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(54) **METHOD AND APPARATUS FOR FORMING A LIQUID-FORGED ARTICLE**

VERFAHREN UND VORRICHTUNG ZUR FORMUNG EINES FLÜSSIGSCHMIEDEARTIKELS
PROCÉDÉ ET APPAREIL POUR FORMER UN ARTICLE FORGÉ AU LIQUIDE

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Description

Field of the Invention

[0001] The invention relates to a method and an apparatus for forming a liquid-forged article and particularly, though not exclusively, to forming a liquid-forged near net-shape article having features with high aspect ratio.

Background

[0002] Articles having features with high aspect ratio are conventionally made by methods including machining, extrusion, forging, or casting a metal such as aluminium (Al). Machining is a process that produces articles with high tolerance control and good surface finishing. However, it is time consuming and expensive and results in a large amount of material wastage, making it unsuitable as a process for mass production. Extrusion and forging are processes that can produce articles with good structural integrity. However, traditional extrusion and forging are unable to form articles requiring a high density of features having high aspect ratio, such as heat sinks having fins and pins in close proximity as shown in FIGS. 1 and 2.

[0003] Die casting (high and low pressure) is a competing technology with some form of indirect pressure during material solidification that is widely used in industry. Gravity or die casting allows articles to solidify under little or no pressure. However, articles made by gravity or die casting methods often suffer from limitations such as porosity in the article structure, for example due to high turbulence of the in-gate in high pressure die casting, or gas entrapment in gravity casting, resulting in poor mechanical properties. Die casting is also unable to form net-shape articles having high-aspect ratio features without distortion, for example, the round heat sink with high aspect ratio fins 10 as shown in FIG. 1 where the height (h) to thickness (t) ratio of each fin 10 is greater than 40 to 1, i.e., $h:t > 40:1$. Furthermore, material choice is naturally limited to only casting alloys, whereas for an article to be used as a thermal management component such as a heat sink, it is desirable for it to be formed from low silicon wrought Al alloys or pure Al due to their enhanced thermal dissipating performance. However, these materials cannot be successfully cast due to shrinkage defects resulting from the casting process.

[0004] Squeeze casting or liquid forging forms articles using at least partially molten metal under direct pressure in a punch and die set. Improved article tolerances with minimized material distortion and shrinkage defects can be obtained. However, issues of porosity and incomplete part formation due to gas entrapment still remain, especially in the formation of articles having high aspect ratio features. This is even more of a problem when the high aspect ratio features are required to be relatively small in size, for example, where the thickness of the feature is 2 mm or less, as porosities in such small features can

make up a substantial proportion of the feature to result in material breakage and/or part failure.

[0005] Document WO 2008/085136 A1 discloses a method of forming an article, comprising: providing an article having at least one cavity in a mold; providing an at least partially molten metal for filling the at least one cavity; closing the mold to allow pressurized contact of the article with the metal; and applying pressure on the molten metal such that the molten metal fills the at least one cavity. Document US 6 298 903 B1 discloses venting a mold cavity and/or the pressure chamber of a diecasting mold during the filling operation by a second venting valve, additionally to a first venting valve. Document US 2002/079613 A1 discloses a molding process for fabricating heat dissipation devices. The molding process includes injection molding at least two differing conductive materials. In one embodiment it is mentioned that a second mold cavity may include a vent hole. Document JPH0386356 A discloses a metal mold with a gas vent, the gas vent having a shape memory alloy.

Summary of the Invention

[0006] According to a first aspect, there is provided a method of forming a liquid-forged article as defined by claim 1.

[0007] The method may further comprise relatively moving the punch away from the die cavity while retaining the article in the die cavity. The article is preferably retained in the die cavity by forming a retaining portion of the article within a recess provided in a retaining pin disposed in a die containing the die cavity.

[0008] According to a second aspect, there is provided an apparatus for forming a liquid-forged article, as defined by claim 5.

[0009] For both aspects, air is released through a gas exhaust passage defined by the air vent insert with the high aspect ratio cavity. Air may further be released through at least one gas vent provided in the air vent insert, the gas vent being in fluid communication with the gas exhaust passage.

[0010] The air vent insert comprises a head portion and an insert portion, the head portion being configured for positioning the air vent insert relative to the high aspect ratio cavity, and the insert portion being configured for extending into the high aspect ratio cavity. The insert portion may be tapered with a decreasing cross-sectional area as it extends into the high aspect ratio cavity.

[0011] The air vent insert may be provided with at least one gas vent, the gas vent being in fluid communication with the gas exhaust passage. The at least one gas vent is preferably provided in the head portion.

[0012] The gas exhaust passage is preferably dimensioned to prevent excessive melt flow therein for preventing clogging of the gas exhaust passage by solidified melt. The gas exhaust passage may have a length ranging between 2 mm and 6 mm, with a gap tolerance of at least 20 μm between the air vent insert and a wall of the

high aspect ratio cavity.

[0013] The apparatus may further comprise a retaining pin for retaining the article in the die cavity while relatively moving the punch away from the die cavity, the retaining pin being disposed in a die containing the die cavity. The retaining pin preferably comprises a recess for solidifying the melt therein such to form a retaining portion of the article within the recess.

[0014] The apparatus may comprise a plurality of high aspect ratio cavities and a corresponding plurality of air vent inserts. The plurality of air vent inserts may be provided individually.

[0015] As an example, there is provided a liquid-forged article having high aspect ratio features obtained by forming with the method of the first aspect.

[0016] As a further example, there is provided a liquid-forged article having high aspect ratio features obtained using the apparatus of the second aspect.

Brief Description of the Drawings

[0017] In order that the invention may be fully understood and readily put into practical effect there shall now be described, by way of non-limitative example only, exemplary embodiments of the present invention, the description being with reference to the accompanying illustrative drawings.

[0018] In the drawings:

FIG. 1(a) is a schematic side view illustration of an article having high aspect ratio features, i.e., a round heat sink having tapered fins;

FIG. 1(b) is a schematic top view illustration of the heat sink of FIG. 1(a);

FIG. 2 shows schematic perspective illustrations of examples of typical articles having high aspect ratio features, i.e., heat sinks with tapered fins, pins and radial fins;

FIG. 3 is a flow chart of an exemplary method of forming liquid-forged articles;

FIG. 4 is a schematic cross-sectional side view illustration of an exemplary apparatus for forming liquid-forged articles at a forming step of introducing a melt into a die cavity;

FIG. 5 is the apparatus of FIG. 4 at a forming step of moving a punch into the die cavity;

FIG. 6 is a schematic cross-sectional side view illustration of air vent inserts in the punch of the apparatus of FIG. 4;

FIG. 7 is a close-up view of an air vent insert of FIG. 6;

FIG. 8 is the apparatus of FIG. 4 at a forming step of relatively moving the punch away from the die cavity;

FIG. 9 is the apparatus of FIG. 4 at a forming step of ejecting a formed article from the die cavity;

FIG. 10 is a schematic side view illustration of removal of a portion of the formed article;

FIG. 11 shows a schematic side view illustration of

high aspect ratio features formed with flash;

FIG. 12 is perspective photographic illustrations of exemplary articles formed by the exemplary method and apparatus of the present invention;

FIG. 13 (a) is a micrograph of material grain size obtained by conventional casting; and

FIG. 13(b) is a micrograph of material grain size obtained by the present invention.

Detailed Description of the Exemplary Embodiments

[0019] As shown in FIGS. 3 to 10, an exemplary method 100 and apparatus 20 are provided for forming a liquid-forged article having at least one high aspect ratio feature with height to width ratio preferably greater than 40 : 1.

[0020] The apparatus 20 comprises a punch 22 having at least one high aspect ratio cavity 24 for forming a high aspect ratio feature 34 in a liquid-forged article 30. For articles having a plurality of high aspect ratio features 34, a corresponding plurality of high aspect ratio cavities 24 are provided in the punch 22. Each high aspect ratio cavity 24 has an internal cavity shape corresponding to a desired feature to be formed in the article 30, such as a pin or a fin as shown in the heat sinks of FIG. 2. The high aspect ratio cavities 24 may be defined by corresponding high aspect ratio features 25 provided in the punch 22.

[0021] The apparatus 20 further comprises a bottom puller or retaining pin 44 disposed in a die 42 for part retention and ejection. In an exemplary embodiment, the bottom puller or retaining pin 44 is provided with a trapezoidally-shaped recess 46 for retaining a formed article using a dovetail fit. The punch 22 and die 42 are preferably oriented and provided as a top punch 22 and a bottom die 42.

[0022] As shown in FIG. 4, in a first step of the exemplary method 100, a melt 52 comprising an at least partially molten material for forming the article 30 is introduced into a die cavity 41 of the die 42, 102, for example, via a launder 50. The melt temperature may range from 710 °C to 750°C, depending on the material chosen.

[0023] Next, as shown in FIG. 5, the punch 22 is moved relative to the die cavity 41 to contact the melt 52 in the die cavity 41, 104, such that the melt 52 enters the recess 46 in the retaining pin 44 to form a retaining portion 36 in the liquid-forged article 30. The melt 52 is also forced to flow and enter the high aspect ratio cavities 24 of the punch 22. This is preferably achieved by bringing the punch 22 towards the die cavity 41 as indicated by the arrow 60. The ram down speed or relative speed between the punch 22 and the die cavity 41 is preferably less than 0.5 ms⁻¹ to allow for thorough filling of the cavities 24 with the melt 52.

[0024] Virtually no air bubbles are trapped in or by the melt 52 that enters and fills the high aspect ratio cavities 24 as air is released or allowed to escape via air vent inserts 80 provided in the punch 22, 106. As shown in FIG. 6, each high aspect ratio cavity 24 is provided with its own air vent insert 80 in the punch 22 to allow air to

be released from each high aspect ratio cavity 24. This ensures that all the cavities 24 are fully filled by the melt 52 to virtually eliminate porosity or incomplete part formation in the article 30 when formed.

[0025] Each air vent insert 80 preferably has a head portion 82 and an insert portion 84. The head portion 82 and the insert portion 84 may be integral with each other. The head portion 82 may be accommodated in a correspondingly shaped recess 23 in the punch 22, and is preferably configured to position the air vent insert 80 relative to its corresponding high aspect ratio cavity 24. The insert portion 84 is configured to extend into the high aspect ratio cavity 24, so that the air vent insert 80 has a generally T-shaped cross-section, as shown hatched in FIG. 7. Accordingly, the air vent insert 80 may comprise, for example, a disc-shaped head portion 82 with a rod-shaped insert portion 84 for forming a high aspect ratio pin, or an elongate, substantially rectangular head portion 82 with an elongate, substantially rectangular insert portion 84 for forming a high aspect ratio fin, depending on the desired high aspect ratio feature to be formed.

[0026] The insert portion 84 is preferably tapered with a decreasing cross-sectional area as it extends into the high aspect ratio cavity 24, such that the insert portion 84 defines a gas exhaust passage 86 with the high aspect ratio cavity 24. Each air vent insert 80 is preferably also provided with at least one gas vent 88 in the head portion 80, the gas vent 88 being in fluid communication with the gas exhaust passage 86. The gas exhaust passage 86 and the gas vent 88 allow air to escape from the cavity 24 as the melt 52 enters the high aspect ratio cavity 24 in the direction shown by the arrow 66 in FIG. 7.

[0027] The air vent insert 80 is preferably made of a metal of high heat conductivity, such as a copper-based material, so that as the melt 52 comes into contact with the air vent insert 80, the melt 52 is rapidly cooled. Rapid cooling of the melt 52 prevents excessive flow of the melt 52 into the gas exhaust passage 86 that can lead to choking or clogging of the gas exhaust passage 86 or gas vent 88. Accordingly, the gas exhaust passage 86 should be dimensioned to prevent excessive melt flow therein so as to avoid clogging by solidified melt 52, while sufficiently allowing air to be released. To that end, the gas exhaust passage 86 may have a length ranging between 2mm and 6mm along the cavity 24, with a gap tolerance of at least 20 μm between the insert portion 84 and a wall 26 of the high aspect ratio cavity 24.

[0028] The punch 22 is configured to exert a forming or direct pressure of between 50 MPa and 120 MPa on the melt 52 while the melt 52 solidifies in the high aspect ratio cavities 24, 108. By exerting a direct forming pressure during solidification, stress is evenly distributed in the solidified material so that virtually all shrinkage defects are eliminated in the formed article. Releasing air via the air vents 80 and solidifying the melt 52 under direct pressure of the punch 22 results in formation of a near net-shape article 30 having high aspect ratio features 34 with virtually no porosity or shrinkage defects.

[0029] After the melt 52 has solidified, the punch 22 is moved relative to the die cavity 41 to separate the liquid-forged article 30 from the punch 22. For example, as shown in FIG. 8, the punch 22 may be retracted from the die 42 as indicated by the arrow 62, leaving behind the liquid-forged article 30 in the die cavity 41. The punch 22 can be retracted without the formed article 30 sticking to the punch 22 because of the dovetailing fit between the recess 46 in the retaining pin 44 and the retaining portion 36 formed in the article 30. The liquid-forged article 30 is then removed or ejected from the die cavity 41 by relative movement between the retaining pin 44 and the die 42 until the formed article 30 is clear of the die cavity 41. The relative movement may preferably be achieved by moving the retaining pin 44 into the die cavity 41 in the direction indicated by the arrow 64 in FIG. 9 so that the formed article 30 is pushed out of the die cavity 41.

[0030] The article 30 may be finished by machining or cutting off the retaining portion 36, as indicated by the dotted line in FIG. 10(a) to result in the formation of a near net-shape liquid forged article 30 having features 34 with high aspect ratio as shown in FIG. 10(b). FIG. 11 shows close-ups of exemplary high aspect ratio features 70, 72 formed with flashes 71, 73 as a result of cooling of the melt 52 in the gas exhaust passage 27. The flashes 71 of a thicker feature 70 as shown in FIG. 11(a) may be removed by sand blasting or tumbling. For a thinner feature 72 as shown in FIG. 11(b) that may not be rigid enough to withstand the forces of sand blasting or tumbling, the flashes 73 may be cut or trimmed away.

[0031] Exemplary liquid-forged articles such as heat sinks 90 having high aspect ratio fins 92 or pins 94 formed by the exemplary method 100 and apparatus 20 described above are shown in FIG. 12. As can be seen in FIG. 13 (b), the microstructural grain size of the liquid-forged articles is significantly smaller than the grain size of articles formed by conventional casting shown in FIG. 13(a). Smaller grain sizes together with virtually no porosity result in improved toughness of the liquid-forged articles over conventionally cast articles, thereby strengthening the high-aspect ratio features formed.

[0032] Whilst there has been described in the foregoing description exemplary embodiments of the present invention, it will be understood by those skilled in the technology concerned that many variations in details of design, construction and/or operation may be made without departing from the present invention. For example, where a plurality of high aspect ratio cavities 24 are provided in the punch 22, the corresponding plurality of air vent inserts 80 may be provided individually for ease of air release or may alternatively be provided as an integral unit comprising a plurality of insert portions 84 disposed on a single head portion 82 for reduced tooling costs. The plurality of high aspect ratio cavities 24 (and their corresponding air vent inserts 80) may or may not be identical, depending on the desired high aspect ratio features 34 to be formed. The liquid-forged article 30 may or may not be symmetrical.

Claims

1. A method (100) of forming a liquid-forged article (30), the method (100) comprising:
 - introducing a melt (52) into a die cavity (41);
 - moving a punch (22) relative to the die cavity (41) such that the melt (52) enters at least one high aspect ratio cavity (24) in the punch (22) and air is released via at least one air vent insert (80) in the punch (22), the high aspect ratio cavity (24) having a height to width ratio greater than 40:1, wherein air is released through a gas exhaust passage (86) defined by the air vent insert (80) with the high aspect ratio cavity (24), the air vent insert (80) comprising a head portion (82) and an insert portion (84), the head portion (82) being configured for positioning the air vent insert (80) relative to the high aspect ratio cavity (24) and the insert portion (84) being configured for extending into the high aspect ratio cavity (24), the air vent insert (80) being made of a metal; and
 - exerting a forming pressure on the melt (52) while the melt (52) solidifies in the high aspect ratio cavity (24), wherein the melt (52) is rapidly cooled as the melt (52) comes into contact with the air vent insert (80).
2. The method (100) of claim 1, further comprising relatively moving the punch (22) away from the die cavity (41) while retaining the article (30) in the die cavity (41).
3. The method (100) of claim 2, wherein the article (30) is retained in the die cavity (41) by forming a retaining portion (36) of the article (30) within a recess (46) provided in a retaining pin (44) disposed in a die (42) containing the die cavity (41).
4. The method (100) of any preceding claim, wherein air is further released through at least one gas vent (88) provided in the air vent insert (80), the gas vent (88) being in fluid communication with the gas exhaust passage (86).
5. An apparatus (20) for forming a liquid-forged article (30), the apparatus comprising:
 - a die cavity (41) for receiving a melt (52); and
 - a punch (22) configured to exert a forming pressure on the melt (52), the punch (22) comprising at least one high aspect ratio cavity (24) for receiving the melt (52) therein and at least one air vent insert (80) for allowing air to be released from the high aspect ratio cavity (24), the high aspect ratio cavity (24) having a height to width ratio greater than 40:1, wherein air vent insert (80) defines a gas exhaust passage (86) with the high aspect ratio cavity (24), the air vent insert (80) comprising a head portion (82) and an insert portion (84), the head portion (82) being configured for positioning the air vent insert (80) relative to the high aspect ratio cavity (24) and the insert portion (84) being configured for extending into the high aspect ratio cavity (24); and
 - the air vent insert (80) being made of a metal so that when the melt (52) comes into contact with the air vent insert (80), the melt (52) is rapidly cooled.
6. The apparatus (20) of claim 5, wherein the insert portion (84) is tapered with a decreasing cross-sectional area as it extends into the high aspect ratio cavity (24).
7. The apparatus (20) of claims 5 or 6, wherein the air vent insert (80) is provided with at least one gas vent (88), the gas vent (88) being in fluid communication with the gas exhaust passage (86).
8. The apparatus (20) of claim 7 when dependent on claim 5 or claim 6, wherein the at least one gas vent (88) is provided in the head portion (82).
9. The apparatus (20) of claims 5 to 8, wherein:
 - the gas exhaust passage (86) is dimensioned to prevent excessive melt flow therein for preventing clogging of the gas exhaust passage (86) by solidified melt; and/or
 - the gas exhaust passage (86) has a length ranging between 2 mm and 6 mm and there is a gap tolerance of at least 20 μm between the air vent insert (80) and a wall (26) of the high aspect ratio cavity (24).
10. The apparatus (20) of any one of claims 5 to 9, further comprising a retaining pin (44) for retaining the article (30) in the die cavity (41) while relatively moving the punch (22) away from the die cavity (41), the retaining pin (44) being disposed in a die (42) containing the die cavity (41), the retaining pin (44) optionally comprises a recess (46) for solidifying the melt (52) therein such to form a retaining portion (36) of the article (30) within the recess (46).
11. The apparatus (20) of any one of claims 5 to 10, further comprising a plurality of high aspect ratio cavities (24) and a corresponding plurality of air vent inserts (80), the plurality of air vent inserts (80) optionally being provided individually.

Patentansprüche

1. Ein Verfahren (100) zum Formen eines flüssig-geschmiedeten Gegenstands (30), das Verfahren (100) umfassend:

Einleiten einer Schmelze (52) in einen Formhohlraum (41);

Bewegen eines Stempels (22) relativ zu dem Formhohlraum (41), so dass die Schmelze (52) in mindestens einen Hohlraum mit hohem Aspektverhältnis (24) in dem Stempel (22) eintritt und Luft über mindestens einen Entlüftungseinsatz (80) in dem Stempel (22) freigesetzt wird, wobei der Hohlraum mit hohem Aspektverhältnis (24) ein Verhältnis von Höhe zu Breite von mehr als 40: 1 hat, wobei Luft durch einen Abgaskanal (86), der durch den Entlüftungseinsatz (80) mit dem Hohlraum mit hohem Aspektverhältnis (24) definiert ist, freigesetzt wird, der Entlüftungseinsatz (80) einen Kopfteil (82) und einen Einsatzteil (84) umfassend, wobei der Kopfteil (82) zum Positionieren des Entlüftungseinsatzes (80) relativ zum Hohlraum mit hohem Aspektverhältnis (24) konfiguriert ist und das Einsatzteil (84) so konfiguriert ist, um sich in den Hohlraum mit hohem Aspektverhältnis (24) zu erstrecken, wobei der Entlüftungseinsatz (80) aus einem Metall besteht; und

Ausüben eines Formdrucks auf die Schmelze (52) während die Schmelze (52) sich in dem Hohlraum mit hohem Aspektverhältnis (24) verfestigt, wobei die Schmelze (52) schnell abgekühlt wird indem die Schmelze (52) mit dem Entlüftungseinsatz (80) in Kontakt kommt.

2. Das Verfahren (100) nach Anspruch 1, ferner umfassend Bewegen des Stempels (22) relativ von dem Formhohlraum (41) weg während der Gegenstand (30) in dem Formhohlraum (41) gehalten wird.

3. Das Verfahren (100) nach Anspruch 2, wobei der Artikel (30) in dem Formhohlraum (41) gehalten wird, indem ein Halteteil (36) des Artikels (30) innerhalb einer Aussparung (46) geformt ist, die in einem Haltestift (44) vorgesehen ist, der in einer Form (42) angeordnet ist, die den Formhohlraum (41) enthält.

4. Das Verfahren (100) nach einem der vorhergehenden Ansprüche, wobei Luft ferner durch mindestens einen Gasabzug (88) freigesetzt wird, die in dem Entlüftungseinsatz (80) vorgesehen ist, wobei der Gasabzug (88) in fluider Verbindung mit dem Abgaskanal (86) ist.

5. Eine Vorrichtung (20) zum Formen eines flüssig-geschmiedeten Gegenstands (30), die Vorrichtung umfassend:

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einen Formhohlraum (41) zum Aufnehmen einer Schmelze (52); und

einen Stempel (22), der konfiguriert ist, um einen Formdruck auf die Schmelze (52) auszuüben, wobei der Stempel (22) mindestens einen Hohlraum mit hohem Aspektverhältnis (24) zum Aufnehmen der Schmelze (52) darin umfasst und mindestens einen Entlüftungseinsatz (80) umfasst, um zu ermöglichen, dass Luft aus dem Hohlraum mit hohem Aspektverhältnis (24) freigesetzt wird,

wobei der Hohlraum mit hohem Aspektverhältnis (24) ein Verhältnis von Höhe zu Breite von mehr als 40: 1 hat, wobei Entlüftungseinsatz (80) einen Abgaskanal (86) mit dem Hohlraum mit hohem Aspektverhältnis (24) definiert, der Entlüftungseinsatz (80) umfassend einen Kopfteil (82) und einen Einsatzteil (84), wobei der Kopfteil (82) zum Positionieren des Entlüftungseinsatzes (80) relativ zu dem Hohlraum mit hohem Aspektverhältnis (24) konfiguriert ist und das Einsatzteil (84) so konfiguriert ist, dass es sich in den Hohlraum mit hohem Aspektverhältnis (24) erstreckt; und

der Entlüftungseinsatz (80) aus einem Metall besteht, so dass die Schmelze (52) schnell abgekühlt wird wenn die Schmelze (52) mit dem Entlüftungseinsatz (80) in Kontakt kommt.

6. Die Vorrichtung (20) nach Anspruch 5, wobei das Einsatzteil (84) mit abnehmender Querschnittsfläche, indem es sich in den Hohlraum mit hohem Aspektverhältnis (24) erstreckt, verjüngt ist.

7. Die Vorrichtung (20) nach Anspruch 5 oder 6, wobei der Entlüftungseinsatz (80) mit mindestens einem Gasabzug (88) versehen ist, wobei der Gasabzug (88) in fluider Verbindung mit dem Abgaskanal (86) ist.

8. Die Vorrichtung (20) nach Anspruch 7, wenn abhängig von Anspruch 5 oder Anspruch 6, wobei der mindestens eine Gasabzug (88) in dem Kopfteil (82) vorgesehen ist.

9. Die Vorrichtung (20) nach Ansprüchen 5 bis 8, wobei:

der Abgaskanal (86) so dimensioniert ist, dass ein übermäßiger Schmelzfluss darin verhindert wird, um ein Verstopfen des Abgaskanals (86) durch erstarrte Schmelze zu verhindern; und/oder

der Abgaskanal (86) eine Länge im Bereich zwischen 2 mm und 6 mm hat und eine Spalttoleranz von mindestens 20 µm zwischen dem Entlüftungseinsatz (80) und einer Wand (26) des Hohlraums mit hohem Aspektverhältnis (24) be-

steht.

10. Die Vorrichtung (20) nach einem der Ansprüche 5 bis 9, ferner umfassend einen Haltestift (44) zum Halten des Artikels (30) in dem Formhohlraum (41) während der Stempel (22) relativ von dem Formhohlraum (41) wegbewegt wird, wobei der Haltestift (44) in einer Form (42) angeordnet ist, die den Formhohlraum (41) enthält, wobei der Haltestift (44) wahlweise eine Aussparung (46) zum Verfestigen der Schmelze (52) darin umfasst, so dass ein Halteabschnitt (36) des Artikels (30) innerhalb der Aussparung (46) geformt ist.
11. Die Vorrichtung (20) nach einem der Ansprüche 5 bis 10, ferner umfassend eine Vielzahl von Hohlräumen mit hohem Aspektverhältnis (24) und eine entsprechende Vielzahl von Entlüftungseinsätzen (80), wobei die Vielzahl von Entlüftungseinsätzen (80) wahlweise individuell zur Verfügung gestellt werden.

Revendications

1. Procédé (100) destiné à former un article par forgeage liquide (30), le procédé (100) comprenant les étapes suivantes :

introduire un produit fondu (52) dans une cavité de matrice (41) ;
 déplacer un poinçon (22) par rapport à la cavité de matrice (41) de telle sorte que le produit fondu (52) pénètre au moins dans une cavité qui présente un rapport de dimensions élevé (24) dans le poinçon (22), et que l'air soit libéré par l'intermédiaire d'au moins une pièce rapportée d'évent (80) dans le poinçon (22), la cavité qui présente un rapport de dimensions élevé (24) présentant un rapport hauteur sur largeur supérieur à 40 : 1, où l'air est libéré à travers un passage d'échappement des gaz (86) défini par la pièce rapportée d'évent (80) avec la cavité qui présente un rapport de dimensions élevé (24), la pièce rapportée d'évent (80) comprenant une partie tête (82) et une partie pièce rapportée (84), la partie tête (82) étant configurée pour positionner la pièce rapportée d'évent (80) par rapport à la cavité qui présente un rapport de dimensions élevé (24), et la partie pièce rapportée (84) étant configurée pour s'étendre dans la cavité qui présente un rapport de dimensions élevé (24), la pièce rapportée d'évent (80) étant réalisée dans un métal ; et
 exercer une pression de formage sur le produit fondu (52) tandis que le produit fondu (52) se solidifie dans la cavité qui présente un rapport de dimensions élevé (24), où le produit fondu (52) est refroidi rapidement lorsque le produit

fondu (52) entre en contact avec la pièce rapportée d'évent (80).

2. Procédé (100) selon la revendication 1, comprenant en outre une étape consistant à déplacer de manière relative le poinçon (22) à partir de la cavité de matrice (41) tout en maintenant l'article (30) dans la cavité de matrice (41).
3. Procédé (100) selon la revendication 2, où l'article (30) est maintenu dans la cavité de matrice (41) en formant une partie retenue (36) de l'article (30) dans un renforcement (46) prévu dans une broche de retenue (44) disposée dans une matrice (42) qui contient la cavité de matrice (41).
4. Procédé (100) selon l'une quelconque des revendications précédentes, où l'air est libéré en outre à travers au moins un événement des gaz (88) disposé dans la pièce rapportée d'évent (80), l'événement des gaz (88) étant en communication de fluide avec le passage d'échappement des gaz (86).
5. Appareil (20) destiné à former un article par forgeage liquide (30), l'appareil comprenant :
- une cavité de matrice (41) destinée à recevoir un produit fondu (52) ; et
 un poinçon (22) configuré pour exercer une pression de formage sur le produit fondu (52), le poinçon (22) comprenant au moins une cavité qui présente un rapport de dimensions élevé (24) destinée à recevoir à l'intérieur le produit fondu (52), et au moins une pièce rapportée d'évent (80) afin de permettre la libération de l'air à partir de la cavité qui présente un rapport de dimensions élevé (24),
 la cavité qui présente un rapport de dimensions élevé (24) présentant un rapport hauteur sur largeur supérieur à 40 : 1, où la pièce rapportée d'évent (80) définit un passage d'échappement des gaz (86) avec la cavité qui présente un rapport de dimensions élevé (24), la pièce rapportée d'évent (80) comprenant une partie tête (82) et une partie pièce rapportée (84), la partie tête (82) étant configurée pour positionner la pièce rapportée d'évent (80) par rapport à la cavité qui présente un rapport de dimensions élevé (24), et la partie pièce rapportée (84) étant configurée pour s'étendre dans la cavité qui présente un rapport de dimensions élevé (24) ; et
 la pièce rapportée d'évent (80) étant réalisée dans un métal, de telle sorte que, lorsque le produit fondu (52) entre en contact avec la pièce rapportée d'évent (80), le produit fondu (52) se refroidisse rapidement.
6. Appareil (20) selon la revendication 5, où la partie

pièce rapportée (84) s'amincit avec une section transversale décroissant lorsqu'elle s'étend dans la cavité qui présente un rapport de dimensions élevé (24).

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7. Appareil (20) selon la revendication 5 ou 6, où la pièce rapportée d'évent (80) est dotée d'au moins un événement des gaz (88), l'événement des gaz (88) étant en communication de fluide avec le passage d'échappement des gaz (86). 10
8. Appareil (20) selon la revendication 7 si elle dépend de la revendication 5 ou de la revendication 6, où l'un au moins des événements de gaz (88) est disposé dans la partie tête (82). 15
9. Appareil (20) selon l'une quelconque des revendications 5 à 8, où :
 - le passage d'échappement des gaz (86) est dimensionné afin d'empêcher à l'intérieur un écoulement de produit fondu excessif afin d'empêcher une obstruction du passage d'échappement des gaz (86) par le produit fondu solidifié ; 20
 - et / ou 25
 - le passage d'échappement des gaz (86) présente une longueur comprise entre 2 mm et 6 mm, et il existe une tolérance de jeu au moins égale à 20 μm entre la pièce rapportée d'évent (80) et une paroi (26) de la cavité qui présente un rapport de dimensions élevé (24). 30
10. Appareil (20) selon l'une quelconque des revendications 5 à 9, comprenant en outre une broche de retenue (44) destinée à maintenir l'article (30) dans la cavité de matrice (41) tout en déplaçant de manière relative le poinçon (22) à partir de la cavité de matrice (41), la broche de retenue (44) étant disposée dans une matrice (42) qui contient la cavité de matrice (41), la broche de retenue (44) comprenant éventuellement un renforcement (46) destiné à solidifier à l'intérieur le produit fondu (52) afin de former une partie retenue (36) de l'article (30) dans le renforcement (46). 35 40 45
11. Appareil (20) selon l'une quelconque des revendications 5 à 10, comprenant en outre une pluralité de cavités qui présentent un rapport de dimensions élevé (24), et une pluralité correspondante de pièces rapportées d'évent (80), la pluralité de pièces rapportées d'évent (80) étant éventuellement prévues individuellement. 50

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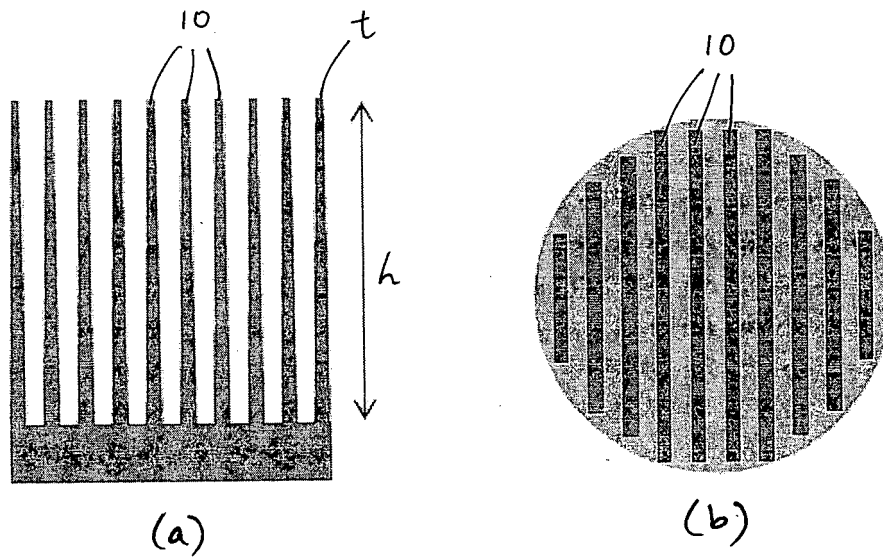


FIG. 1

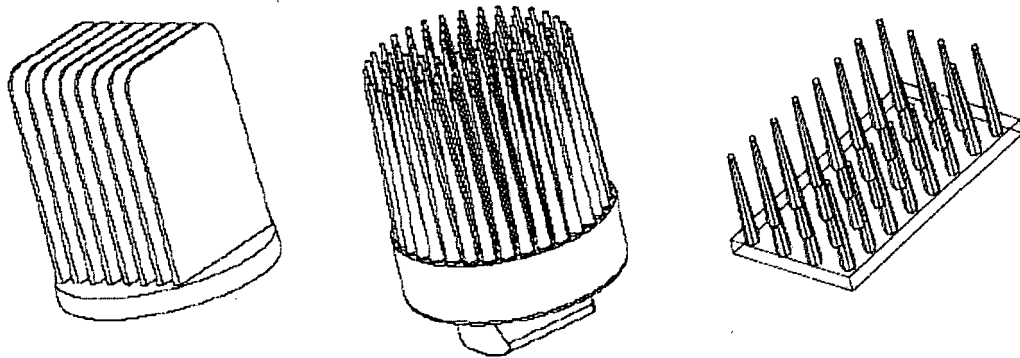


FIG. 2

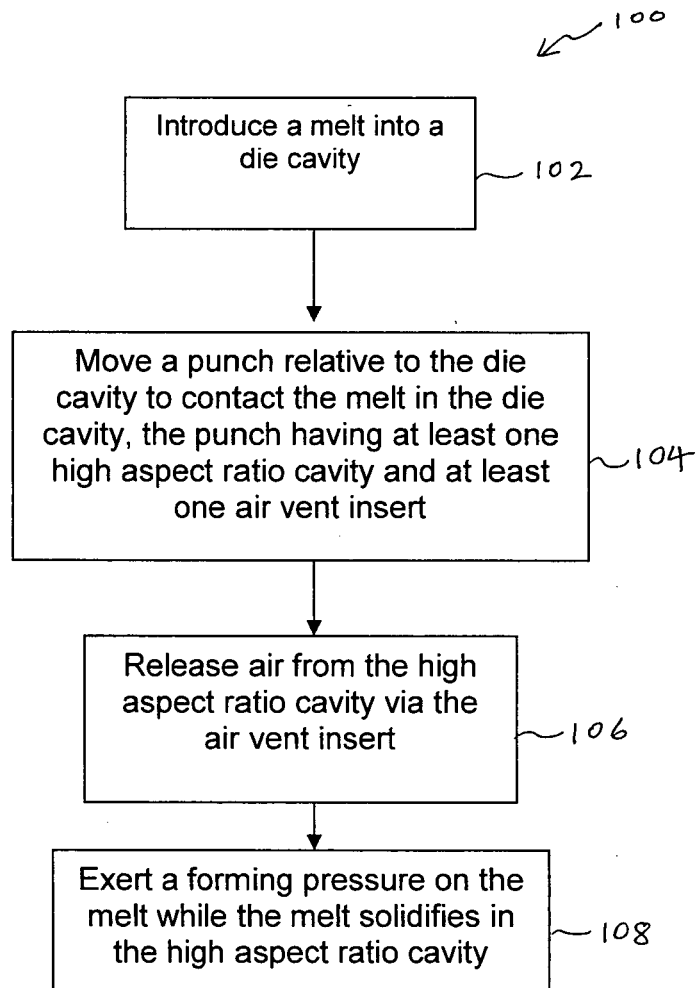


Fig. 3

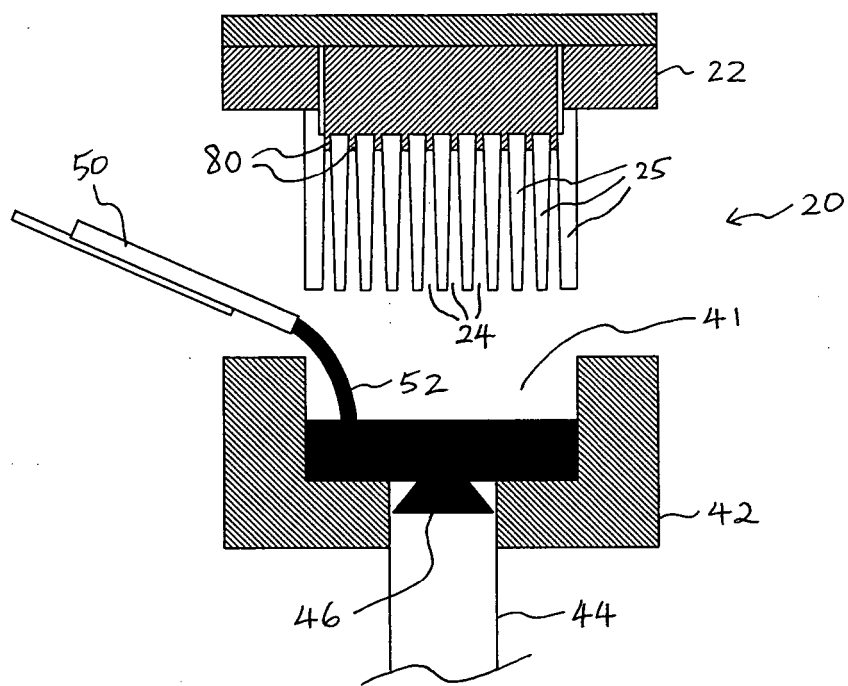


FIG. 4

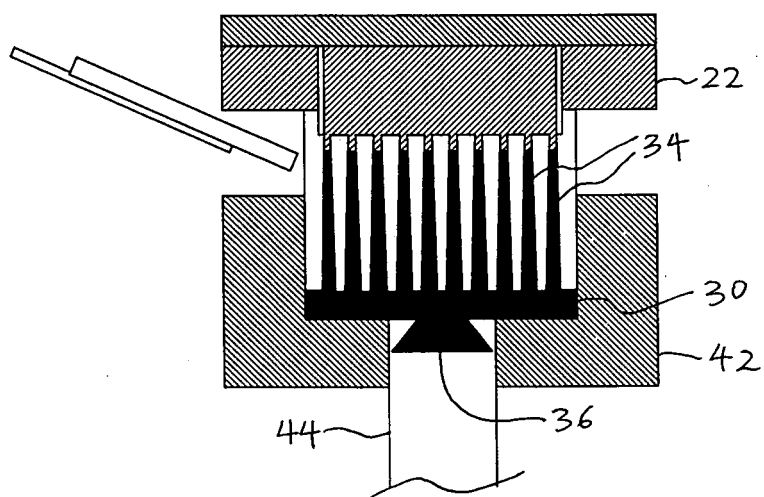
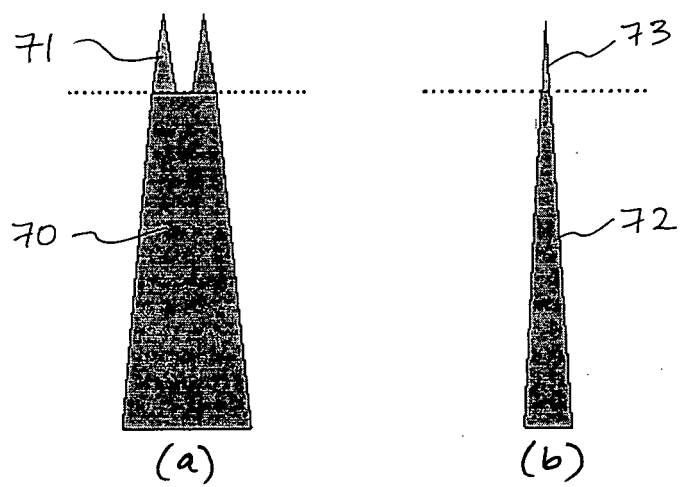
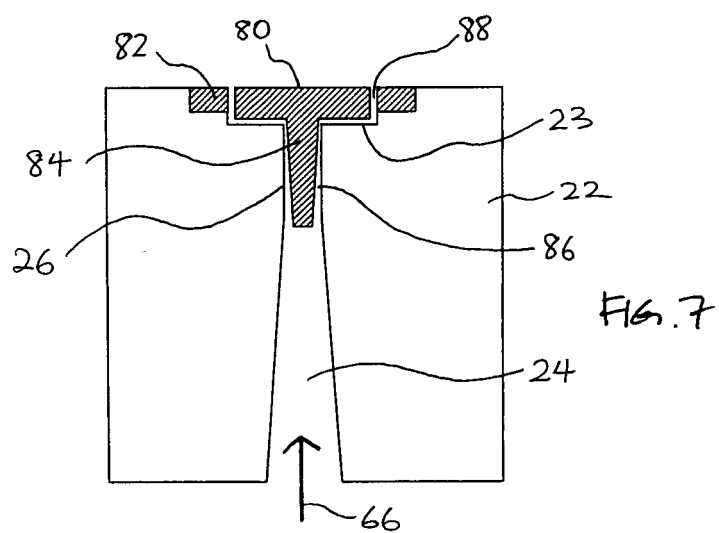
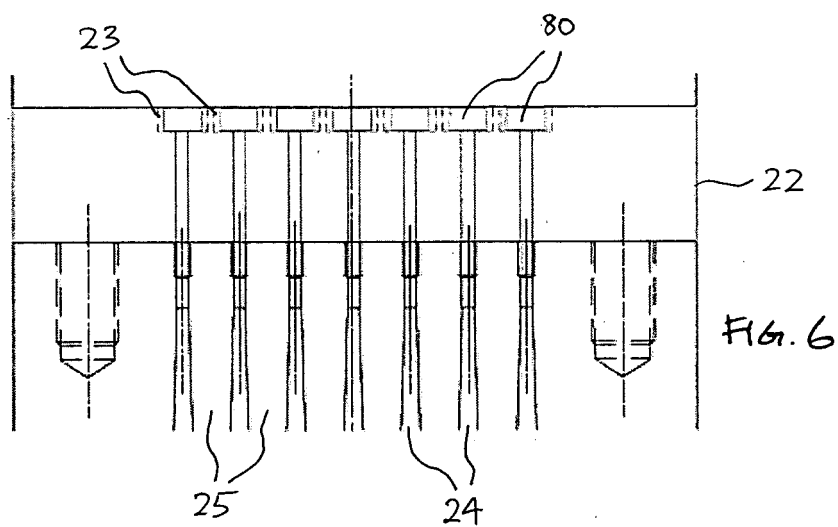
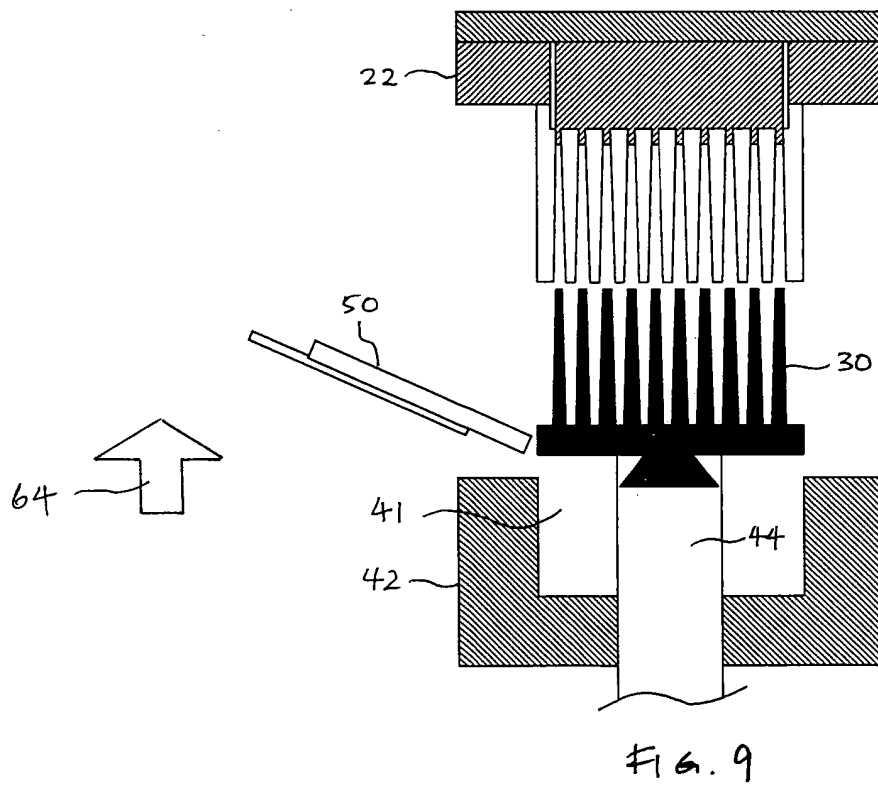
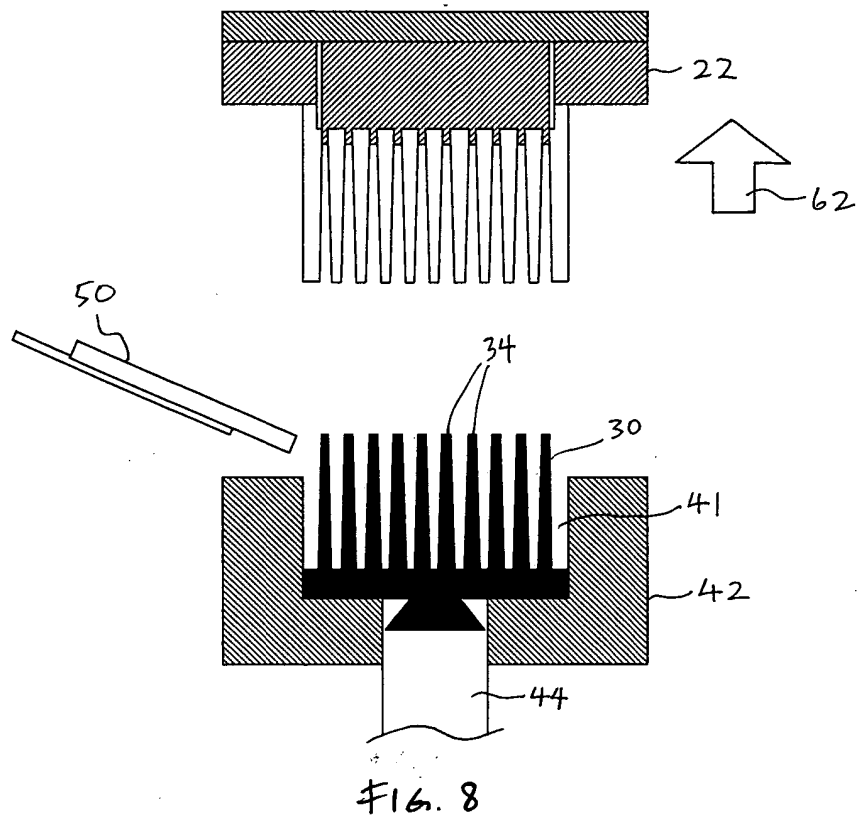


FIG. 5





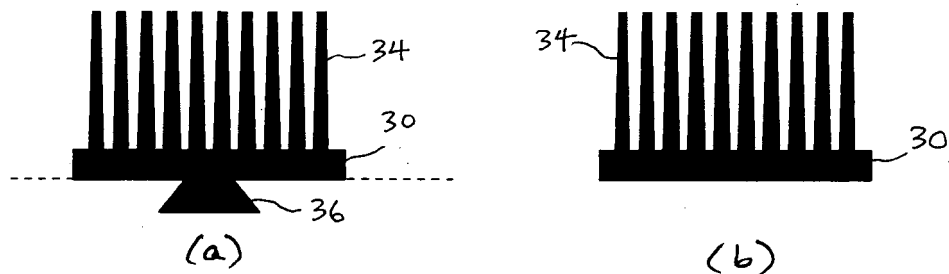


FIG. 10

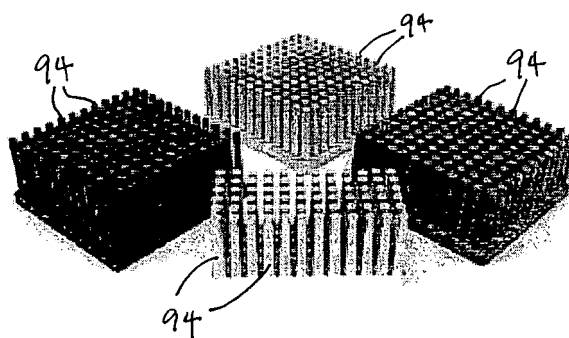
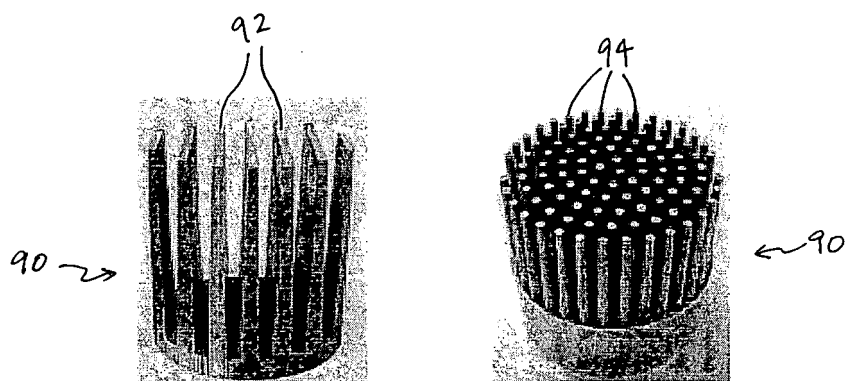
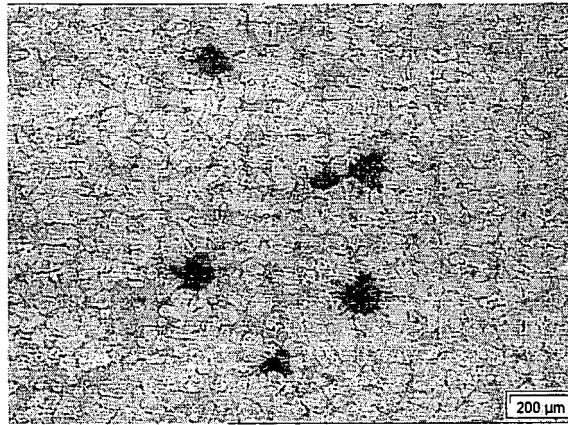
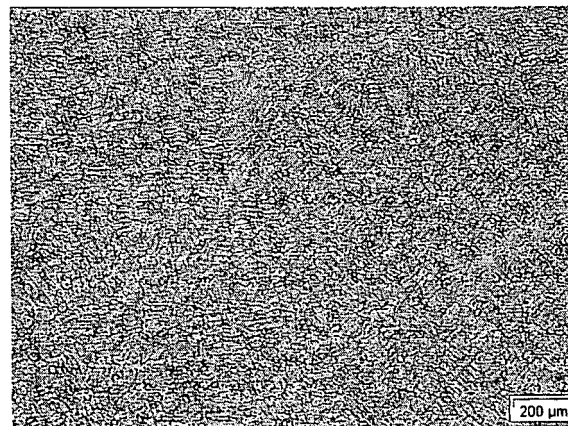


FIG. 12



(a)



(b)

Fig. 13

REFERENCES CITED IN THE DESCRIPTION

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