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Chanclon Fernandez et al.

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(54) **ADDITIVE MANUFACTURING TRAY**

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CPC ***B29C 64/245*** (2017.08); ***B29C 64/35*** (2017.08); ***B33Y 30/00*** (2014.12); ***B33Y 40/20*** (2020.01)

(58) **Field of Classification Search**
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See application file for complete search history.

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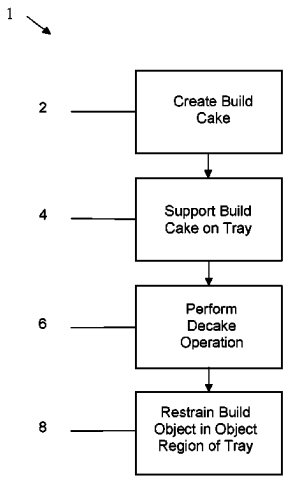
(57) **ABSTRACT**

An additive manufacturing process which comprises carrying out an additive manufacturing build process to create a build cake. The build cake comprises a build object and non-solidified build material and the build object is built in a build location within the build cake. The build cake is supported on a tray which comprises a mesh having openings therethrough. The tray also includes an object region and a restraining feature to restrain a build object within the object region. The process comprises performing a decake operation in which non-solidified build material from the build cake passes through the openings of the mesh and the object moves into contact with the tray in the object region so that the object is restrained within the object region of the tray by the restraining feature.

15 Claims, 6 Drawing Sheets



(51) **Int. Cl.**
B33Y 30/00 (2015.01)
B33Y 40/20 (2020.01)

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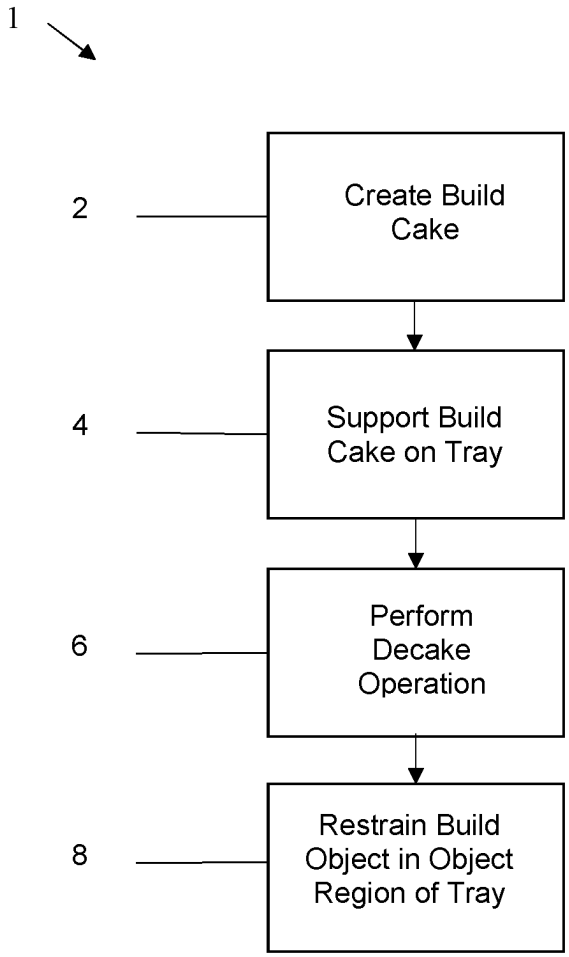
1
2
Create Build Cake
4
Support Build Cake on Tray
6
Perform Decake Operation
8
Restrain Build Object in Object Region of Tray

Fig 1

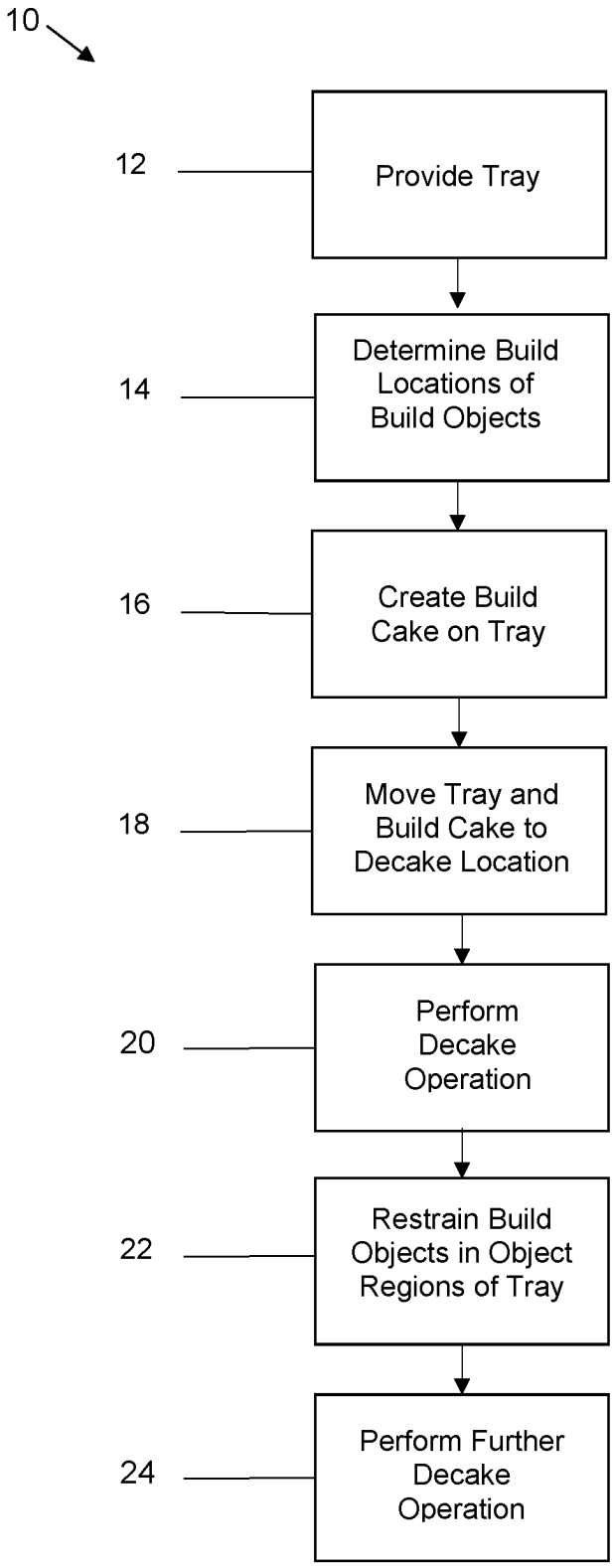
10
12
Provide Tray
14
Determine Build Locations of Build Objects
16
Create Build Cake on Tray
18
Move Tray and Build Cake to Decake Location
20
Perform Decake Operation
22
Restrain Build Objects in Object Regions of Tray
24
Perform Further Decake Operation

Fig 2

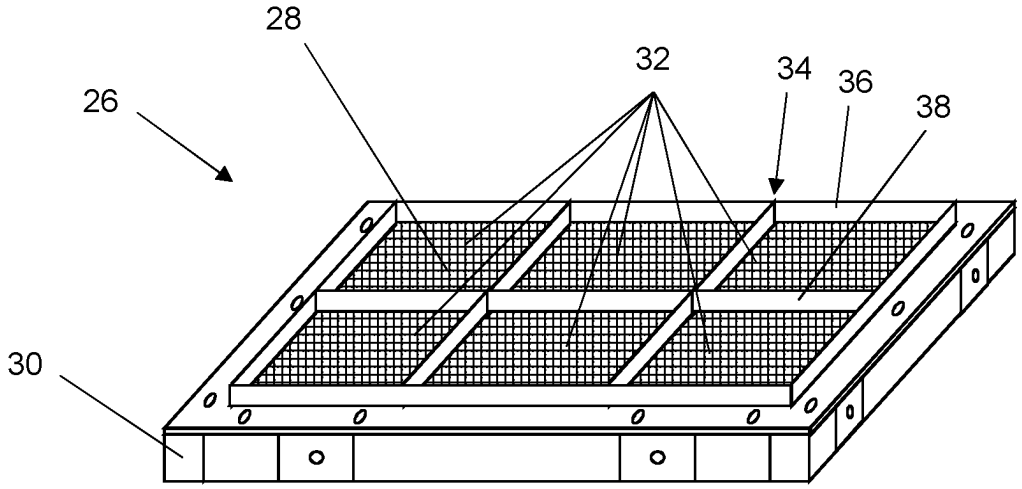

Fig 3

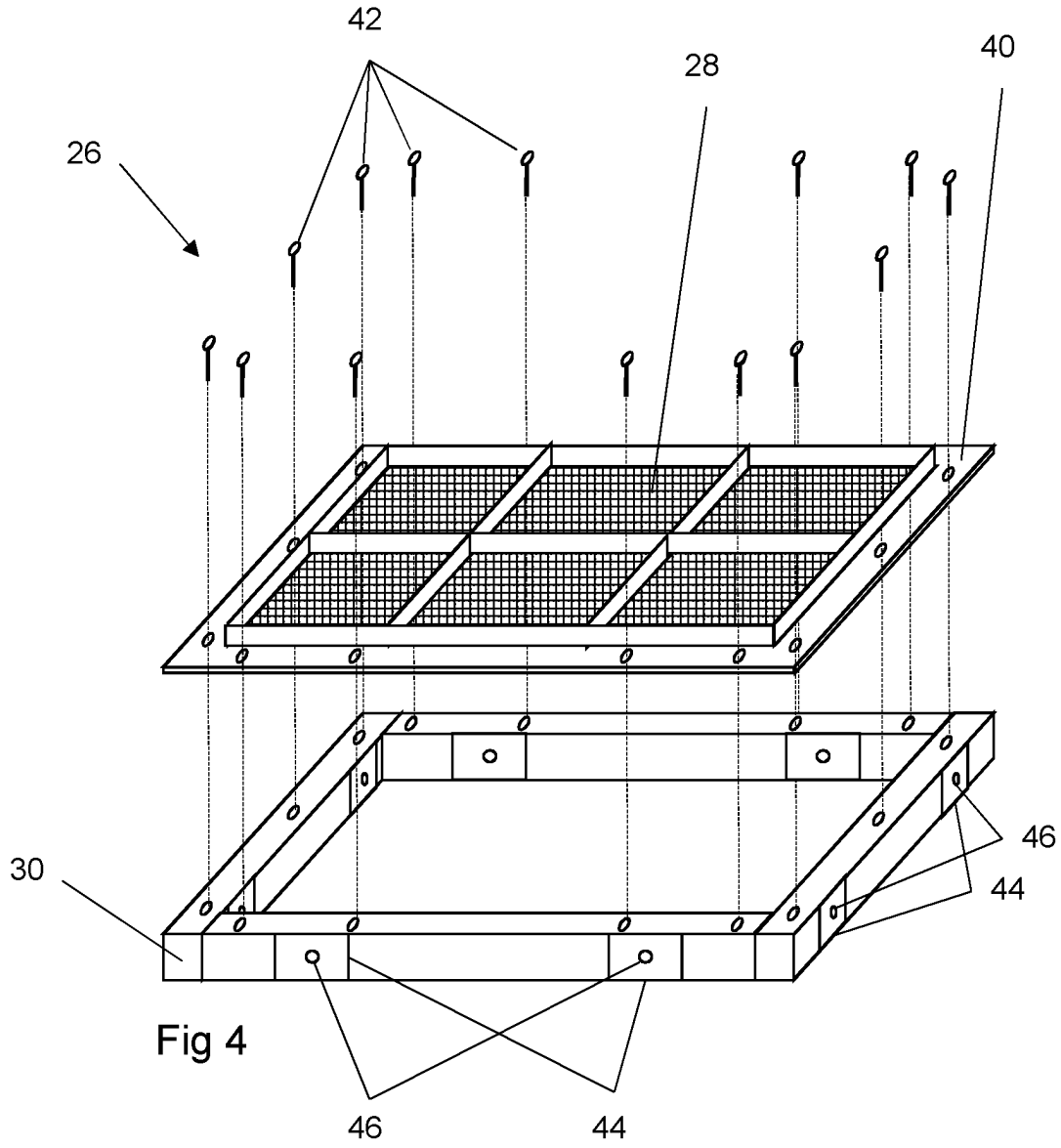

Fig 4

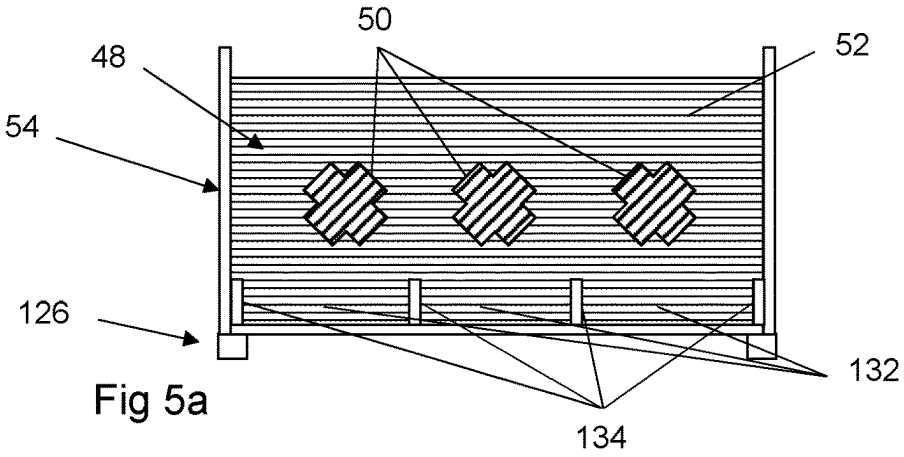

Fig 5a

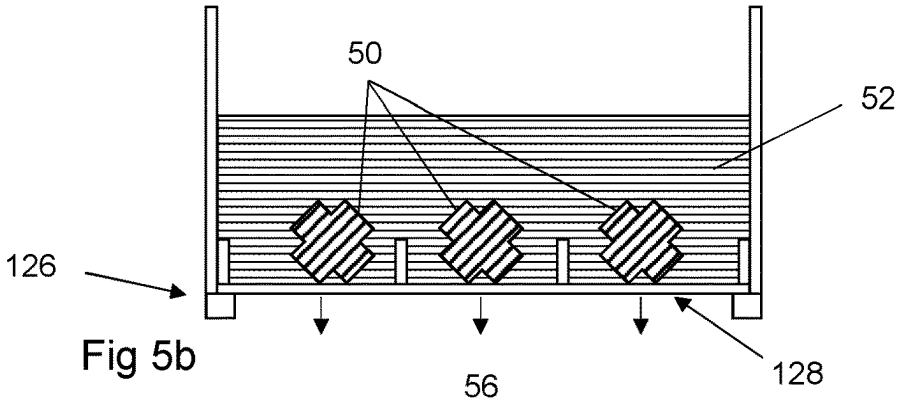

Fig 5b

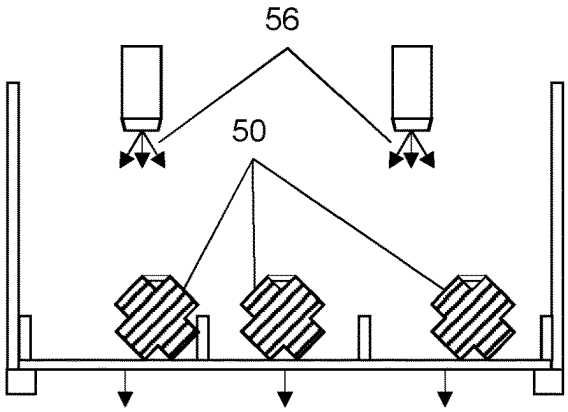

Fig 5c

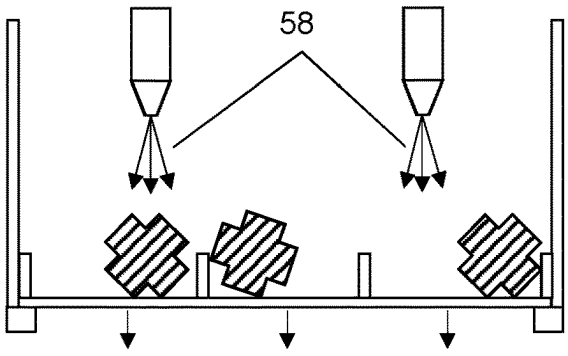

Fig 5d

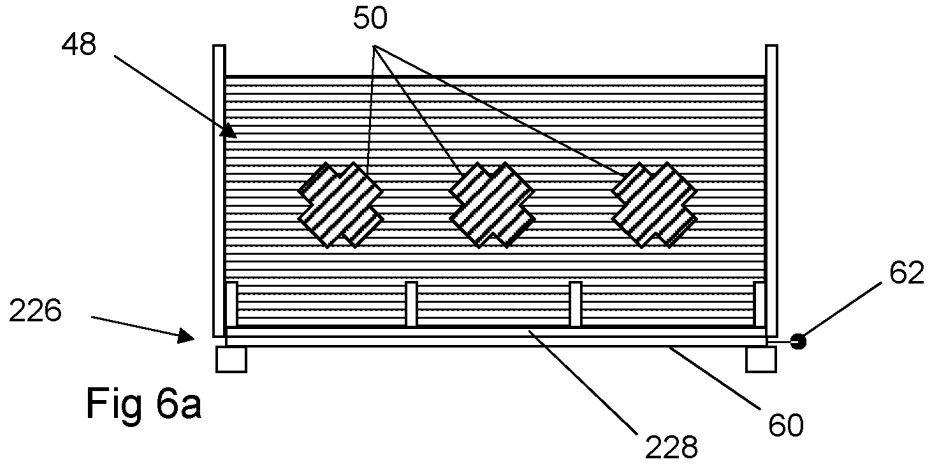

Fig 6a

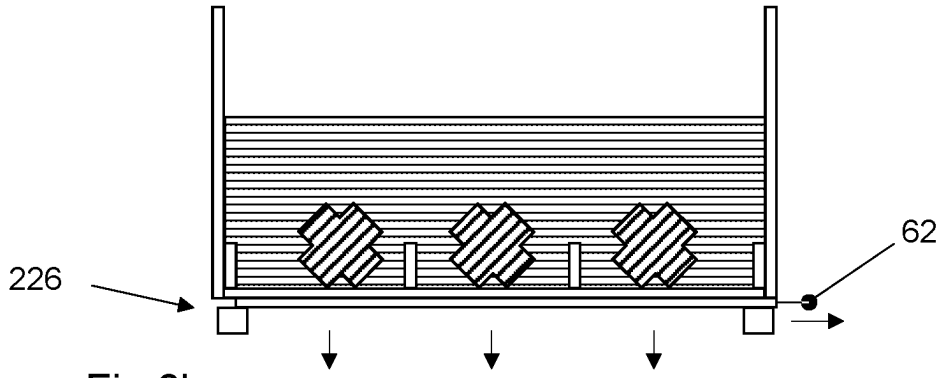

Fig 6b

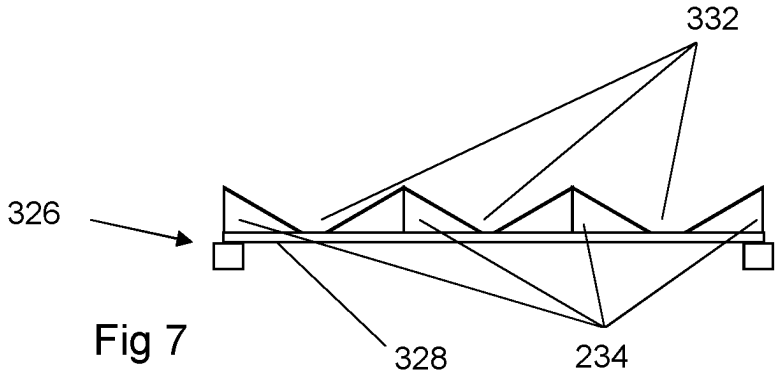

Fig 7

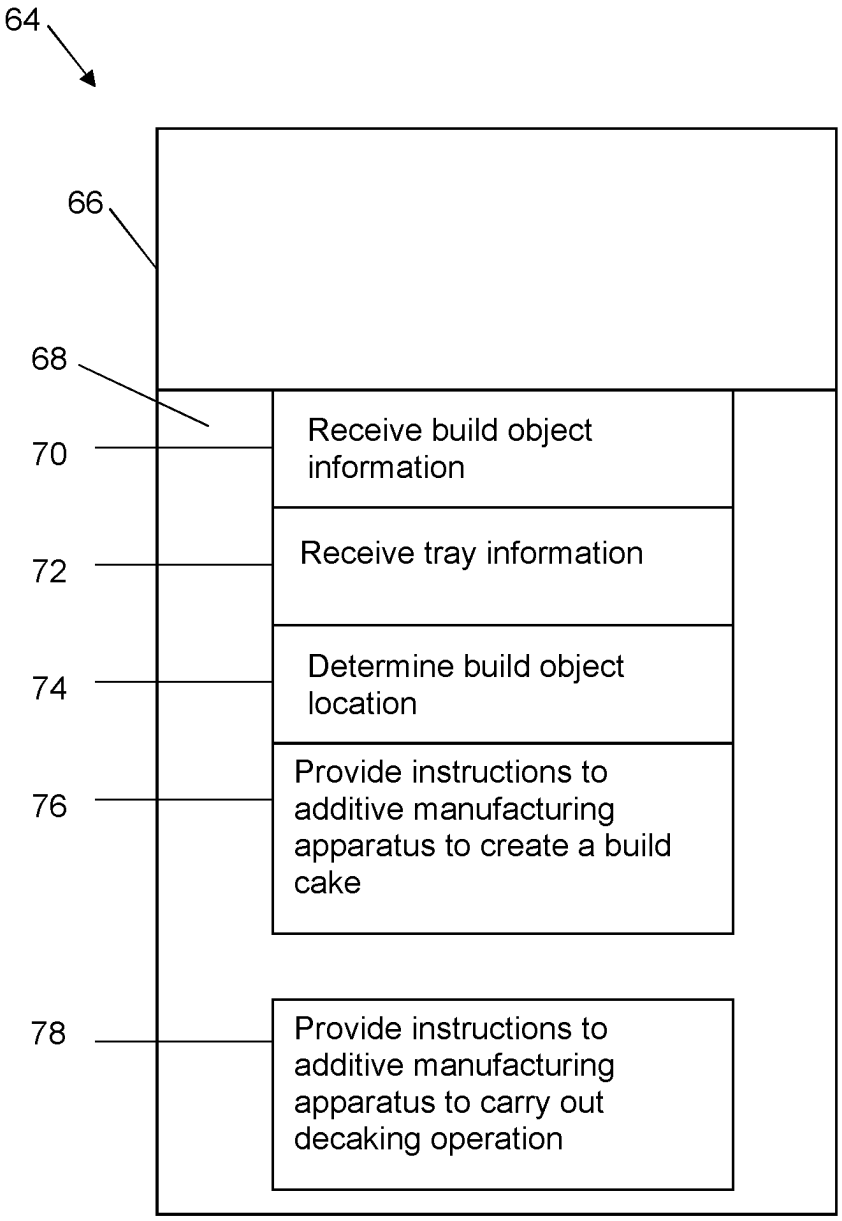
64
66
68
70
Receive build object information
72
Receive tray information
74
Determine build object location
76
Provide instructions to additive manufacturing apparatus to create a build cake
78
Provide instructions to additive manufacturing apparatus to carry out decaking operation

Fig 8

ADDITIVE MANUFACTURING TRAY

Additive manufacturing systems can be used to manufacture three-dimensional (3D) objects. This can be achieved, for example, by forming successive layers of a build material on a build platform and selectively solidifying portions of those layers to build up a 3D object within a build cake. Objects such as product components can be built up in layers within the build cake in an additive manufacturing system in accordance with object descriptions as part of build instructions that are interpreted and applied by a print controller.

In an example additive manufacturing process the object is separated from the build cake in a decaking operation in which the build cake is supported on a tray and non-solidified build material of the build cake is removed from the object.

Examples of the present disclosure will now be described with reference to the accompanying Figures, in which:

FIG. **1** shows an example of an additive manufacturing process;

FIG. **2** shows another example of an additive manufacturing process;

FIG. **3** shows an example of a tray;

FIG. **4** shows an exploded view of the example of a tray of FIG. **3**;

FIGS. **5***a*, **5***b*, **5***c* and **5***d* show schematic cross sections of an example of a sequence of stages of an example of a build cake supported on a tray during a decake operation;

FIGS. **6***a* and **6***b* show schematic cross sections of another example of stages of an example of a build cake supported on a tray during a decake operation;

FIG. **7** shows an example of a tray comprising troughs; and

FIG. **8** shows an example of a schematic diagram of an example of a controller.

FIG. **1** shows an example of an additive manufacturing process **1**. The process **1** comprises carrying out an additive manufacturing build process to create **2** a build cake. The build cake created comprises a build object and non-solidified build material. The build object is built in a build location within the build cake.

In this example, the additive manufacturing system that is used in the build process to create the build cake uses build material which is spread over a build platform to form a build layer in a build chamber. Selected portions of the build layer may be solidified, for example by fusing, sintering, melting, binding or otherwise joining the build material using, for example, heat energy applied from an energy source and a fusing agent. The build platform is then lowered by a predetermined amount and a new build layer formed on the previously formed layer and the process repeated. In this way the build object is created within a build cake which is made up of the build object and non-solidified build material.

The build material may comprise any suitable form of build material, for example fibres, granules or powders. The build material can include thermoplastic materials, ceramic material and metallic materials. A store of build material may be provided in a supply vessel and build material may be distributed from the supply vessel to form an intermediate volume of build material from which build material may be spread over a build platform, either directly such as using a roller to spread the intermediate volume, or indirectly by moving some or all of the intermediate volume to another location prior to spreading.

During the additive manufacturing process **1** the build cake is supported **4** on a tray on a build platform. The tray comprises a mesh having openings therethrough. The tray includes an object region and a restraining feature to restrain a build object within the object region. In one example the build cake is created on the tray by the additive manufacturing system. In other examples the build cake is created in a build chamber and is transferred onto the tray either manually or automatically.

The object region of the tray is a region defined on the tray as a region in which a build object can be restrained by the restraining feature. There may be a plurality of object regions defined on the tray so that a build object can be restrained in a plurality of different regions of the tray, or so that a plurality of build objects can each be restrained in an associated object region of the tray. In this example an object location is to restrain a single build object, but in other examples a plurality of build objects can be restrained in a single object region.

Restraining features may comprise any feature which could restrain a build object within an object region of a tray. Suitable restraining features include walls, troughs, projections, pins, and deformable regions into which a build object can sink into, for example pressed by gravity. In one example an object is considered restrained within an object region if there is an enhanced resistance to lateral movement of a build object in a direction across the tray from within the object region to outside object region. In one example the restraining feature of the tray comprises a wall which surrounds an object region to define a compartment within which a build object, or a portion thereof, can be located so that the build object is restrained within the object region. In one example the tray comprises a plurality of compartments. In one example the restraining feature may be configured to provide a cup into which a build object can nest so that the build object can be restrained in predetermined position and possibly also a predetermined orientation. In one example this nesting can be achieved by configuring a cup as a negative of a portion of a build object. The cup may be provided by a continuous surface, or a plurality of surface sections each of which is a negative of a portion of the associated build object.

The additive manufacturing process **1** comprises performing a decake operation **6** in which non-solidified build material from the build cake passes through the openings of the mesh of the tray. The decake operation **6** of this example comprises vibrating the mesh. As a result of the removal of non-solidified build material from the base of the build cake through the mesh the build object moves into contact with the tray.

In this example the openings of the mesh are sized so that the non-solidified build material forms a natural bridge over the opening so that non-solidified build material will not readily flow through the openings without agitation of the mesh, or other energy input. The openings may be any suitable shape. In other examples the tray includes an obstruction member than can be moved between an open configuration in which the build material is able to pass through the openings of the mesh to pass through the tray, the tray also comprising a closed configuration in which the obstruction member occludes openings of the mesh. In such examples the decaking operation comprising moving the tray between a closed configuration and an open configuration.

During the decake operation the build object moves into contact with the tray within the object region of the tray so that the object is restrained **8** within the object region of the tray by the restraining feature.

In one example, the movement of the build object into the object region of the tray is achieved by selecting the build location of the build object with in the cake and the object location on the tray such that, when the build cake is supported on the tray the build object is located vertically above the object location. In this example, during the decake operation, as the non-solidified build material from the build cake is removed through the openings of the mesh of the tray, the build object moves under gravity into the object location and is restrained therein. The removal of the build material may be passive with the build material massing through the mesh under gravity, or the removal may be assisted, for example using suction. In one example the build location of the build object within the build cake is determined based upon the object location of a tray to be used in the process. In other examples the object location of a tray is determined based upon the build location of a build object within a build cake to be created during an additive manufacturing process.

FIG. **2** shows an example of an additive manufacturing process **10** in which a plurality of build objects are to be created within a build cake. The process **10** comprises providing **12** a tray. The tray comprises a mesh having openings therethrough. The tray includes a plurality of object regions and restraining features to restrain build objects within the object regions. In one example the tray comprises a mesh removably attached to a frame which supports the mesh.

The process **10** comprises a determining **14** the build locations of the plurality of build objects within the build cake based on the locations of the object locations of the tray.

The process **10** comprises carrying out an additive manufacturing build process to create **16** a build cake so that the build cake created comprises a plurality of build objects at build locations within the build cake and non-solidified build material.

In this example, the additive manufacturing system used in the build process to create the build cake is similar to that described above, but in this example the build cake is created on the tray. In other examples the build cake may be transferred onto the tray after it has been created.

Once the build cake has been created on the tray the tray is used to support the build cake as the tray and build cake are moved to a decake location. In this example the movement of the tray and build cake to the decake location is carried out automatically using automatic handling equipment which engage with handling portions of the frame. The handling portions of the frame include mechanical features to which the automatic handling equipment, such as a robotic arm, can releasably engage so that the automatic handling equipment can move the tray. In other examples the tray and build cake are moved manually, or by other means.

With the tray and build cake in the decake location the additive manufacturing process **10** comprises performing a decake operation **20** in which non-solidified build material from the build cake passes through the openings of the mesh of the tray. In this example the decake operation **20** comprises vibrating the mesh and also directing gas streams towards the build objects to disturb non-solidified material. As a result of the loss of non-solidified build material from the build cake through the mesh the build objects move into contact with the tray.

As the build locations of the build objects in the build cake were determined based on the position of the object locations of the build tray, the build objects move into contact with the tray within the object regions of the tray so that the objects are restrained **22** within the object regions of the tray by the restraining features.

In one example the process **10** further comprises performing a further decake process **24**. The further decake process may be more aggressive, for example it may be more energetic, than the initial decake. The more aggressive further decake process may result in a greater likelihood of the build objects moving relative to the tray. In this example the further decake process **24** comprises directing high velocity gas streams, for example air streams, at the build objects to dislodge non-solidified build material which may be trapped in, or retained on, parts of the build objects. This may be combined with vibration of the tray which may assist with dislodging build material from the build object.

The high velocity gas streams may have sufficient energy to move the build objects relative to the mesh of the tray and the restraining features act to restrain the build objects within the object locations into which they came into contact. Restraining build objects in this way may aid traceability of build objects which may assist with quality control. Restraining build objects in this way may also reduce or avoid contacts between build objects and/or between a build object and tray other components during a decake operation which could damage the build objects. This restraining of the build objects within object regions of the tray may reduce or avoid damage to the build objects which may be delicate. Restraining build objects within an object region may also facilitate automation of subsequent processes, for example a pick and place process using a robot since the initial location of the object is known with greater certainty.

FIG. **3** shows an example of a tray **26** to be used in an additive manufacturing process, for example the additive manufacturing process **1** of FIG. **1**, of the additive manufacturing process **10** of FIG. **2**.

The tray **26** of this example comprises a substantially flat mesh **28** removably attached to a frame **30** which supports the mesh **28**. The construction of the tray **26** will be described in more detail with reference to FIG. **3**. The tray **26** of this example comprises six object regions **32** and restraining features **34** to restrain a build object within the object regions **32**. In this example the restraining features **32** comprise walls, including a peripheral wall **32** extending around the mesh **28** and internal walls **38** which cooperate with the peripheral wall to define the object regions **32** which, in this example are in the form of compartments.

In other examples the restraining features may comprise projections from the mesh, valleys or depressions in the mesh. These may be used separately, or in combination with each other and/or walls.

Six object regions are shown in this example, but in other examples there may be more, or fewer, object regions.

The restraining feature may be made of any suitable material and may comprise a deformable contact portion to reduce the risk of damage to a build object through contact with the restraining feature. In one example the restraining feature comprises walls made from a deformable foam material. In other examples the restraining feature includes a deformable coating layer, for example a rubber, foam, latex or a silicone coating.

The type of restraining features **34**, their size and the material from which they are constructed may be selected based upon the build objects being built and the way in which they are to be restrained. In one example the restraining features may comprise pins to contact the build object and restrain it, but still allow air to circulate around the build object.

FIG. **4** shows an exploded view of the example of a tray **26** of FIG. **3**. In this example the restraining features **34** are carried on the mesh **28** and are secured thereto by welding. In other examples the restraining features may be secured to the mesh, permanently or releasably, by any suitable means, for example adhesives or bonding agents, or fixings such as screws, rivets or clips. In other examples the restraining features may be integrally formed with the mesh. In one example the mesh may be formed in a three-dimensional shape such that there are hills which provide the restraining features which restrain the build objects in the valleys.

In this example the mesh **28** is surrounded by a peripheral edge portion **40** through which fixings, in this example screws **42**, are inserted to releasably secure the mesh **28** to the frame **30**.

The frame **30** comprises handling portions **44** which include coupling features **46** to which the automatic handling equipment can releasably engage so that automatic handling equipment can move the tray.

Since the mesh **28** is releasably secured to the frame **30** it is possible to remove one mesh **28** and replace it with different mesh which may have different object regions and/or different restraining features which may be selected to be appropriate for a planned build operation. The mesh may be selected from a set of a plurality of meshes having different configurations of object portions and/or restraining features.

FIGS. **5***a*, **5***b*, **5***c* and **5***d* show schematic cross sections of an example of a sequence of stages of an example of a build cake **48** supported on a tray **126** during a decake operation.

Referring initially to FIG. **5***a* which shows an initial state, the build cake **48** comprises build objects **50** and non-solidified build material **52** and is retained at the sides by walls **54**, which form part of a box into which the build cake is transferred. The build objects **50** have been built within the build cake at build locations which are located above object regions **132** of the tray **126**. The tray **126** includes restraining features **134** adjacent the object regions **132**, the restraining features **134** comprising walls forming a compartment which surrounds the object region **132**. In this example the assembly of the tray **126**, build cake **48** and walls **54** have been automatically moved to a decaking location by an automated handling apparatus which engages with the tray **126**, for example with the handling portions **40** of the tray of FIG. **3**.

Referring now to FIG. **5***b* which shows a state during a decaking operation and, in this example, the mesh **128** of the tray **126** is being vibrated so that non-solidified powder is passing though the mesh **128** of the tray **126**. As a result of the non-solidified powder passing though the mesh **128** from below the build objects, the build objects **50** have moved into contact with the mesh **128** of the tray **126** within the object regions **132**.

Referring now to FIG. **5***c* which shows a state during a decaking operation later than that of FIG. **5***b*. Air streams **56** are being used to assist the decaking operation. However, as a result of the build objects **50** contacting the tray and the air streams **56** impacting the build objects **50**, the build objects **50** have moved within the object regions **132**. The build objects **50** have been restrained within their respective object regions **132** by the restraining features **134**.

Referring now to FIG. **5***d* which shows a state during a further decaking operation. High velocity air streams **58** are being used to dislodge non-solidified build material from the build objects **50**. As a result of the high velocity air streams **58** the build objects **50** contacting the tray have moved further within the object regions **132**. The build objects **50** have been restrained within the object regions **132** by the restraining features **134**.

Restraining the build objects **50** within the object regions **132** helps to reduce contact between the build objects which could cause damage to the build objects **50**, and also helps to maintain traceability of the build objects **50** during the process.

FIGS. **6***a* and **6***b* show schematic cross sections of another example of stages of an example of a build cake **48** supported on another example of a tray **226** during a decake operation.

The tray **226** of this example comprises an obstruction member **60** and the tray **226** has an open configuration in which the build material is able to pass through the openings of the mesh **228** to pass through the tray **226**. The tray also has a closed configuration in which the obstruction member **60** occludes openings of the mesh **228**. As shown in FIG. **6***a* the tray **226** is in the closed configuration and the obstruction member **60** is occluding the openings of the mesh **228** such that non-solidified build material is prevented from passing through the openings of the mesh **228**. This can facilitate moving of the tray **226** with a build cake supported thereon. In this example the obstruction member comprises an obstruction element with openings therethrough and, in the closed position, the openings of the obstruction element are not aligned with the openings of the mesh and so occlude the openings through the mesh.

In other examples the obstruction member may comprise a filter, for example a paper filter, attached under the mesh of the tray to prevent build material from passing through the openings of the mesh. The filter can be removed manually by a user, or automatically by a machine, to allow the build material to pass through the openings of the mesh.

The tray **226** includes a lever **62** with which a user, or an automated, or partly automated, mechanism, can move the tray **226** between the open and closed configurations.

In FIG. **6***b* the tray **226** has been moved into the open configuration by pulling the lever **62** so that non-solidified build material can pass through the openings of the mesh **228**. Thus, the decaking operation comprises moving the tray between a closed configuration to an open configuration. In this example the obstruction element of the obstruction member has been moved so that the openings of the obstruction element are aligned with the openings of the mesh and so build material can pass through the mesh. In some embodiments the degree of alignment between the openings of the obstruction element and the mesh can be varied to alter the amount by which the openings of the mesh are occluded by the obstruction member as this can vary the rate at which build material can pass through the mesh.

FIG. **7** shows another example of a tray **326** to be used in an additive manufacturing process, for example the additive manufacturing process **1** of FIG. **1**, of the additive manufacturing process **10** of FIG. **2**.

The tray **326** comprises restraining features **234** which comprise sloping surfaces along which a build object moving towards the mesh **328** of the tray **326** under gravity would tend to move so that the build object is directed towards an object region **332**. In some examples the sloping surfaces may be continuous and may surround an object region forming a compartment.

FIG. **8** shows a schematic diagram of a controller **64**. In this example the controller **64** comprises a non-transitory computer-readable storage medium **66** comprising instructions **68** executable by a processor. The computer-readable storage medium **68** comprising:

Instructions **70** receive build object information which comprises information relating to a build object to be built within a build cake created during an additive manufacturing process, for example the additive manufacturing process **1** of FIG. **1** or the additive manufacturing process **10** of FIG. **2**.

Instructions **72** to receive tray information which comprises information relating to a tray to be used to support the build cake during a decake process of the additive manufacturing process. The tray comprises a mesh having openings therethrough. The tray further comprising an object region and a restraining feature to restrain a build object within the object region.

Instructions **74** determine, based upon the build object information and the tray information, a build location of the build object within a build cake so that, during the decake operation of the additive manufacturing process, in which non-solidified build material from the build cake passes through the openings of the mesh, the object will move into contact with the tray in the object region so that the object is restrained within the object region of the tray by the restraining feature.

Instructions **76** to provide instructions to an additive manufacturing apparatus to carry out an additive manufacturing process using the tray in which a build cake is created with the build object in the determined build location.

As set out above, there may be a plurality of build objects and the tray may include a plurality of object regions.

The computer-readable storage medium **68** also optionally comprises instructions **78** to provide instructions to an additive manufacturing apparatus to support the build cake on the tray and carry out a decaking operation in which non-solidified build material from the build cake passes through the openings of the mesh.

The invention claimed is:

1. An additive manufacturing process comprising:

carrying out an additive manufacturing build process to create a build cake, the build cake comprising a build object and non-solidified build material, the build object being built in a build location within the build cake;

supporting the build cake on a tray, the tray comprising a mesh having openings therethrough and a plurality of object regions, each object region of the plurality of object regions comprising a restraining feature to restrain a build object within each object region of the plurality of object regions, wherein the restraining feature comprises a dividing wall around each object region;

performing a decake operation in which non-solidified build material from the build cake passes through the openings of the mesh and the object moves into contact with the tray in the object region so that the object is restrained within the object region of the tray by the restraining feature.

2. An additive manufacturing process as claimed in claim **1**, in which the build location of the object is determined based upon the position of the object region of the tray within which the object is to make contact with the tray.

3. An additive manufacturing process as claimed in claim **1**, in which the build cake comprises a plurality of build objects, each build object being at a different build location within the build cake, and the object region of the tray receives a set of the plurality of build objects during the decake operation and the set of the plurality of build objects is restrained within the object region of the tray by the restraining feature.

4. An additive manufacturing process as claimed in claim **3**, in which the tray comprises a plurality of object regions, each object region comprising a restraining feature to restrain a build object within the object region, and in which each object region of the tray receives a set of the plurality of build objects during the decake operation, and each set of the plurality of build objects is restrained by the restraining feature within the object region of the tray within which it was received.

5. An additive manufacturing process as claimed in claim **1**, the wherein the dividing wall defines a compartment into which the build object moves during the decake operation.

6. An additive manufacturing process as claimed in claim **5**, in which the process comprises performing a further decake process when the build object is restrained within the object region of the tray by the restraining feature.

7. An additive manufacturing process as claimed in claim **1**, in which the cake is created on the tray during the additive manufacturing build process.

8. An additive manufacturing process as claimed in claim **7**, in which the build process is carried out at a build location and the tray is moved to a decaking location prior to the decaking operation.

9. An additive manufacturing process as claimed in claim **8**, in which the tray is automatically moved to a decaking location prior to the decaking operation.

10. An additive manufacturing process as claimed in claim **1**, in which the object region of the tray is selected, and the restraining feature configured, based upon the position of the build location of the build object within the build cake.

11. An additive manufacturing process as claimed in claim **1**, in which the tray comprises an obstruction member and the tray has an open configuration in which the build material is able to pass through the openings of the mesh to pass through the tray, the tray also comprising a closed configuration in which the obstruction member occludes openings of the mesh, the decaking operation comprising moving the tray between a closed configuration and an open configuration.

12. A tray to support a build cake comprising a build object and non-solidified build material during an additive manufacturing build process, the tray comprising a mesh having openings therethrough and a plurality of object regions, each object region of the plurality of object regions comprising a restraining feature to restrain a build object within each object region of the plurality of object regions, wherein the restraining feature comprises a dividing wall around each object region.

13. A non-transitory machine-readable storage medium comprising instructions executable by a processor, the machine-readable storage medium comprising instructions to:

receive build object information, the build object information comprising information relating to a build object to be built within a build cake created during an additive manufacturing process;

receive tray information, the tray information comprising information relating to a tray to be used to support the build cake during a decake process of the additive manufacturing process, the tray comprising a mesh having openings therethrough and an object region of a plurality of object regions and a restraining feature to restrain a build object within each object region of the plurality of object regions, wherein the restraining feature comprises a dividing wall around each object region;

determine, based upon the build object information and the tray information, a build location of the build object within a build cake so that, during the decake operation of the additive manufacturing process, in which non-solidified build material from the build cake passes through the openings of the mesh, the object will move into contact with the tray in the object region so that the object is restrained within the object region of the tray by the restraining feature; and

provide instructions to an additive manufacturing apparatus to carry out an additive manufacturing process using the tray in which a build cake is created with the build object in the determined build location.

14. A non-transitory machine-readable storage medium as claimed in claim **13**, in which:

the build object information comprises information relating to a plurality of build objects to be built within a build cake created during an additive manufacturing process;

the tray information comprises information relating to a tray including a plurality of object regions and restraining features to restrain a build object within each object region;

the machine-readable storage medium comprising instructions to:

determine, based upon the build object information and the tray information, build locations of the build objects within a build cake so that, during a decake operation of the additive manufacturing process, in which non-solidified build material from the build cake passes through the openings of the mesh, each build object will move into contact with the tray in an object region so that each object is restrained within an object region of the tray by the restraining features; and

provide instructions to an additive manufacturing apparatus to carry out an additive manufacturing process using the tray in which a build cake is created with the build objects in the determined build locations.

15. A non-transitory machine-readable storage medium as claimed in claim **13**, in which the machine-readable storage medium comprises instructions to:

provide instructions to an additive manufacturing apparatus to support the build cake on the tray and carry out a decaking operation in which non-solidified build material from the build cake passes through the openings of the mesh.

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