat shield 60 from the idle position 62 towards the deployed position 61 and from the deployed position 61 towards the idle position 62, respectively. The heat shield 60 may be rotated around an axis (not shown) parallel to the axis 4 of FIGs 7 and 8, fixed around a point (not shown), for example fixed about one of the corners (not shown) of the heat shield 60.

As also shown in FIG 15, in another embodiment of the AM apparatus 1, in the deployed position 61 and in the idle position 62 the heat shield 60 is spatially oriented parallel to the surface 9 of the powder bed 8. In this embodiment the heat shield 60 is changeable between the deployed position 61 and the idle position 62 by translation movements as shown by the arrows 98 and 99 that represent movement of the heat shield 60 from the idle position 62 towards the deployed position 61 and from the deployed position 61 towards the idle position 62, respectively. Thus, in this embodiment the heat shield 60 may be moved by the drive mechanism 70 to and fro between the idle position 62 and the deployed position 61 by gliding action of the heat shield 60 parallel to the surface 9.

As shown in FIG 16, in another embodiment of the AM apparatus 1, in the deployed position 61 the heat shield 60 is spatially oriented parallel to the surface 9 of the powder bed 8, wherein in the idle position 62 the heat shield 60 is spatially oriented at an angle 66 to the surface 9 of the powder bed 8. Optionally, the angle 66 is 90 degree. In this embodiment of the AM apparatus 1, the heat shield 60 is changeable between the deployed position 61 and the idle position 62 by a pivotal movement of the heat shield 60 as shown by the arrows 98 and 99 that represent pivotal movement of the heat shield 60 from the idle position 62 towards the deployed position 61 and from the deployed position 61 towards the idle position 62, respectively. Thus, the heat shield 60 is realized as a flap hinged or attached on one side 67 of the heat shield 60 and moved between the deployed position 61 and the idle position 62 to cover and uncover above the surface 9 of the powder bed 8 by swinging or pivoting the heat shield 60 around the hinged side 67.

As shown in FIGs 6 and 9, in another embodiment of the AM apparatus 1, the heat shield 60 is at least partially permeable to the power beam 42. The power beam arrangement 40 directs the power beam 42 to the surface 9 the powder bed 8 through the heat shield 60 in the deployed position 61 for selectively scanning portions of the surface 9 of the powder bed 8. The heat shield 60 may be formed of a material which is at least partially permeable to the power beam 42 e.g. laser, and preferably substantially or completely permeable to laser, which does not get overheated while transmitting the laser energy through the material, and which withstands the conventional heating by the surrounding gas without significant thermal expansion, for example clear glass. In an embodiment, a clear glass with high capacity is used as a material of the heat shield 60 for example Fused quartz, Sodium borosilicate glass and other thermal-resistant types of glass. In another embodiment, a colored glass shield is used as the material of the heat shield 60. Since the colored glass transmits only the electromagnetic waves with the wavelength which corresponds to the glass' color, such glass does not get substantially heated while transmitting the laser with the relevant wavelength.

The AM apparatus 1 may include a heating mechanism 80 as shown in different embodiment depicted schematically in FIG 17, FIG 18, FIG 19, and FIGs 20 and 21.

As depicted in FIG 17, the additive manufacturing apparatus 1 may include a heating element 81, as the heating mechanism 80, positioned underneath the surface 15 of the build platform 16. The heating element 81 may be embedded in the build platform 16 as depicted in FIG 17 or alternatively may be present beneath the build platform 16 in another embodiment (not shown). Any desired pre-heating or post heating of the powder bed 8 can be achieved by installing the heating element 81 embedded in or placed underneath the build platform 16. In this approach the build platform 16, and the powdered material 7 on top of the build platform 16, i.e. the powder bed 8, are heated up by conductive heating to the temperature between 65 percent and 90 percent of a liquidus temperature of the powdered material 7 present on top of the build platform 16. In order to prevent the excessive heating of the surrounding structure, passive cooling, for example use of insulation, as well as active cooling may be applied. The temperature of the build platform 16, and particularly of the surface 15 of the platform 16, and/or the surface 9 of the powder bed 8 may be constantly monitored, for example by a thermocouple probe (not shown) such that the pre-heating of the surface 9 of the bed 8, is maintained within a desired range.

As depicted in FIG 18, the additive manufacturing apparatus 1 may include an Infra-red heater 82, as the heating mechanism 80, positioned above build platform 16, and particularly above the powder bed 8. The infra-red heater 82 emits infra-red 83 from a position over top of the build platform 16 as depicted in FIG 18. Any desired pre-heating or post-heating of the powder bed 8 can be achieved by the infra-red heating. In this approach the surface 9 of the powder bed 8, and optionally the powdered material 7 in the feed cartridge 20, are heated up by infra-red heating to a desired temperature range.

As depicted in FIG 19, the additive manufacturing apparatus 1 may be equipped for laser-beam heating of the layer 6 of the powder bed 8. The additive manufacturing apparatus 1 may include an energy beam pre-heating arrangement 40′, as the heating mechanism 80, in addition to the power beam arrangement 40 depicted in FIG 2. The energy beam pre-heating arrangement 40′ generally has an energy source 41′ from which an energy beam 42′ or power beam 42′ such as a Laser beam 42′ or an electron beam 42′ is generated, and a scanning mechanism 44′ that directs the beam 42′ to specific selected parts of the surface 9 of the powder bed 8 to pre-heat portions of the surface 9 of the powder bed 8, i.e. to pre-heat portions of the surface 9 of the layer 6 that are subsequently to be scanned by the power beam arrangement 40 in order to be melted or sintered. The specific portions of the surface 9 to which the beam 42′ is directed by action of the scanning mechanism 44′ are based on the 3D model, for example the CAD model, of the part that has to be built. The power of the beam 42′ is regulated or maintained or fixed such that selected portions of the surface 9 of the powder bed 8 are heated up by laser-beam heating to a desired temperature range.

Alternatively, the apparatus 1 may not include the energy beam pre-heating arrangement 40′, and in such apparatus 1 the power beam arrangement 40 may function as the energy beam pre-heating arrangement 40′. Thus selected portions of the surface 9 of the powder bed 8 are scanned in two stages, the pre-heating stage and the melting/sintering stage by the power beam arrangement 40.

As depicted in FIGs 20 and 21, the additive manufacturing apparatus 1 may include an induction coil 84, as the heating mechanism 80, embedded in the walls 11,12,13,14 of the module 10. As a result, when the workpiece 5 is positioned on the build platform 16 and/or the layer 6 is spread on the build platform 16, the induction coil 84 surrounds the workpiece 5 and/or the layer 6 and thus induction heating of the workpiece 5 and/or the layer 6 is achieved. FIG 21 shows the induction coil 84 when not embedded in the walls 11,12,13,14 of the module 10, whereas FIG 20 shows the induction coil 84 embedded in the walls 11,12,13,14 of the module 10. The cross-section of the induction coil 84 is visible in FIG 20 along lines 95,96 schematically presented in FIGs 20 and 21. The inductive heating provides the pre-heating of workpiece 5 and/or the layer 6 to a desired temperature.

As aforementioned, besides the techniques for heating presented in FIGs 17 to 21, other suitable techniques may also be used that can provide pre-heating of the surface 9 of the layer 6 or of the powder bed 8 to a desired temperature.

While the present technique has been described in detail with reference to certain embodiments, it should be appreciated that the present technique is not limited to those precise embodiments. Rather, in view of the present disclosure which describes exemplary modes for practicing the invention, many modifications and variations would present themselves, to those skilled in the art without departing from the scope and spirit of this invention. The scope of the invention is, therefore, indicated by the following claims rather than by the foregoing description. All changes, modifications, and variations coming within the meaning and range of equivalency of the claims are to be considered within their scope.

LIST OF REFERENCE CHARACTERS

1	additive manufacturing apparatus
2	conventionally known system
3	thickness of the layer
4	axis perpendicular to the surface
5	work piece/substrate
6	layer
7	powdered material
8	bed of powdered material
9	surface
10	part building module
11	wall
12	wall
13	wall
14	wall
15	surface of the build platform
16	build platform
18	piston
19	direction of movement of the piston
20	powder supply module
21	side wall
22	side wall
26	powder platform
28	piston
29	direction of movement of the piston
30	spreading mechanism
32	direction of spreading of the powdered material
33	axis along the direction of spreading of the powdered material
40	power beam arrangement
40′	energy beam pre-heating arrangement
41	energy source
41′	energy source
42	power beam

42′ pre-heating power beam
44 scanning mechanism
44′ scanning mechanism
50 build chamber
51 cooler volume within the build chamber
52 ambient gas environment
53 hotter volume within the build chamber
54 space
55 surface of the work piece/substrate
56 direction of movement of cooler gas
58 direction of movement of hotter gas
59 distance
60 heat shield
61 deployed position
62 idle position
63 flat sheet shaped part
64 overhanging side
65 angle
66 angle
68 shield holders
69 plane of the surface
70 drive mechanism
72 guide system
80 heating mechanism
81 heating element
82 Infra-red heater
83 infrared radiation
84 Induction heating arrangement
95 line
96 line
98 direction of movement of the heat shield
99 direction of movement of the heat shield

PATENT CLAIMS:

1. An additive manufacturing apparatus (1) comprising:

- a part building module (10) configured to bound a bed (8) of powdered material (7) and comprising a build platform (16) configured to receive the powdered material (7) and to support the bed (8) of powdered material (7);

- a build chamber (50) configured to confine an ambient gas environment (52), wherein at least a portion of the part building module (10) is housed within the build chamber (50);

- a powder supply module (20) configured to provide the powdered material (7) to the part building module (10);

- a spreading mechanism (30) configured to spread the powdered material (7) along a direction (32) of spreading of the powdered material (7) to form a layer (6) of the powdered material (7) on the build platform (16) and/or on the bed (8) of the powdered material (7);

- a power beam arrangement (40) configured to emit a power beam (42) and to selectively scan portions of a surface (9) of the layer (6) of the bed (8) of the powdered material (7) by using the power beam (42) to melt or sinter the selectively scanned portions;

characterized in that,

the additive manufacturing apparatus (1) further comprises:

- a heat shield (60) and a drive mechanism (70) for the heat shield (60),

- wherein the heat shield (60) is configured to be changeable, by the drive mechanism (70), between a deployed position (61) and an idle position (62),

- wherein a spatial orientation of the heat shield (60) in the deployed position (61) is distinct from a spatial orientation of the heat shield (60) in the idle position (62), and

- wherein in the deployed position (61) the heat shield (60) is housed within the build chamber (50) and spatially oriented above the surface (9) of the layer (6) of the bed (8) of the powdered material (7) such that heat lost from the surface (9) of the layer (6) of the bed (8) of the powdered material (7) and/or from the selectively scanned portions of the surface (9) of the layer (6) of the bed (8) of the powdered material (7) is at least partially entrapped within a space (54) between the heat shield (60) in the deployed position (61) and the surface (9) of the layer (6) of the bed (8) of the powdered material (7).

2. The additive manufacturing apparatus (1) according to claim 1, wherein in the idle position (62) the heat shield (60) is spatially oriented by the drive mechanism (70) such that the spreading of the powdered material (7) by the spreading mechanism (30) is not interfered by the heat shield (60).

3. The additive manufacturing apparatus (1) according to claim 1 or 2, wherein the heat shield (60) is a flat sheet shaped part (63) and is configured to be parallelly disposed in the deployed position (61) above the surface (9) of the layer (6) of the bed (8) of the powdered material (7).

4. The additive manufacturing apparatus (1) according to claim 3, wherein in the deployed position (61) the heat shield (60) is configured to be at a distance (59) between 10 mm and 100 mm.

5. The additive manufacturing apparatus (1) according to claim 3 or 4, wherein the heat shield (60) comprises at least one overhanging side (64) emanating at an angle (65) from the flat sheet shaped part (63), and wherein the overhanging side (64) is configured to be disposed, in the deployed position (61) of the heat shield (60), between the flat sheet shaped part (63) and a plane (69) of the surface (9) of the layer (6) of the bed (8) of the powdered material (7).

6. The additive manufacturing apparatus (1) according to any of claims 1 to 5, wherein the heat shield (60) is configured to be changeable between the deployed position (61) and the idle position (62) by a translation movement along an axis (4) perpendicular to the surface (9) of the layer (6) of the bed (8) of the powdered material (7).

7. The additive manufacturing apparatus (1) according to claim 6, comprising at least one guide system (72) configured to guide the translation movement of the heat shield (60).

8. The additive manufacturing apparatus (1) according to any of claims 1 to 5, wherein in the deployed position (61) and in the idle position (62) the heat shield is configured to be spatially oriented parallel to the surface (9) of the layer (6) of the bed (8) of the powdered material (7), and wherein the heat shield (60) is configured to be changeable between the deployed position (61) and the idle position (62) by a rotational movement and/or translational movement of the heat shield (60) parallel to the surface (9) of the layer (6) of the bed (8) of the powdered material (7).

9. The additive manufacturing apparatus (1) according to any of claims 1 to 5, wherein in the deployed position (61) the heat shield (60) is configured to be spatially oriented parallel to the surface (9) of the layer (6) of the bed (8)

of the powdered material (7) and in the idle position (62) the heat shield (60) is configured to be spatially oriented at an angle (66) to the surface (9) of the layer (6) of the bed (8) of the powdered material (7), and wherein the heat shield (60) is configured to be changeable between the deployed position (61) and the idle position (62) by a pivotal movement of the heat shield (60).

10. The additive manufacturing apparatus (1) according to claim 9, wherein the angle (66) is 90 degree.

11. The additive manufacturing apparatus (1) according to any of claims 1 to 10, wherein the heat shield (60) is at least partially permeable to the power beam (42), and wherein the power beam arrangement (40) is configured to direct the power beam (42) to the surface (9) of the layer (6) of the bed (8) of powdered material (7) through the heat shield (60) in the deployed position (61) to selectively scan portions of the surface (9) of the layer (6) of the bed (8) of the powdered material (7).

12. The additive manufacturing apparatus (1) according to any of claim 1 to 11, wherein a material of the heat shield (60) comprises one of a clear glass, Fused quartz, Sodium borosilicate glass, and a glass selectively permeable to a predetermined range of wavelength.

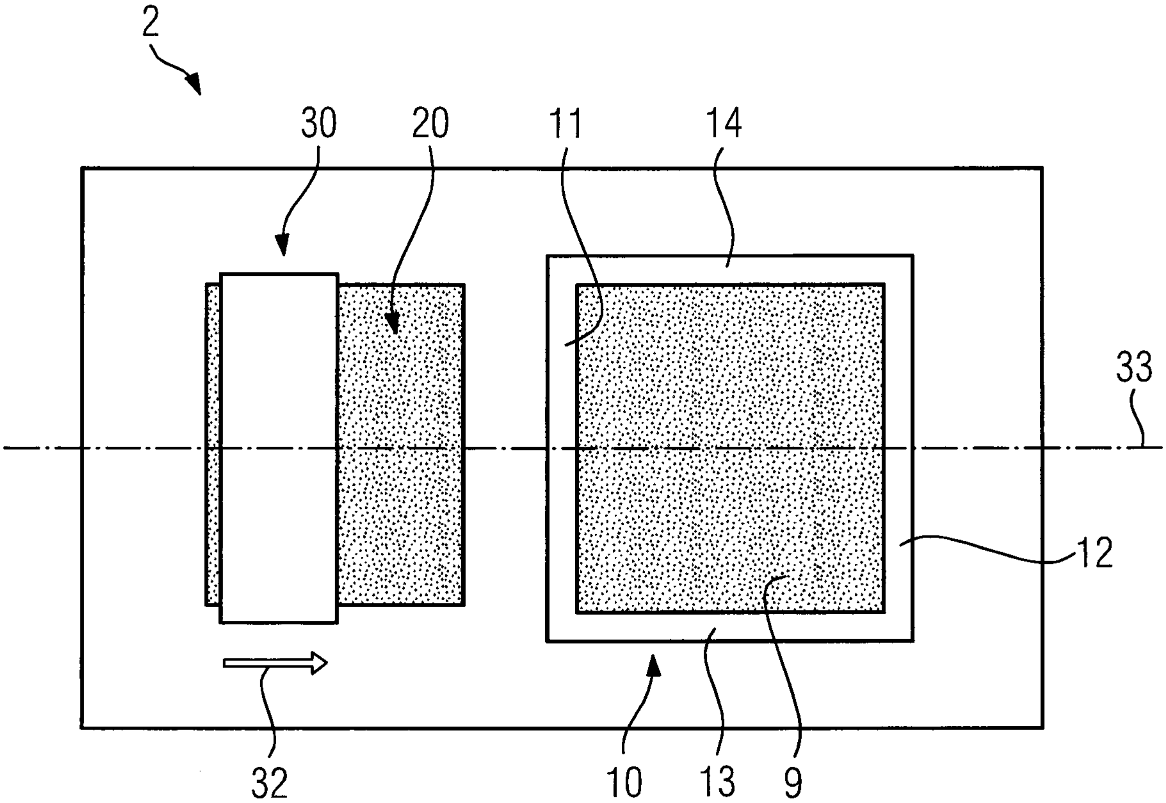
13. The additive manufacturing apparatus (1) according to any of claims 1 to 12, wherein the drive mechanism (70) comprises one of an electrical drive, a hydraulic drive.

14. The additive manufacturing apparatus (1) according to any of claims 1 to 13, further comprising a heating mechanism (80) configured to heat the bed (8) of the powdered material (7) before and/or after the selective scanning, by the power

beam arrangement (40), of the portions of the surface (9) of the layer (6) of the bed (8) of the powdered material (7).

15. The additive manufacturing apparatus (1) according to claim 14, wherein the heating mechanism (80) comprises one of a heating element (81), an Infra-red heater (82), an energy beam pre-heating arrangement (40’), an Induction heating arrangement (84), and a combination thereof.

FIG 1



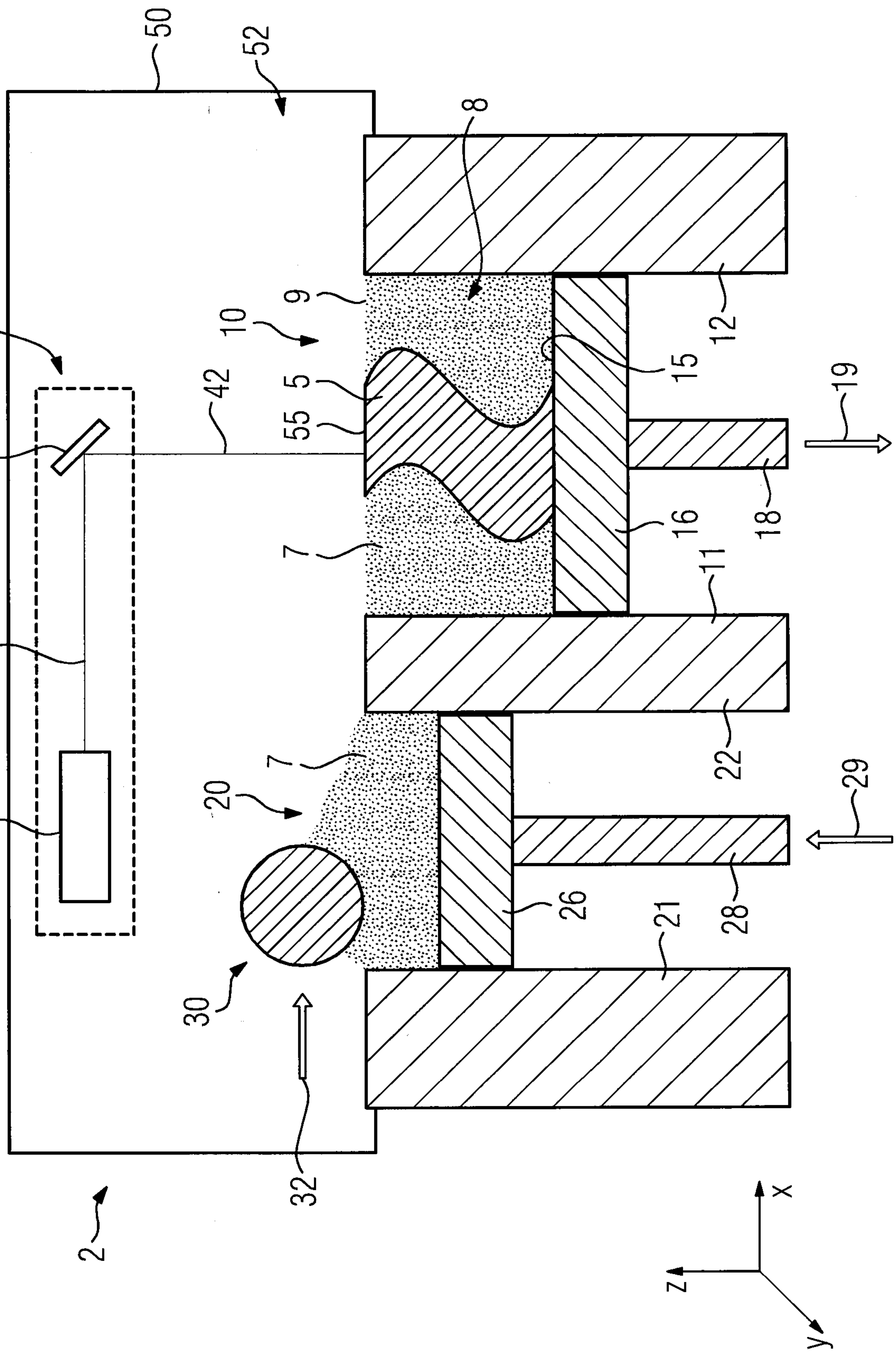

50
52
8
40
10
9
42
5
55
44
15
12
19
16
18
7
11
42
22
29
20
7
41
26
28
21
30
32
2
x
z
y

FIG 2

FIG 3

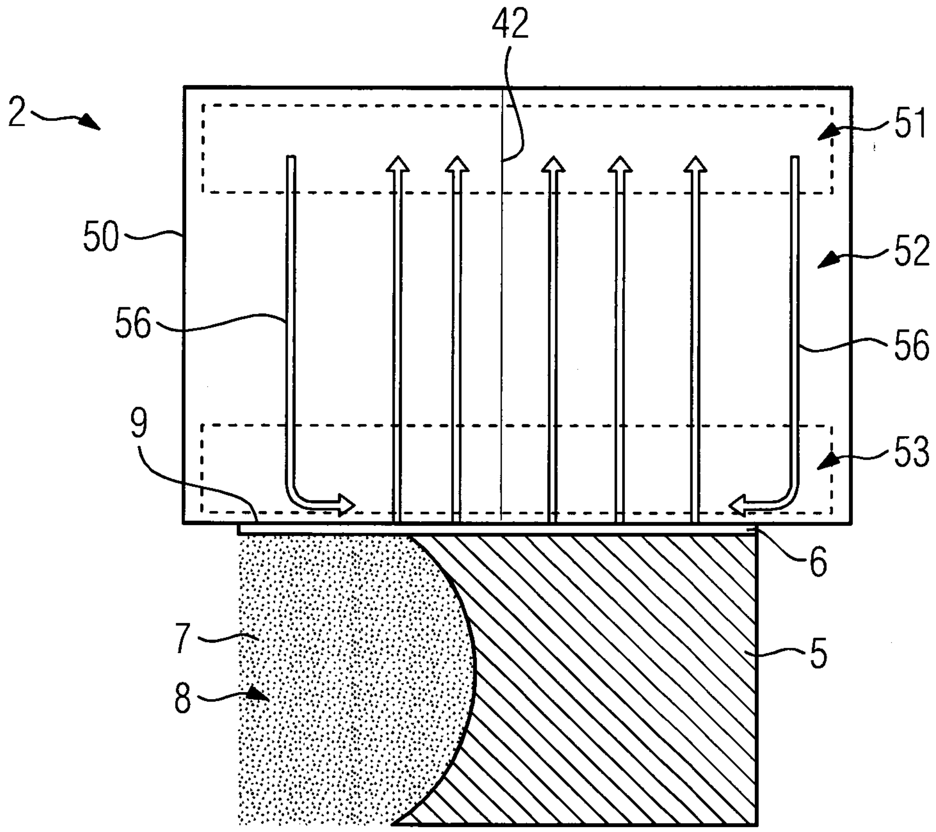
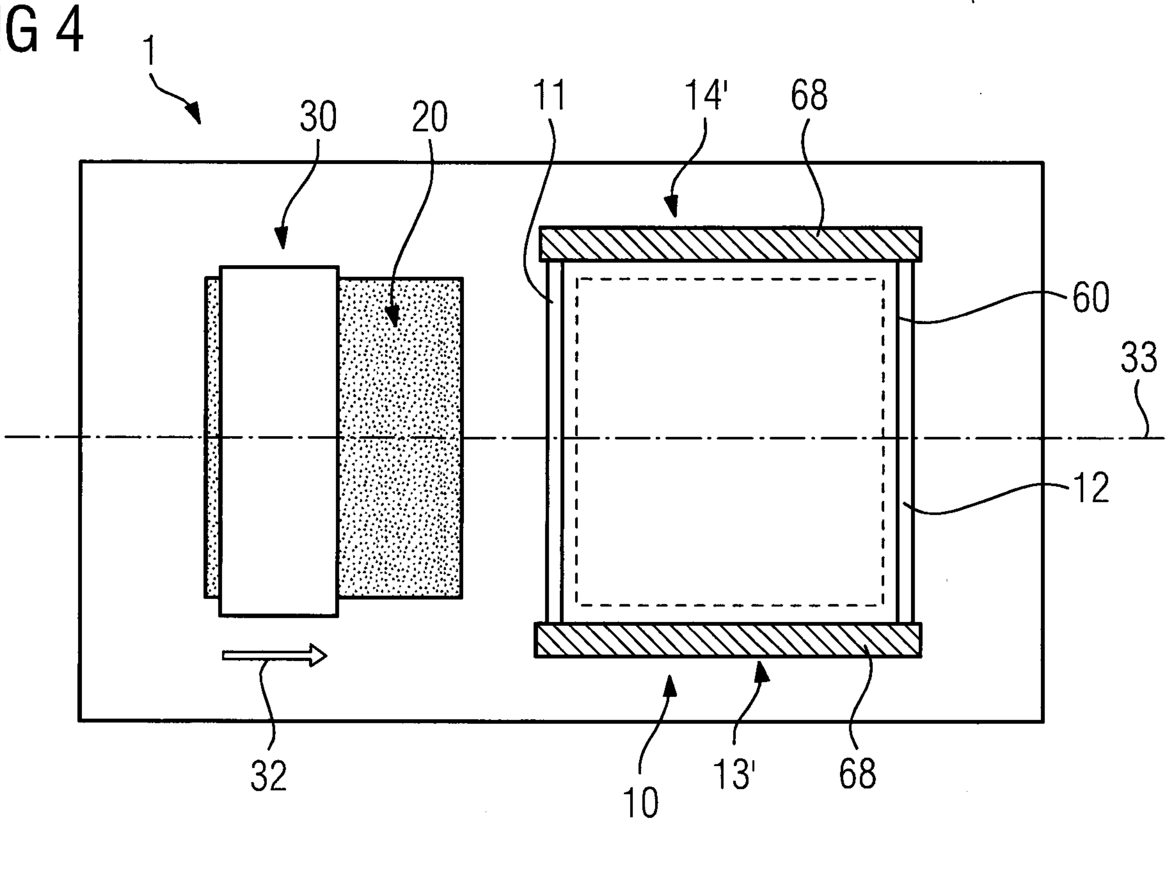


FIG 4



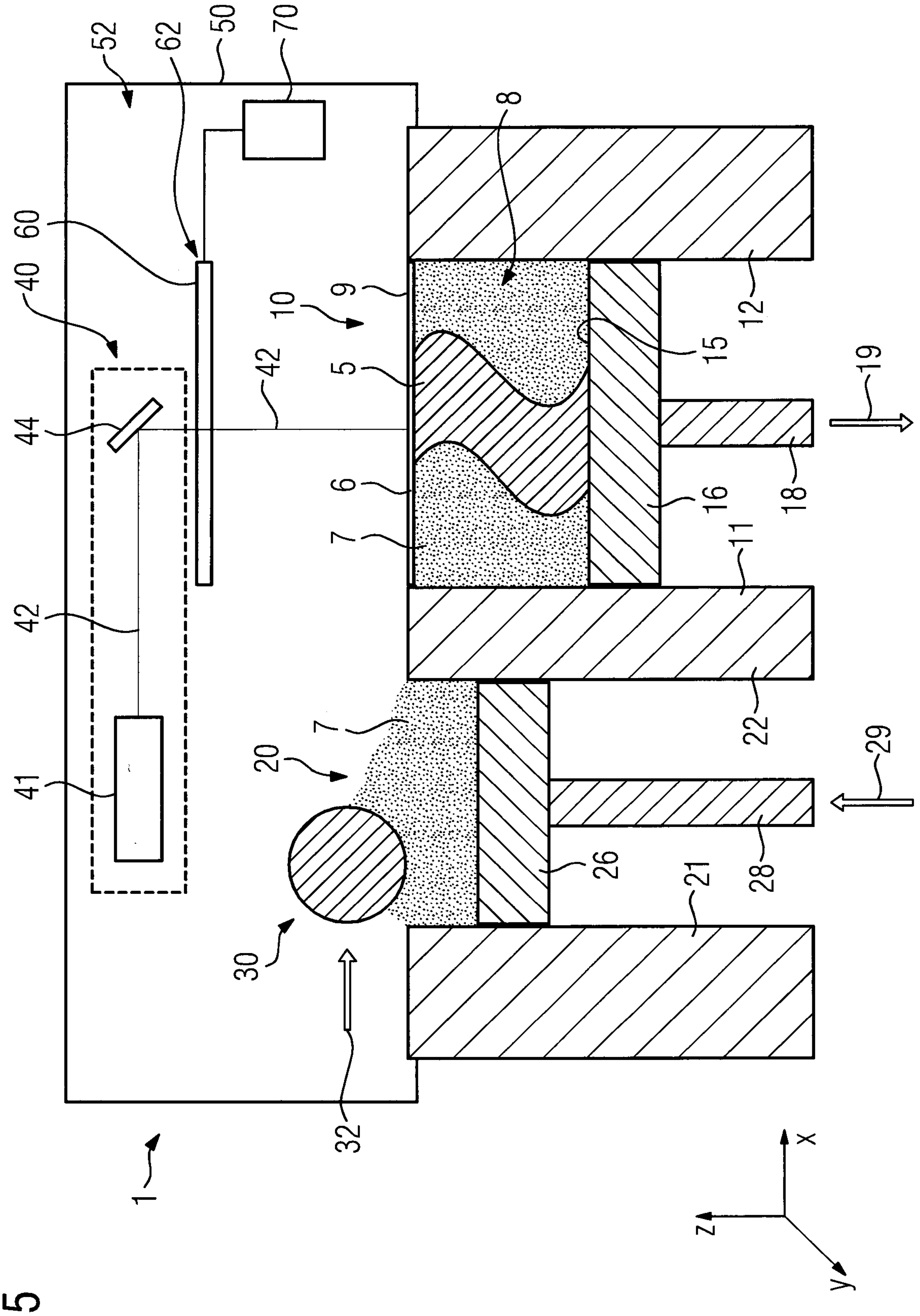

52
62
50
70
8
40 60
9
10
12
15
42
5
19
44
6
16
18
7
42
11
22
7
29
20
41
26
28
21
30
32
1
x
z
y

FIG 5

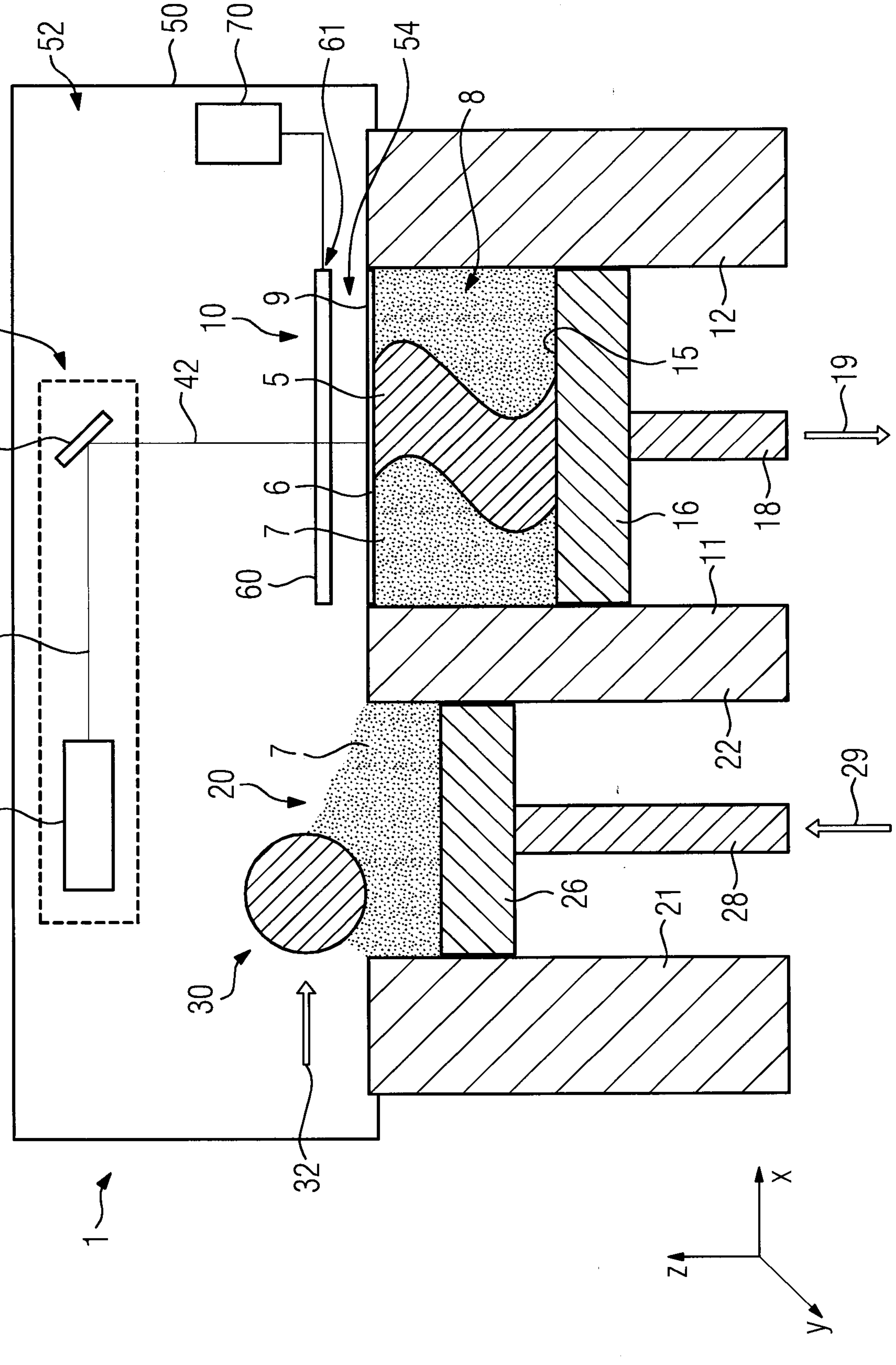

52
50
70
61
54
8
40
10
9
42
5
15
12
44
6
16
18
19
7
60
11
42
22
7
20
29
41
26
28
21
30
32
1
x
z
y

FIG 6

FIG 8

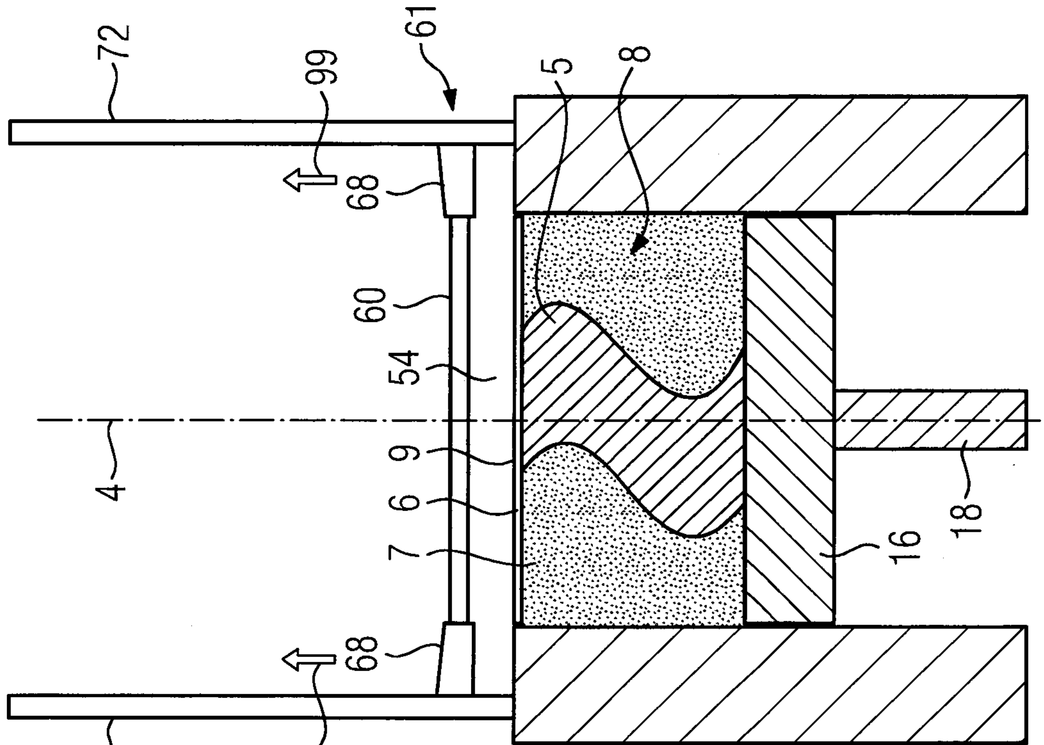

72
61
99
68
60
54
9
6
7
4
5
8
16
18
68
99
72

FIG 7

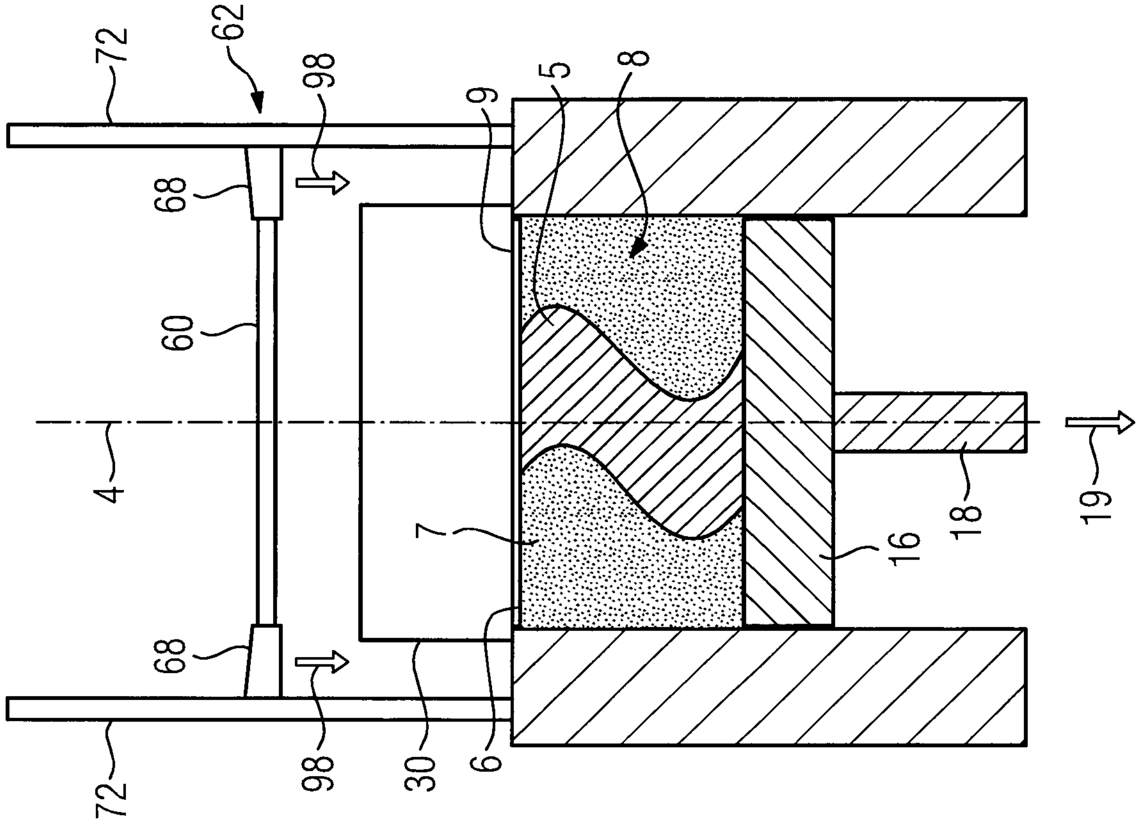

72
62
98
68
60
9
5
8
4
7
16
18
19
68
98
30
6
72

FIG 9

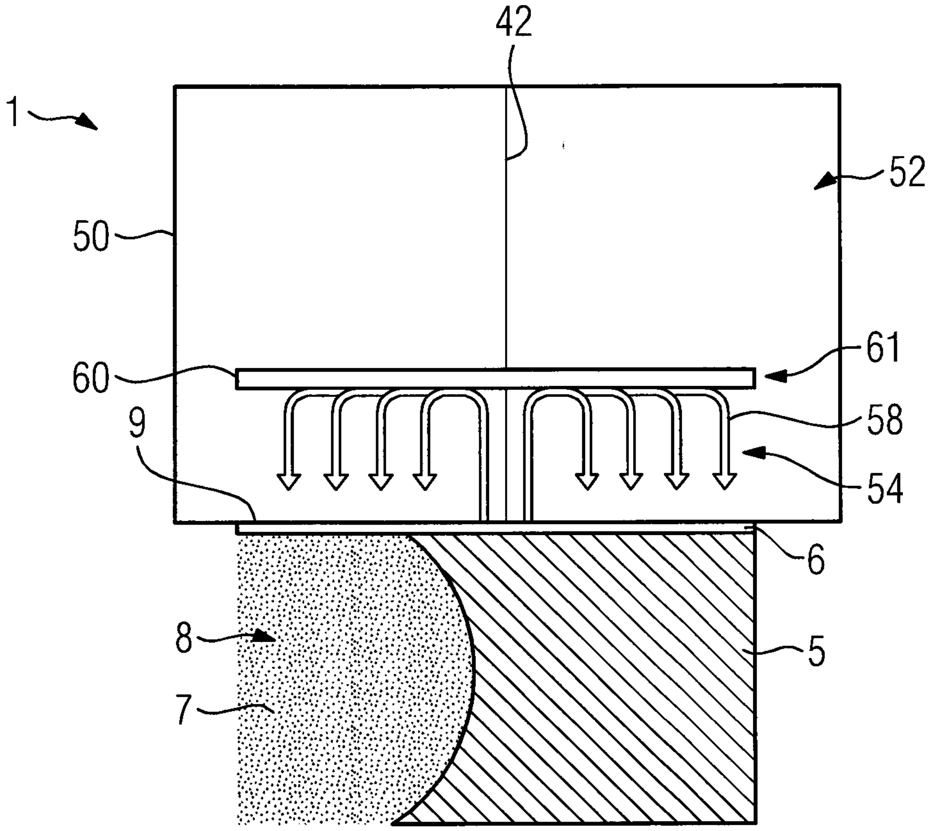


FIG 10

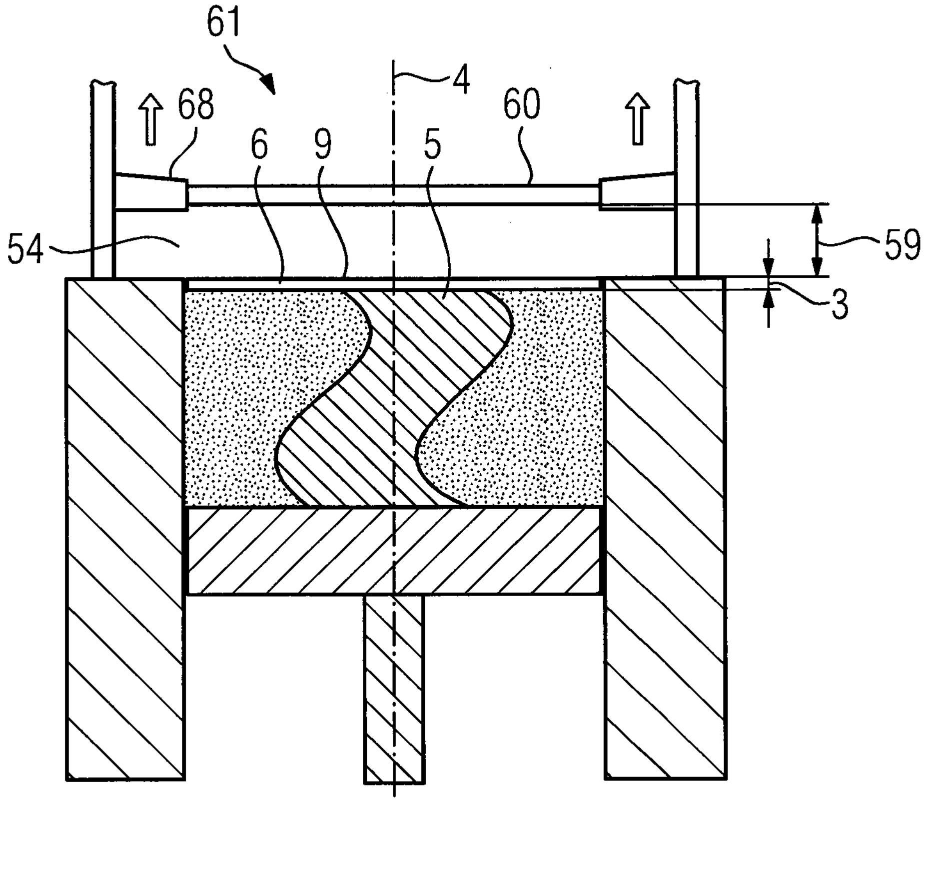


FIG 11

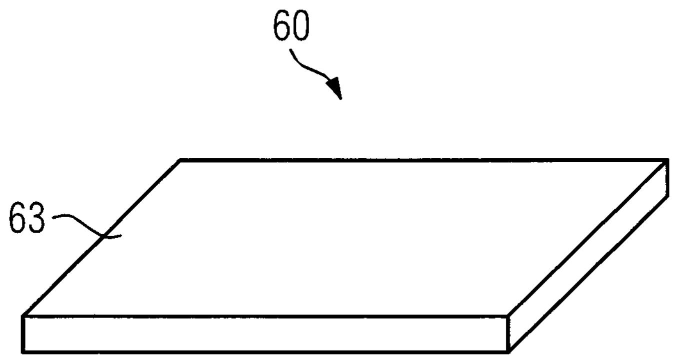


FIG 12

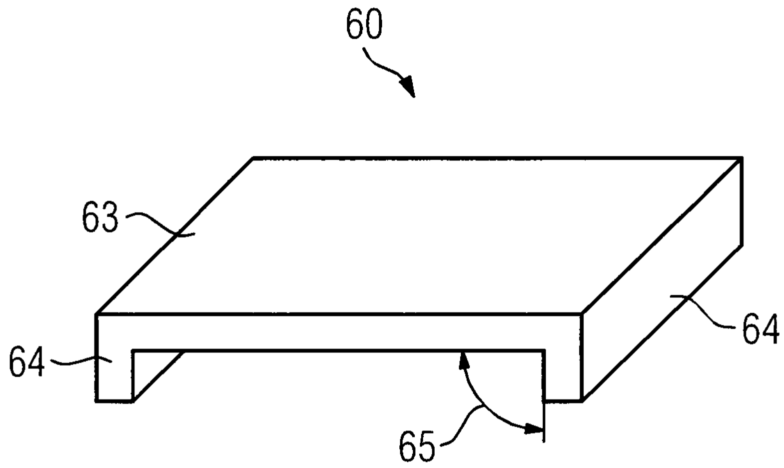


FIG 13

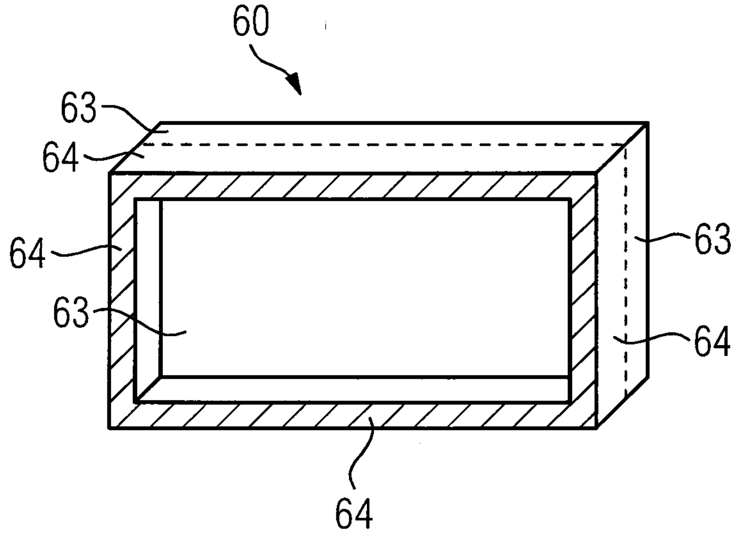
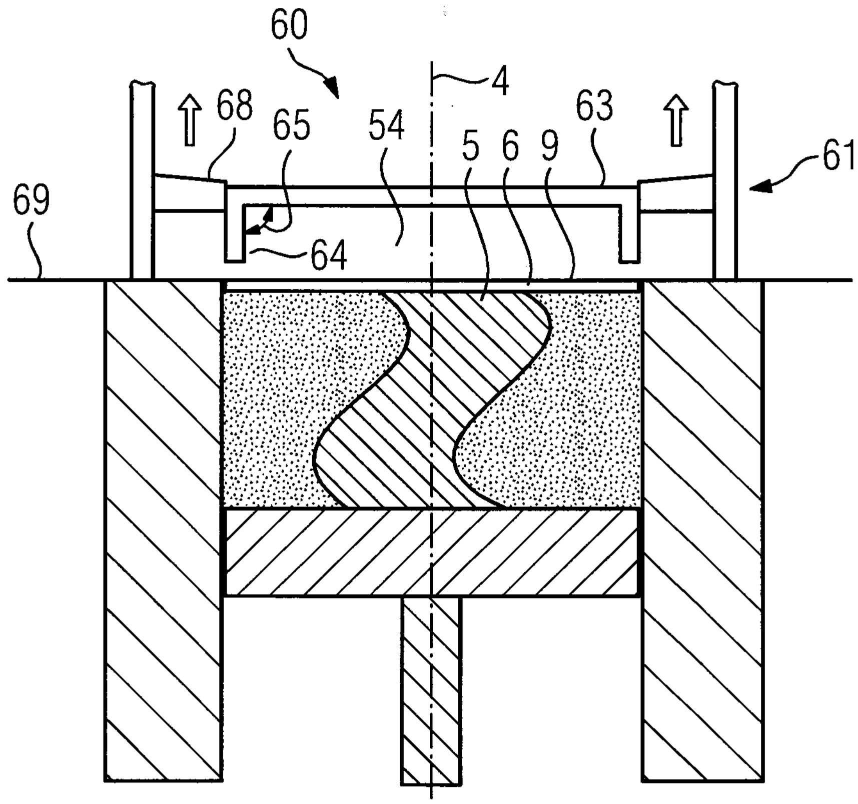


FIG 14



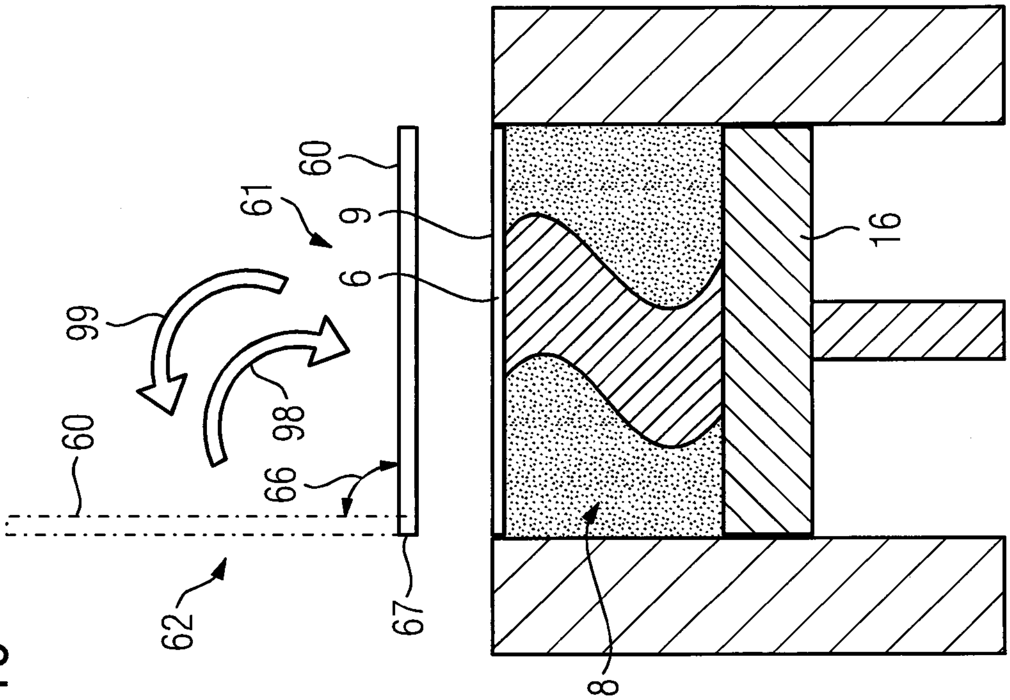


FIG 16

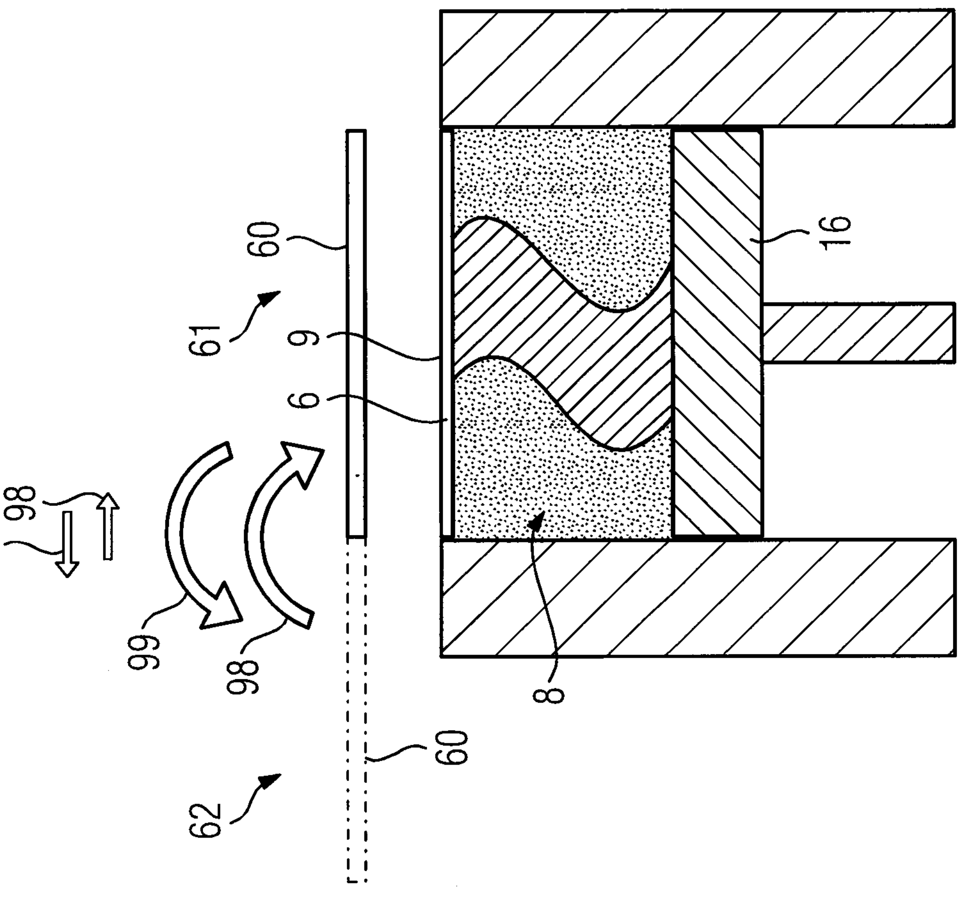


FIG 15

FIG 17

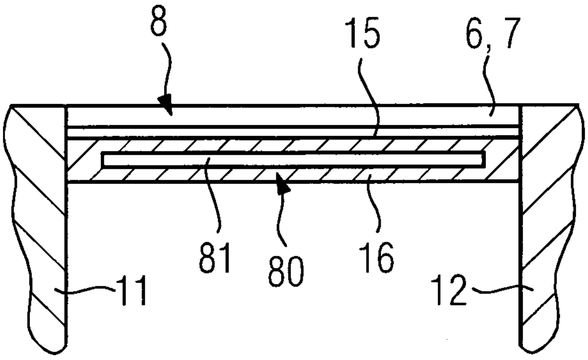


FIG 18

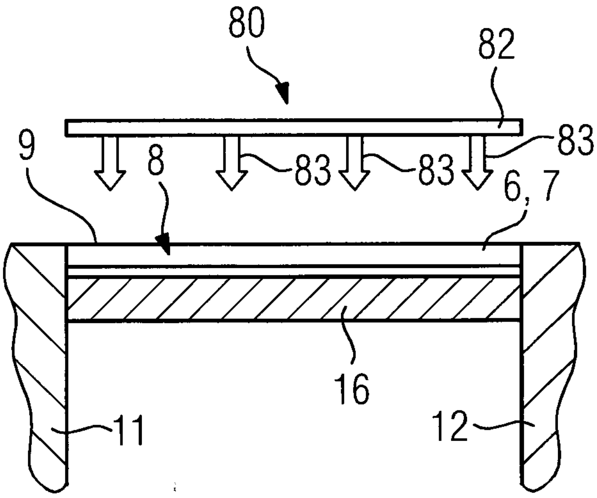


FIG 19

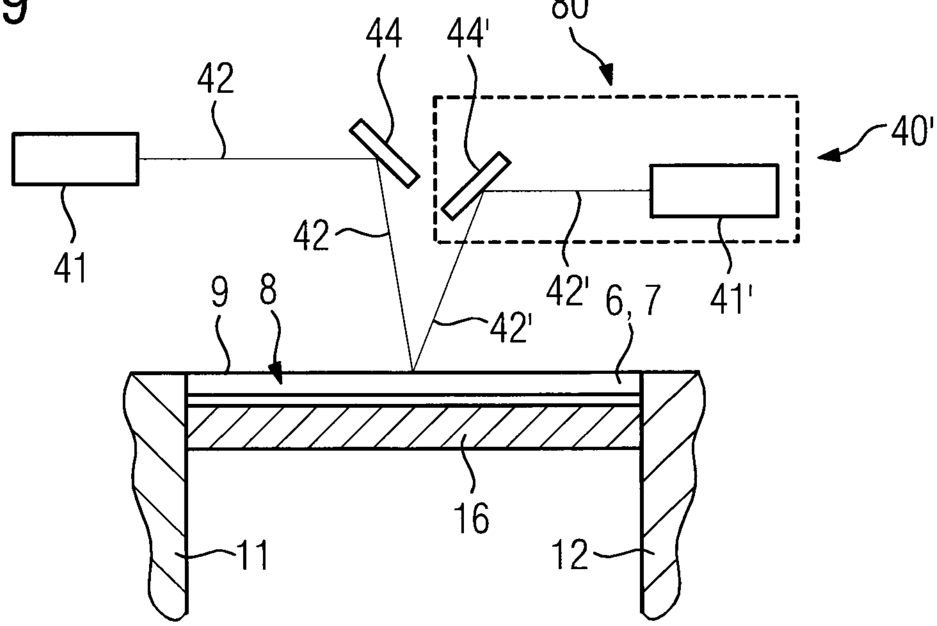


FIG 20

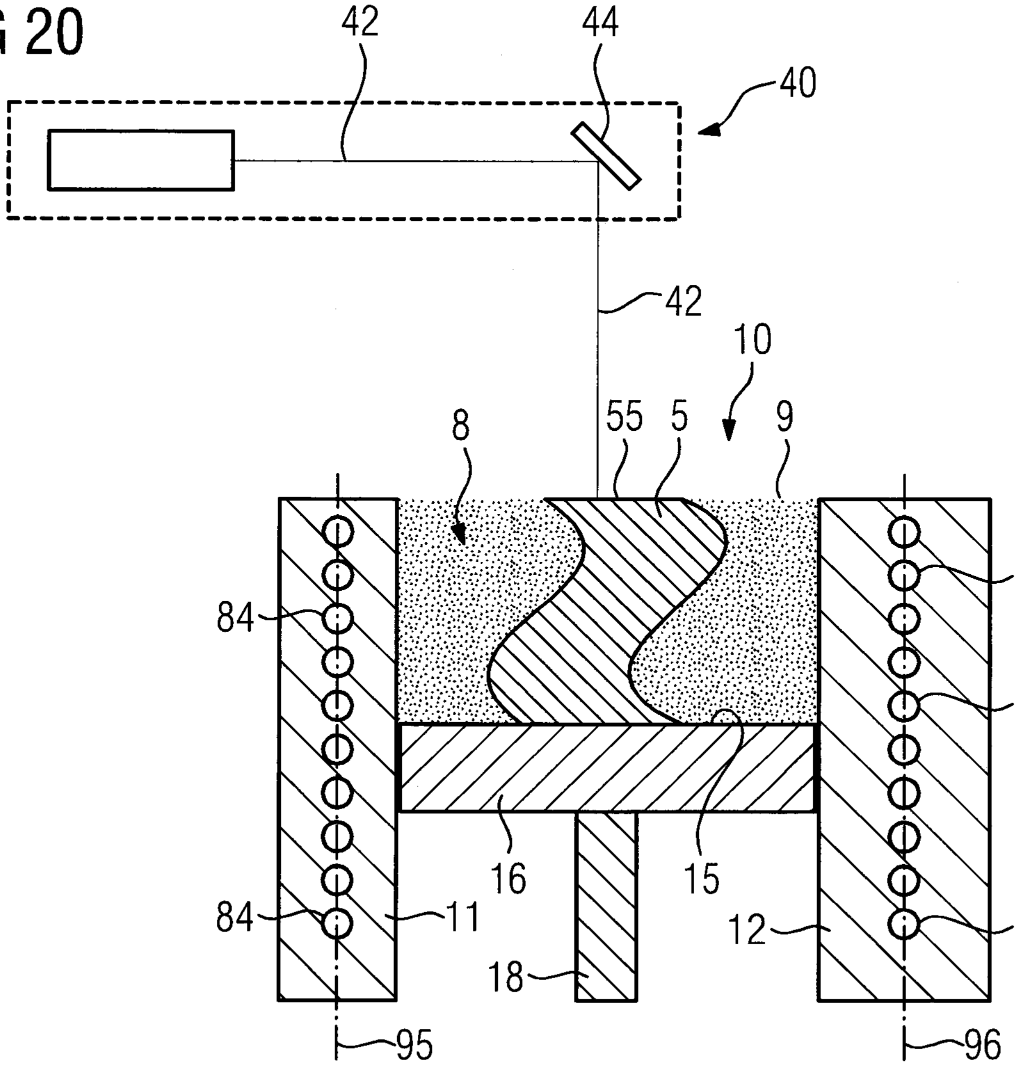
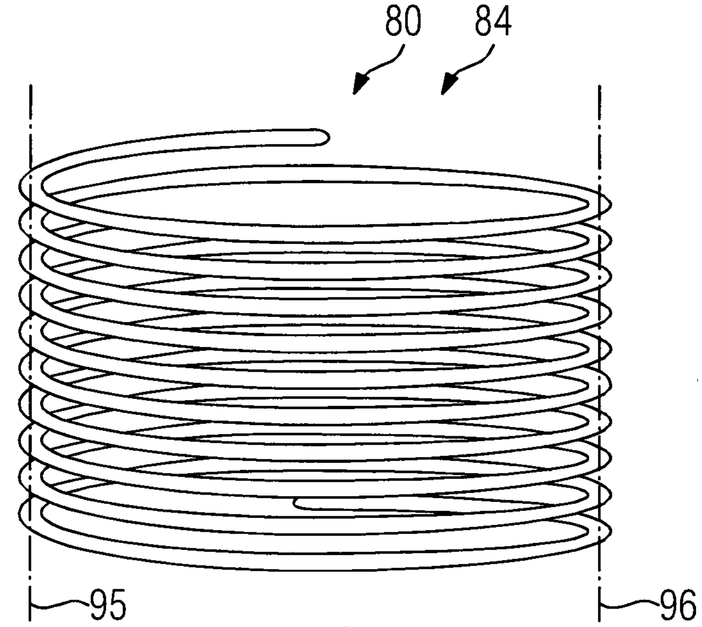


FIG 21



INTERNATIONAL SEARCH REPORT

International application No
PCT/RU2017/000581

A. CLASSIFICATION OF SUBJECT MATTER
INV. B33Y30/00 B33Y40/00 B29C64/153 B29C64/214 B29C64/30
B29C64/295 B29C64/371 B29C64/227 B29C64/268
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)
B33Y B22F B29C

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	DE 10 2015 005780 A1 (CL SCHUTZRECHTSVERWALTUNGS GMBH [DE]) 15 December 2016 (2016-12-15) figure 1 figure 2 figure 3 paragraph [0010] paragraph [0019] paragraph [0022] - paragraph [0024] -----	1-8,13 9-12,14, 15
Y	DE 10 2015 109841 A1 (ACONITY3D GMBH [DE]) 22 December 2016 (2016-12-22) figure 1 -----	9,10

-/--

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

[X] See patent family annex.

* Special categories of cited documents :

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

"E" earlier application or patent but published on or after the international filing date

"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

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 April 2018	30/05/2018

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Borsch, Sebastian

INTERNATIONAL SEARCH REPORT

International application No
PCT/RU2017/000581

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2010/006228 A1 (ABE SATOSHI [JP] ET AL) 14 January 2010 (2010-01-14) figure 15 figure 16 paragraph [0096] -----	11,12
Y	DE 20 2009 012628 U1 (EOS ELECTRO OPTICAL SYST [DE]) 10 December 2009 (2009-12-10) figure Fig.1 paragraph [0021] -----	14,15

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/RU2017/000581

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 102015005780 A1	15-12-2016	NONE	
DE 102015109841 A1	22-12-2016	DE 102015109841 A1	22-12-2016
		EP 3310554 A1	25-04-2018
		WO 2016202867 A1	22-12-2016
US 2010006228 A1	14-01-2010	CN 101541511 A	23-09-2009
		DE 112008000027 T5	10-06-2009
		DE 202008017990 U1	10-02-2011
		JP 4238938 B2	18-03-2009
		JP 5027780 B2	19-09-2012
		JP 2009007669 A	15-01-2009
		JP 2009078558 A	16-04-2009
		KR 20090035713 A	10-04-2009
		US 2010006228 A1	14-01-2010
		WO 2008146920 A1	04-12-2008
DE 202009012628 U1	10-12-2009	NONE	