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(54) **Title**: MOLD-TOOL SYSTEM INCLUDING RESIN-CONTACT BODY HAVING HIERARCHICAL SURFACE MICRO-STRUCTURE

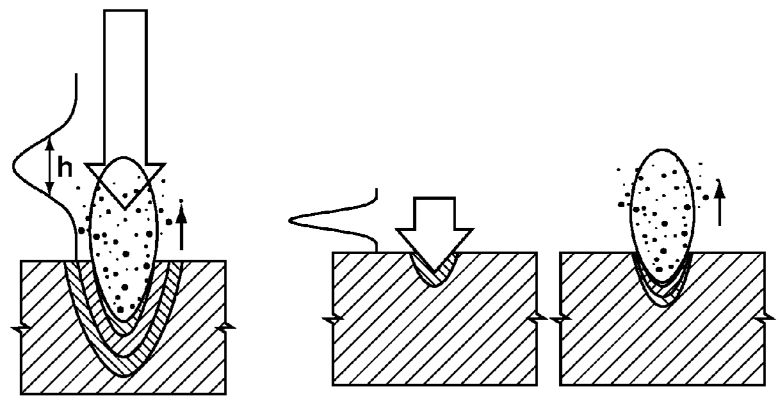

FIG. 1E

(57) **Abstract**: A mold-tool system (100), comprising: a frame assembly (102); and a resin-contact body (104) being supported, at least in part, by the frame assembly (102), the resin-contact body (104) having, at least in part, a hierarchical surface microstructure (106) facing, at least in part, a melt channel (108), the melt channel (108) being configured to convey, in use and at least in part, a resin.

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MOLD-TOOL SYSTEM INCLUDING RESIN-CONTACT BODY HAVING HIERARCHICAL SURFACE MICROSTRUCTURE

TECHNICAL FIELD

An aspect generally relates to (but is not limited to) a mold-tool system including a resin-contact body having, at least in part, a hierarchical surface microstructure.

SUMMARY

The inventor has researched a problem associated with known molding systems that inadvertently manufacture bad-quality molded articles or parts and/or has low productivity. After much study, the inventor believes he has arrived at an understanding of the problem and its solution, which are stated below, and the inventors believe this understanding is not known to the public.

In conventional hot runner manifolds, the resins may become grafted to a melt channel wall, which may hinder resin flow leading to high pressure drop (across the manifold), and increase color change times, and sometimes degrade the resin due to high residence time at the melt channel wall. With this condition (steel manifold material and injection molding resin flow rates) it may not be possible to induce adhesive slip (that is, complete resin debonding from the runner wall) to move the resin that is attached the melt channel wall. This condition may be due to: (i) the resin-steel interface condition where the presence of oxides and hydroxides at the steel melt channel wall enable the formation of hydrogen bonds with organic resins (grafting of the resin to steel), and/or (ii) the extreme high flow rates required to induced slip to detach the resin from the melt channel wall are practically impossible to produce.

To resolve the above issues, according to one aspect, there is provided a mold-tool system (100), comprising: a frame assembly (102); and a resin-contact body (104) being supported, at least in part, by the frame assembly (102), the resin-contact body (104) having, at least in part, a hierarchical surface microstructure (106) facing, at least in part, a melt channel (108), the melt channel (108) being configured to convey, in use and at least in part, a resin.

Other aspects and features of the non-limiting embodiments will now become apparent to those skilled in the art upon review of the following detailed description of the non-limiting embodiments with the accompanying drawings.

DETAILED DESCRIPTION OF THE DRAWINGS

The non-limiting embodiments will be more fully appreciated by reference to the following detailed description of the non-limiting embodiments when taken in conjunction with the accompanying drawings, in which:

FIG. 1A depicts a photograph of a microscopic view of a lotus leaf;

FIG. 1B depicts a schematic representation of a hierarchical microscopic structure of the lotus leaf of FIG. 1A;

FIGS. 1C, 1D depict schematic representations of a lotus microstructure;

FIG. 1E depicts an example of femto-second laser ablation on a surface of a metal alloy;

FIGS. 1F, 1G depict examples of a fabricated protuberation structure on a surface of a metal alloy;

FIG. 1H depicts an example of a fabricated protuberation structure of the lotus leaf.

FIG. 1I depicts an example of a fabricated protuberation structure of the lotus leaf.

FIGS. 2 and 5 depict examples of the mold-tool system;

FIGS. 3A, 3B depict views of a femtosecond-pulsed laser ablation microstructure;

FIG. 4A depicts a close up view of a plasma-etched surface; and

FIG. 4B depicts a close up view of a lithographically etched surface.

The drawings are not necessarily to scale and may be illustrated by phantom lines, diagrammatic representations and fragmentary views. In certain instances, details not necessary for an understanding of the embodiments (and/or details that render other details difficult to perceive) may have been omitted.

DETAILED DESCRIPTION OF THE NON-LIMITING EMBODIMENT(S)

FIGS. 2 and 5 depict examples of the mold-tool system (**100**). The mold-tool system (**100**) may include components that are known to persons skilled in the art, and these known components will not be described here; these known components are described, at least in part, in the following reference books (for example): (i) "*Injection Molding Handbook*" authored by OSSWALD/TURNG/GRAMANN (ISBN: 3-446-21669-2), (ii) "*Injection Molding*

Handbook" authored by ROSATO AND ROSATO (ISBN: 0-412-99381-3), (iii) "*Injection Molding Systems*" 3rd Edition authored by JOHANNABER (ISBN 3-446-17733-7) and/or (iv) "*Runner and Gating Design Handbook*" authored by BEAUMONT (ISBN 1-446-22672-9). It will be appreciated that for the purposes of this document, the phrase "includes (but is not limited to)" is equivalent to the word "comprising". The word "comprising" is a transitional phrase or word that links the preamble of a patent claim to the specific elements set forth in the claim that define what the invention itself actually is. The transitional phrase acts as a limitation on the claim, indicating whether a similar device, method, or composition infringes the patent if the accused device (etc) contains more or fewer elements than the claim in the patent. The word "comprising" is to be treated as an open transition, which is the broadest form of transition, as it does not limit the preamble to whatever elements are identified in the claim.

The definition of the mold-tool system (**100**) is as follows: a system that may be positioned and/or may be used in an envelope defined by a platen system of the molding system, such as an injection-molding system for example. The platen system may include a stationary platen and a movable platen that is moveable relative to the stationary platen. Examples of the mold-tool system (**100**) may include (and is not limited to): a runner system, such as a hot runner system or a cold runner system, a runner nozzle, a manifold system, and/or any sub-assembly or part thereof.

FIGS. 2 and 5 depict examples of the mold-tool system (**100**), in which (generally) the mold-tool system (**100**) may include (and is not limited to): (i) a frame assembly (**102**), and also may include (ii) a resin-contact body (**104**) that may be supported, at least in part, by the frame assembly (**102**). The resin-contact body (**104**) may have, at least in part, a hierarchical surface microstructure (**106**) facing, at least in part, a melt channel (**108**). The melt channel (**108**) may be configured to convey, in use (at least in part), a resin. The hierarchical surface microstructure (**106**) may include (for example and is not limited to): (i) a first protuberation structure (**110**), and (ii) a second protuberation structure (**112**) that may be placed over, at least in part, the first protuberation structure (**110**). The first protuberation structure (110) may also be called a first-level hierarchical microstructure. The second protuberation structure (112) may also be called a second-level hierarchical microstructure. By way of example, the first protuberation structure (**110**) may include (and is not limited to) micro-protuberations. Also by way of example, the second protuberation structure (**112**) may include (and is not limited to) micro-protuberations. Alternatively, the second protuberation structure (**112**) may include (and is not limited to) nano protuberations.

For example, the first protuberation structure (**110**) may be manufactured from a subtractive forming method applied to a material, such as by using chemical etching or laser ablation or any other subtractive forming method on a steel alloy or melt-channel substrate. The first protuberation structure (**110**) may be manufactured from an additive forming method applied to a material, such as a deposition or coating method. The second protuberation structure (**112**) may be manufactured using a subtractive forming method. As well, the second protuberation structure (**112**) may be manufactured using an additive forming method. The second protuberation structure (**112**) may be manufactured using a low surface energy material. The second protuberation structure (**112**) may be manufactured using a polymer melt repelling substance equivalent in its effect to polytetrafluoroethylene (PTFE). The second protuberation structure (**112**) may be manufactured using a coating method to reduce its surface energy and/or provide it with a polymer melt repelling characteristic. The second protuberation structure (**112**) may be manufactured using a surface modification method (to reduce its surface energy and/or provide it with a polymer melt repelling characteristic).

The mold-tool system (**100**), such as (but not limited to) any component of a runner assembly (**512**) or runner system, provides ~~provide~~ adhesive slip and, therefore, reduced pressure drop and degradation as well as fast color change of organic resins during molding of a resin by a molding system. Various manufacturing method enables manufacturing of micro-patterns (e.g., micro-protuberations) on a surface facing the melt channel (**108**) before or after modifying the surface facing the melt channel (**108**) to reduce and/or eliminate resin grafting to the wall of the melt channel (**108**) by making it more oleophobic (repels organic resins) and/or to prevent the formation or presence of oxides and hydroxides. One of the manufacturing methods may include (and is not limited to) starting with split manifolds to produce micro-protuberation on the surface of the melt channel (**108**) using laser ablation prior to joining then after joining split manifold halves (of a runner system) together, treating the melt channel (**108**) with a fluoridation process to reduce the amount of oxygen, and increasing the amount of metal fluorides such as iron fluorides which are know to provide high lubricity.

The Lotus effect refers to the effect of self cleaning observed on the lotus leaves, which are characterized by their extreme hydrophobicity (repulsion of water). Analysis of the lotus leaves shows that the hydrophobicity of the lotus leaves is due to the coupling of two properties: a microstructure having microscopic protuberations, and a wax crystal on the microscopic protuberations.

One example of the mold-tool system (**100**) may include (and is not limited to) micro-protuberation placed on split manifold halves, as depicted in FIG. 2, prior to joining the halves by laser ablation or plasma etching or lithography etching, etc. In addition, for the case where closes manifolds are used, chemical etching may be used to manufacture the micro-protuberations. The surface modification to reduce the presence of oxides and hydroxides and provide lubricity for improved slip may be provided through a process of fluoridation where the oxygen content of the surface is reduced and replaced preferably by metal fluorides such iron fluorides. Other methods may be used to apply a coating to the melt channel (**108**) prior or after texturing of the melt channel (**108**) using laser ablation or any method of etching.

FIG. 1A depicts a photograph of a microscopic view of a lotus leaf. FIG. 1B depicts a schematic representation of a hierarchical microscopic structure of the lotus leaf of FIG. 1A. The first protuberation structure (110) is depicted as leaf protuberations. The second protuberation structure (112) is depicted as a wax crystal. FIG. 1C depicts a schematic representation of a lotus microstructure with a hydrophilic surface (that is, a no slip surface). FIG. 1C depicts the case where if the microscopic protuberations are not treated with a hydrophobic coating, such as wax, the Lotus effect may not likely be reproduced. FIG. 1D depicts a schematic representation of a lotus microstructure with a hydrophobic surface (that is, a high slip surface). The self-cleaning characteristic of the lotus leaf may include micro- or nano-patterning. An already hydrophobic surface may make that surface even more hydrophobic. Such surfaces may be called super-hydrophobic surfaces ~~or 'fakir surface'~~.

FIG. 1E depicts an example of femto-second laser ablation on a surface of a metal alloy. FIG. 1F depicts an example of a fabricated protuberation structure on a surface of a metal alloy. FIG. 1G depicts an example of a fabricated protuberation structure on a metal alloy. FIG. 1H depicts an example of a fabricated protuberation structure (also called a microstructure) similar to that of a lotus-like leaf surface. FIG. 1I depicts an example of a fabricated protuberation structure (which may also be called a hierarchical surface microstructure) similar to that of the lotus-like leaf surface.

FIG. 2 depicts a perspective view of a split manifold half of a runner system. The resin-contact body (**104**) includes a split manifold half (200).

FIG. 3A depicts a close up view of a femtosecond-pulsed laser ablation microstructure, ~~in which there is a square hole microstructure~~ manufactured on a steel alloy.

FIG. 3B depicts a close up view of a femtosecond-pulsed laser ablation microstructure, in which there is a more complex geometric microstructure manufactured on a steel alloy.

FIG. 4A depicts a close up view of a plasma-etched surface. FIG. 4B depicts a close up view of a lithographically etched surface patterned with 30 mm (millimeter) tall cubic microposts.

FIG. 5 depicts another example of the mold-tool system (**100**). The resin-contact body (**104**) may include (and is not limited to) any one (or more) of the following components of a runner system: a manifold bushing assembly (**500**), a valve stem interface assembly (**502**), a valve gate area assembly (**504**), a manifold assembly (**506**), a nozzle assembly (**508**), a hot tip gate area assembly (**510**), etc. For example, the frame assembly (**102**) may include (and is not limited to) a runner assembly (**512**). An advantage that may be achieved with the manifold bushing assembly (**500**), and/or the valve stem interface assembly (**502**) is reduced weepage of resin. An advantage that may be achieved with the valve gate area assembly (**504**) includes (i) reduction in valve stem sticking, (ii) improvement in color change. An advantage achieved with the manifold assembly (**506**) and/or the nozzle assembly (**508**) may include: (i) reduction of pressure drop, (ii) improvement in color change improvement, and/or (iii) reduction in stem drag. An advantage achieved in using the hot tip gate area assembly (**510**) may include improved color change.

It will be appreciated that the assemblies and modules described above may be connected with each other as may be required to perform desired functions and tasks that are within the scope of persons of skill in the art to make such combinations and permutations without having to describe each and every one of them in explicit terms. There is no particular assembly, components, or software code that is superior to any of the equivalents available to the art. There is no particular mode of practicing the inventions and/or examples of the invention that is superior to others, so long as the functions may be performed. It is believed that all the crucial aspects of the invention have been provided in this document. It is understood that the scope of the present invention is limited to the scope provided by the independent claim(s), and it is also understood that the scope of the present invention is not limited to: (i) the dependent claims, (ii) the detailed description of the non-limiting embodiments, (iii) the summary, (iv) the abstract, and/or (v) description provided outside of this document (that is, outside of the instant application as filed, as prosecuted, and/or as granted). It is understood, for the purposes of this document, the phrase "includes (and is not limited to)" is equivalent to the word "comprising". It is noted that the foregoing has outlined the non-limiting embodiments (examples). The description is made for particular non-limiting embodiments (examples). It is understood that the non-limiting embodiments are merely illustrative as examples.

CLAIMS

WHAT IS CLAIMED IS:

1. A mold-tool system (**100**), comprising:

a frame assembly (**102**); and

a resin-contact body (**104**) being supported, at least in part, by the frame assembly (**102**), the resin-contact body (**104**) having, at least in part, a hierarchical surface microstructure (**106**) facing, at least in part, a melt channel (**108**), the melt channel (**108**) being configured to convey, in use and at least in part, a resin.

2. The mold-tool system (**100**) of claim 1, wherein:

the hierarchical surface microstructure (**106**) includes:

a first protuberation structure (**110**); and

a second protuberation structure (**112**) being placed over, at least in part, the first protuberation structure (**110**).

3. The mold-tool system (**100**) of claim 2, wherein:

the first protuberation structure (**110**) includes micro-protuberations.

4. The mold-tool system (**100**) of claim 2, wherein:

the second protuberation structure (**112**) includes micro-protuberations.

5. The mold-tool system (**100**) of claim 2, wherein:

the second protuberation structure (**112**) includes nano protuberations.

6. The mold-tool system (**100**) of claim 2, wherein:

the first protuberation structure (**110**) is manufactured from a subtractive forming method applied to a material.

7. The mold-tool system (**100**) of claim 2, wherein:

the first protuberation structure (**110**) is manufactured from an additive forming method applied to a material.

8. The mold-tool system (**100**) of claim 2, wherein:

the second protuberation structure (**112**) is manufactured using a subtractive forming method.

9. The mold-tool system (**100**) of claim 2, wherein:

the second protuberation structure (**112**) is manufactured using an additive forming method.

10. The mold-tool system (**100**) of claim 2, wherein:

the second protuberation structure (**112**) is manufactured using a low surface energy material.

11. The mold-tool system (**100**) of claim 2, wherein:

the second protuberation structure (**112**) is manufactured using a polymer melt repelling substance equivalent in its effect to polytetrafluoroethylene (PTFE).

12. The mold-tool system (**100**) of claim 2, wherein:

the second protuberation structure (**112**) is manufactured using a coating method.

13. The mold-tool system (**100**) of claim 2, wherein:

the second protuberation structure (**112**) is manufactured using a surface modification method.

14. The mold-tool system (**100**) of claim 2, wherein:

the resin-contact body (**104**) includes a manifold bushing assembly (**500**).

15. The mold-tool system (**100**) of claim 2, wherein:

the resin-contact body (**104**) includes: a valve stem interface assembly (**502**).

16. The mold-tool system (**100**) of claim 2, wherein:

the resin-contact body (**104**) includes: a valve gate area assembly (**504**).

17. The mold-tool system (**100**) of claim 2, wherein:

the resin-contact body (**104**) includes: a manifold assembly (**506**).

18. The mold-tool system (**100**) of claim 2, wherein:

the resin-contact body (**104**) includes: a nozzle assembly (**508**).

19. The mold-tool system (**100**) of claim 2, wherein:
the resin-contact body (**104**) includes: a hot tip gate area assembly (**510**).

20. The mold-tool system (**100**) of claim 2, wherein:
the resin-contact body (**104**) includes: a split manifold half (**200**).

21. The mold-tool system (**100**) of claim 2, wherein:
the frame assembly (**102**) includes a runner assembly (**512**).

22. A molding system having the mold-tool system (**100**) of any preceding claim.

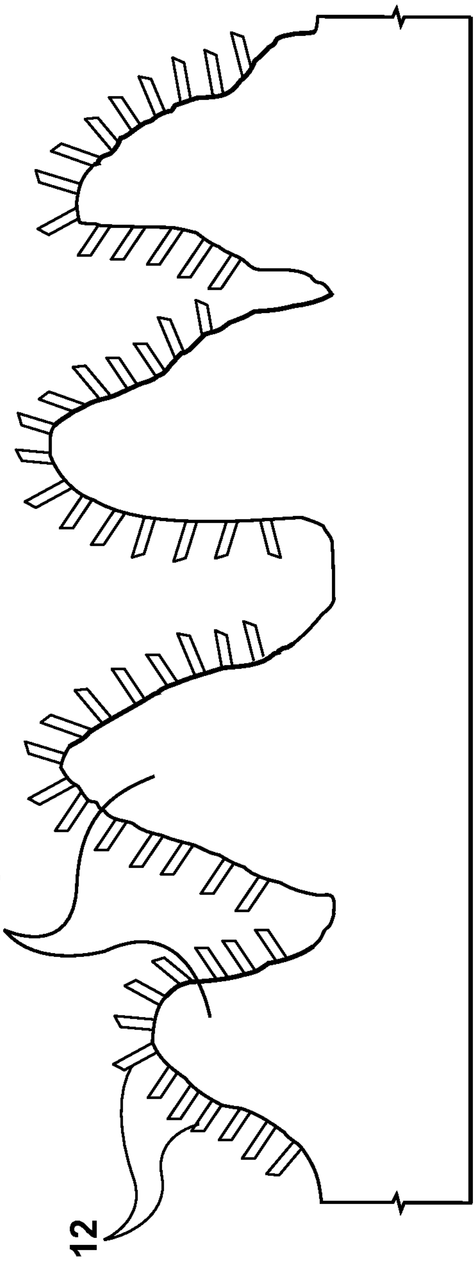

FIG. 1B

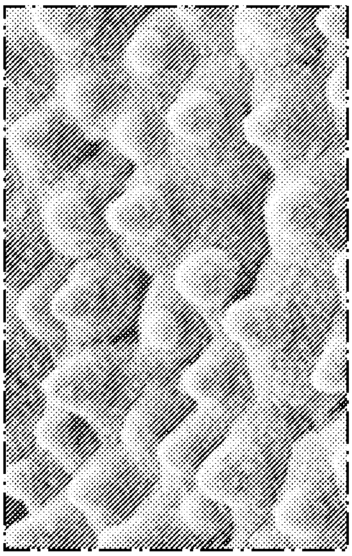

FIG. 1A

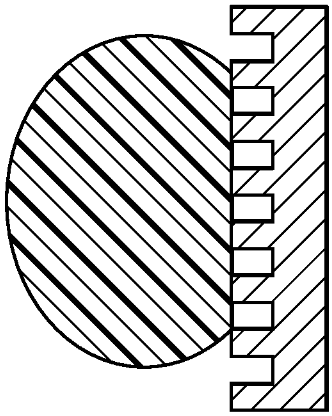

FIG. 1D

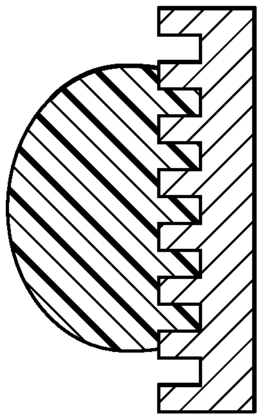

FIG. 1C

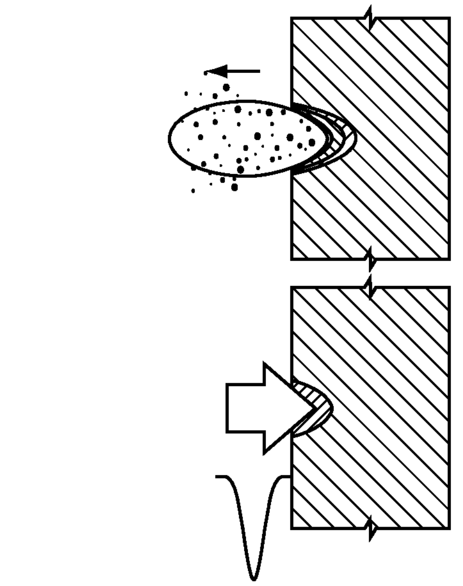

FIG. 1E

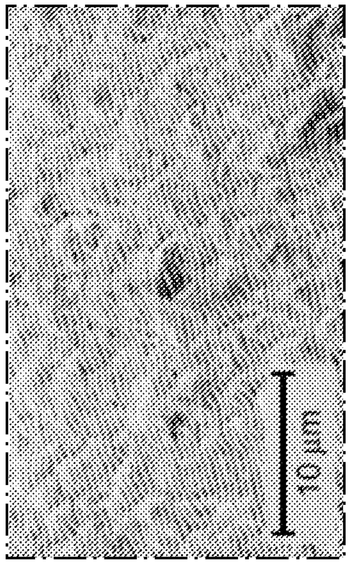

FIG. 1G

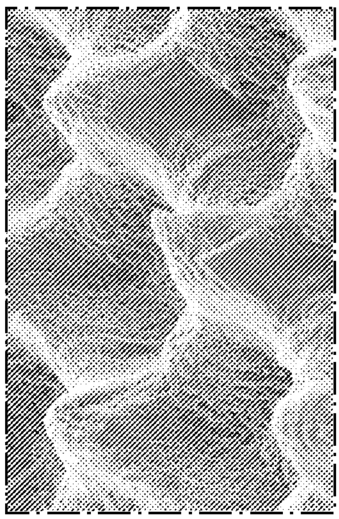

FIG. 1F

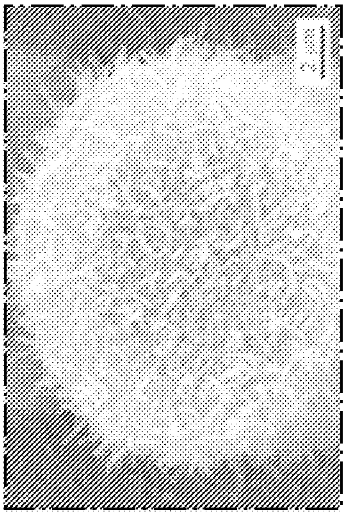

FIG. 1I

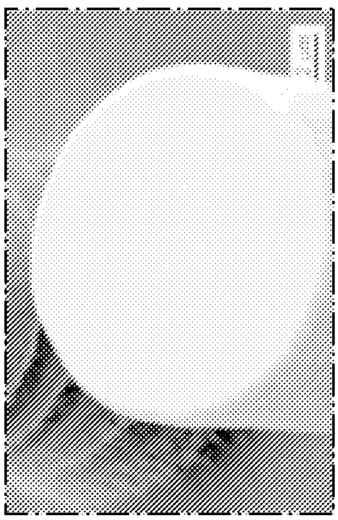

FIG. 1H

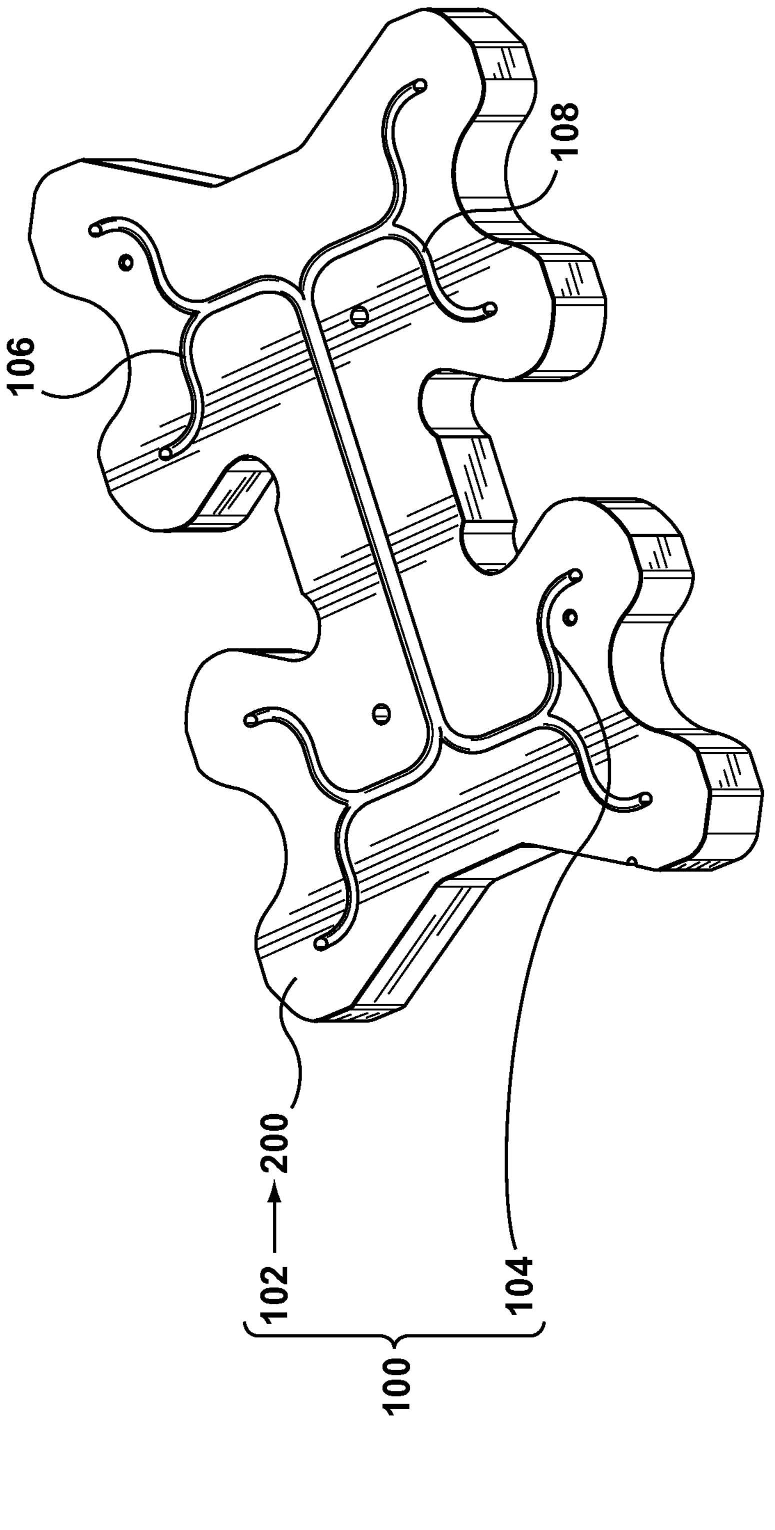

FIG. 2

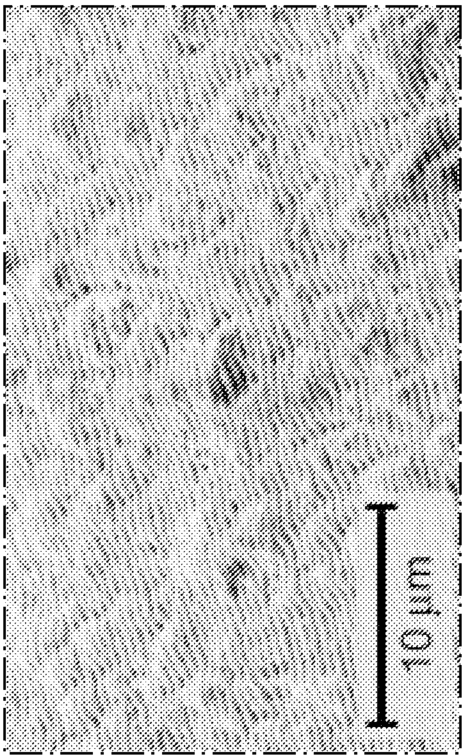

FIG. 3A

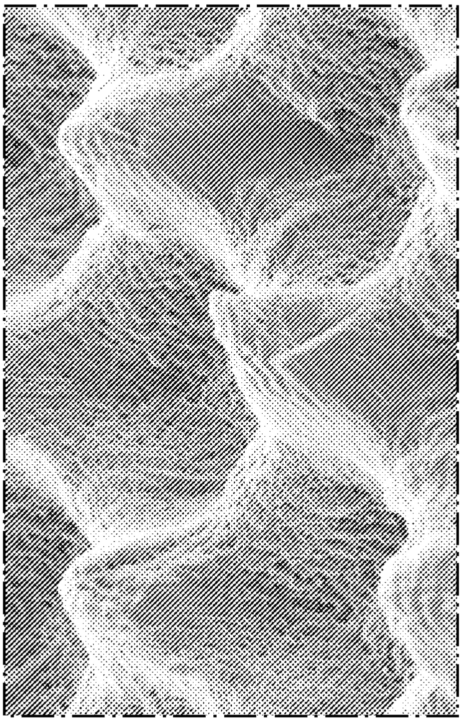

FIG. 3B

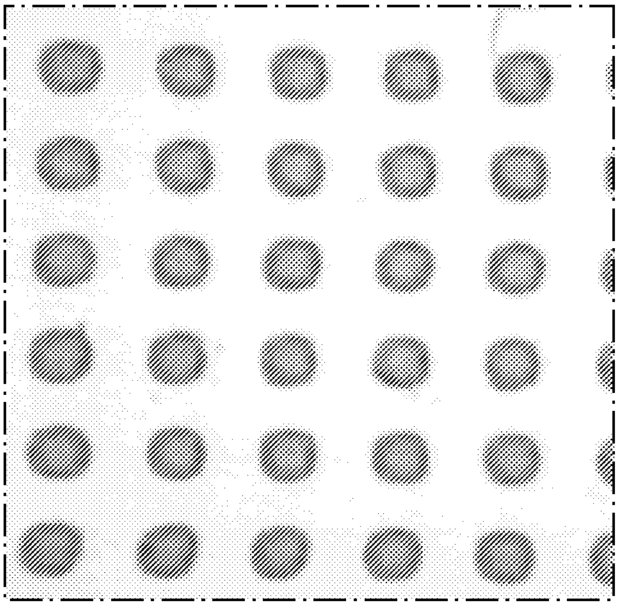

FIG. 4B

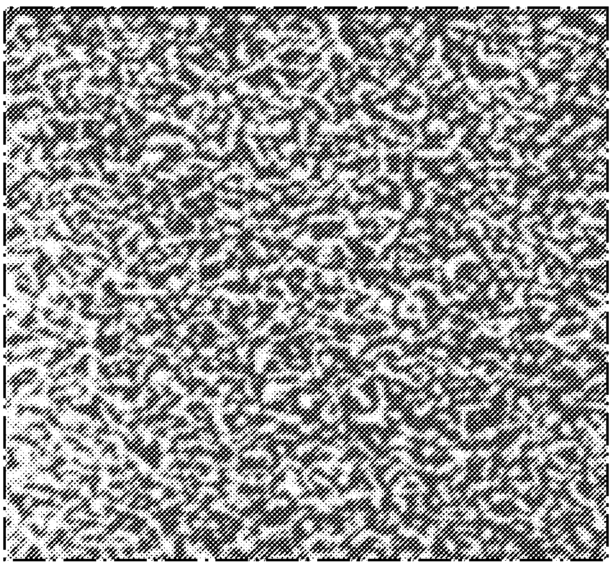

FIG. 4A

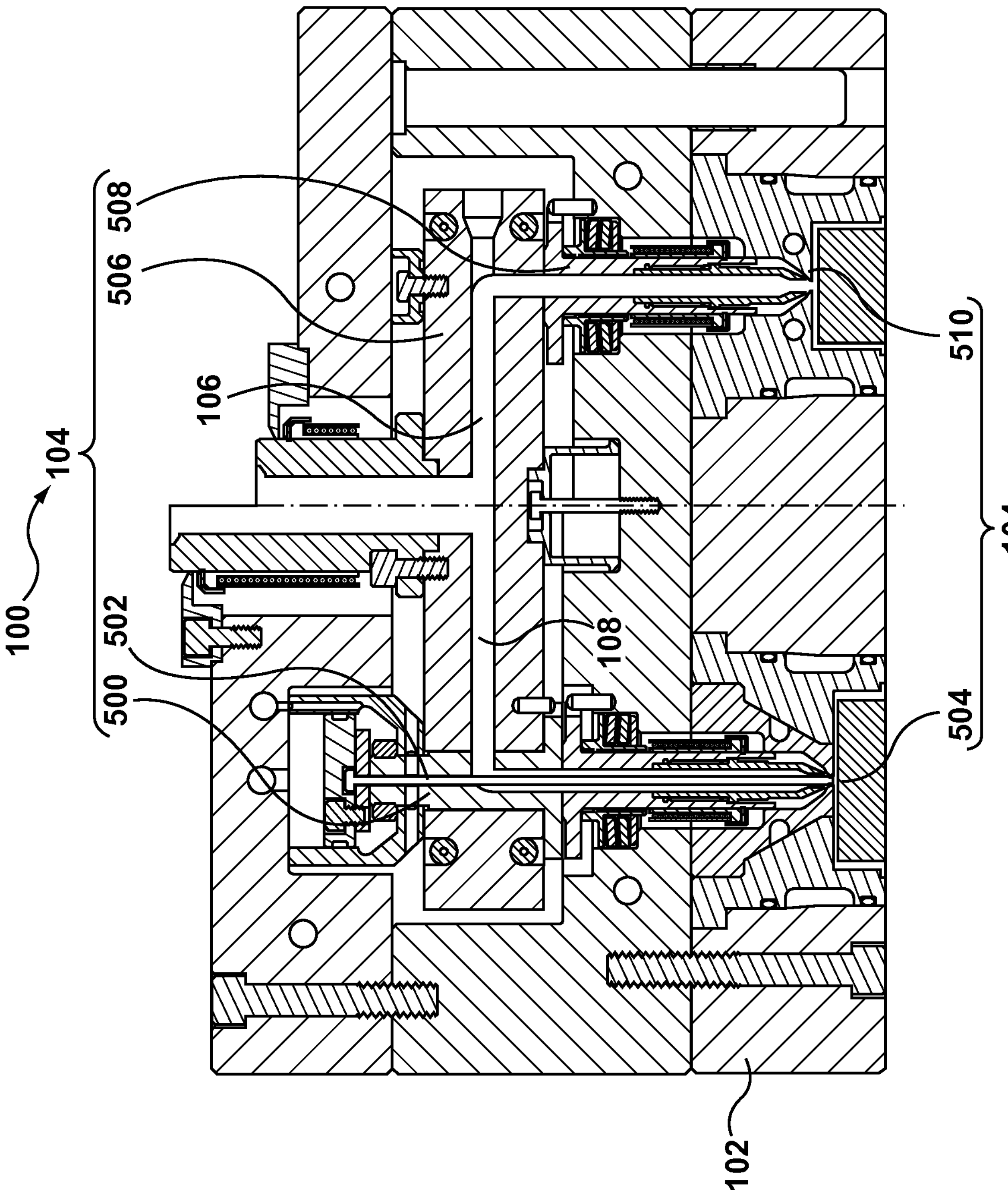

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No. PCT/US 12/28393

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - B29C 45/00 (2012.01)

USPC - 425/117

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 (8) - B29C 45/00 (2012.01)
USPC - 425/117

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC - 425/549; 425/117 (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWEST (PGPB,USPT,USOC,EPAB,JPAB) Terms - injection mold molding hydrophobic oleophobic superphobic ultraphobic microstructure nanostructure runner channel nozzle hierarchical
Google - injection-molding-(nozzle OR channel) phobic surface-microstructure

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6,419,476 B1 (OUELLETTE) 16 July 2002 (16.07.2002), col 6, ln 55-66; col 7, ln 60 to col 8, ln 7; col 9, ln 10-28; col 12, ln 28-34	1-22
Y	US 2009/0114618 A1 (ZHANG, ET AL.) 07 May 2009 (07.05.2009), para [0013], [0032], [0036]-[0039]	1-22
A	US 2010/0330340 A1 (ROTHSTEIN, ET AL.) 30 December 2010 (30.12.2010), entire document	1-22

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

* 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
07 June 2012 (07.06.2012)	19 JUN 2012

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774