Title: APPARATUS AND METHOD FOR FORMING THREE-DIMENSIONAL OBJECTS USING LINEAR SOLIDIFICATION

Abstract: An apparatus and method for making a three-dimensional object from a solidifiable material using a linear solidification device is shown and described. In certain examples, the linear solidification device includes a laser diode that projects light onto a scanning device, such as a rotating polygonal mirror or a linear scanning micromirror, which then deflects the light onto a photohardenable resin. As a result, the linear solidification device scans a line of solidification energy in a direction that is substantially orthogonal to the direction of travel of the laser diode. In other examples, the linear solidification device is a laser device array or light emitting diode array that extends in a direction substantially orthogonal to the direction of travel of the array.
Published: (88) Date of publication of the international search report:
11 June 2015

— with international search report (Art. 21(3))
— before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))
### INTERNATIONAL SEARCH REPORT

**International application No.**

PCT/US 14/17267

---

**A. CLASSIFICATION OF SUBJECT MATTER**

**IPC (8)** - B28B 3/20, B29C 47/12, B82Y 30/00, G01N 25/38 (2015.01)

**CPC** - B28B 3/20, B29C 47/12, B29C 47/126, B82Y 30/00, G01 N 25/38

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)

IPC: B28B 3/20, B29C 47/12, B82Y 30/00, G01N 25/38 (2015.01)

CPC: B28B 3/20, B29C 47/12, B29C 47/126, B82Y 30/00, G01 N 25/38

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


Patents and NPL (classification, keyword; search terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)


---

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>US 2013/0001834 A1 (EL-SIBLANI et al.) 03 January 2013 (03.01.2013), para [0050], [0055], [0070], [0071], [0086]-[0088], [0092], [0100], [0118], [0124], [0127], [0142], [0146], [0164], [0168]-[0170], [0178]-[0193], [0198], [0206]-[0235], [0242]</td>
<td>1-20, 45, 46</td>
</tr>
<tr>
<td>Y</td>
<td>US 2003/0095186 A1 (AMAN et al.) 22 May 2003 (22.05.2003), para [0063]-[0390]</td>
<td>1-20, 45, 46</td>
</tr>
<tr>
<td>Y</td>
<td>US 5,121,329 A (CRUMP) 09 June 1992 (09.06.1992), col 2, in 67 to col 16, in 29</td>
<td>1-20, 45, 46</td>
</tr>
</tbody>
</table>

* Further documents are listed in the continuation of Box C.

---

<table>
<thead>
<tr>
<th>Date of the actual completion of the international search</th>
<th>Date of mailing of the international search report</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 April 2015 (01.04.2015)</td>
<td>16 APR 2015</td>
</tr>
</tbody>
</table>

Name and mailing address of the ISA/US:

P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-3201

Authorized officer: Lee W. Young

PCT Helpdesk: 571-272-4300

PCT OSP: 571-272-7774

Form PCT/ISA/2 10 (second sheet) (January 2015)
**INTERNATIONAL SEARCH REPORT**

<table>
<thead>
<tr>
<th>Box No. II</th>
<th>Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:</td>
</tr>
<tr>
<td>1. □</td>
<td>Claims Nos.: because they relate to subject matter not required to be searched by this Authority, namely:</td>
</tr>
<tr>
<td>2. □</td>
<td>Claims Nos.: because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:</td>
</tr>
<tr>
<td>3. □</td>
<td>Claims Nos.: because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Box No. III</th>
<th>Observations where unity of invention is lacking (Continuation of item 3 of first sheet)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>This International Searching Authority found multiple inventions in this international application, as follows:</td>
</tr>
<tr>
<td></td>
<td>- Please See Extra Sheet --</td>
</tr>
<tr>
<td>1. □</td>
<td>As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.</td>
</tr>
<tr>
<td>2. □</td>
<td>As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.</td>
</tr>
<tr>
<td>3. □</td>
<td>As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:</td>
</tr>
<tr>
<td>4. △</td>
<td>No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:</td>
</tr>
<tr>
<td></td>
<td>1-20, 45, 46</td>
</tr>
</tbody>
</table>

**Remark on Protest**

- □ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- □ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- □ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (January 2015)
Box III: lack of unity

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I: Claims 1-20, 45, and 46, drawn to a method of making a three-dimensional object from a solidifiable material.

Group II: Claims 21-31, 38-44, and 47, drawn to an apparatus for making a three-dimensional object from a solidifiable material.

Group III: Claims 32-37 and 48, drawn to a method of forming a three-dimensional object.

The inventions listed as Groups I through III do not relate to a single general inventive concept under PCT Rule 13.2 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

Special Technical Features

Groups II and III do not require a method of making a three-dimensional object from a solidifiable material, comprising:

- providing original solidification energy source event data corresponding to a cross-section of the three-dimensional object, wherein the original solidification energy source event data comprises a plurality of original solidification energy source event data items, and each original solidification energy source event data item is associated with a position along a build envelope scanning axis and is indicative of a change in the energization state of a solidification energy source;
- calculating modified solidification energy source event data corresponding to the cross-section of the three-dimensional object, wherein the modified solidification energy source event data comprises a plurality of modified solidification energy source event data items, each modified solidification energy source event data item corresponds to one of the respective original solidification energy source event data items and is based on the associated position along the build envelope scanning axis of its corresponding original solidification energy source event data item;
- solidifying the solidifiable material in accordance with the modified solidification energy source event data to form the cross-section of the three-dimensional object; or
- a method of making a three-dimensional object from a solidifiable material, comprising:
  - providing object data representative of a cross-section of the three-dimensional object;
  - providing a linear solidification device that moves in a first direction and progressively solidifies the solidifiable material in a second direction at a scanning speed that varies with a position of solidification energy along the second direction as it moves in the first direction, modifying the object data to compensate for the variation of the scanning speed in the second direction; and
  - solidifying the solidifiable material based on the modified object data, as required by Group I.

Groups I and III do not require an apparatus for making a three-dimensional object from a solidifiable material, comprising:

- a linear solidification device that moves in a first direction and progressively solidifies the solidifiable material in a second direction while moving in the first direction based on modified object data;
- a controller operatively connected to the linear solidification device to control the movement of the linear solidification device in the first direction and the progressive solidification of the solidifiable material in the second direction based on the modified object data;
- a computer readable medium having computer executable instructions programmed thereon to calculate the modified object data based on original object data, the instructions performing the following steps:
  - receiving the original object data, wherein the original object data comprises a plurality of original object data items, each data item being indicative of a solidification energy source event and being associated with a location along the second direction;
  - calculating modified object data items corresponding to each original object data item, wherein the modified object data item is calculated based on the corresponding original object data and the location along the second direction with which the corresponding original object data item is associated; or
  - apparatus for making a three-dimensional object from a solidifiable material, comprising:
    - a first linear solidification device operatively connected to a second linear solidification device such that when the first linear solidification device moves in a first direction, the second linear solidification device moves in the first direction, and wherein the first linear solidification device progressively supplies solidification energy in a second direction as the first linear solidification device moves in the first direction, the second linear solidification device progressively supplies solidification energy in the second direction as the second linear solidification device moves the first direction, the first linear solidification device has a solidification energy supply maximum position along the second direction, the second linear solidification device has a solidification energy supply minimum position along the second direction, and the second linear solidification device minimum position overlaps the first linear solidification device maximum position, as required by Group II.

Group I and II do not require a method of forming a three-dimensional object, comprising:

- providing a linear solidification device;
- providing a blade;
- traversing the blade in a first direction along a solidifiable material and in contact with the solidifiable material; and
- traversing the linear solidification device in the first direction as the blade is traversed in the first direction and progressively supplying solidification energy from the first linear solidification device in a second direction as the linear solidification device is traversed in the first direction, as required by Group III.

-- Please See Extra Sheet --
Continued from previous page

Shared Common Features

The only feature shared by Groups I through III that would otherwise unify the groups is a solidifiable material; three-dimensional object; linear solidification device; and moving/movement/traversing a first and a second direction. However, this shared technical feature does not represent a contribution over prior art, because the shared technical feature is anticipated by US 2012/0195994 A1 to El-Siblani et al. (hereinafter "El-Siblani").

El-Siblani discloses a solidifiable material (para [0052]); three-dimensional object (para [0053]); linear solidification device (para [0135]); and moving/movement/traversing a first and a second direction (para [0052]).

The only feature shared by Groups I and II that would otherwise unify the groups is solidification energy and calculating. However, this shared technical feature does not represent a contribution over prior art, because the shared technical feature is anticipated by El-Siblani.

El-Siblani discloses a solidification energy (para [0053]) and calculating (para [0064], [0140], generating energy pattern with pixels or voxels that define a location in the x,y plane... rotating energy deflector.).

As the technical feature was known in the art at the time of the invention, this cannot be considered a special technical feature that would otherwise unify the groups.

Groups I through III therefore lack unity under PCT Rule 13 because they do not share a same or corresponding special technical feature.