

APPARATUS AND METHOD FOR MOULDING ARTICLES USING HIGH TEMPERATURE SILICA-BASED MATERIAL

Field of the Invention

- 5 This invention relates to apparatus and method for the moulding of articles using high temperature silica-based material and refers particularly, though not exclusively, to such apparatus and method for moulding articles requiring a relatively smooth surface.

Background to the Invention

- 10 When moulding articles requiring a relatively smooth surface the mould surface must be correspondingly smooth. Examples of such articles include, but are not limited to, optical lenses including lenses for digital cameras such as digital cameras incorporated into mobile telephones, personal digital assistants, computers, web cameras, and the like; and lenses uses in laser devices, measurement equipment, projectors, projector television receivers, sensor lenses,
15 spectacle lenses, contact lenses, telescope lenses, microscope lenses, and lenses uses in medical devices.

- Common techniques for preparing the surface of the mould, or mould insert, include fine machining, plating with zinc, then polishing. This is slow, time consuming, expensive, and
20 unreliable. Furthermore, the zinc coating has a tendency to lift off with use, resulting in the mould or insert having to be resurfaced.

Summary of the Invention

- In accordance with a first preferred aspect there is provided apparatus for moulding an article, the
25 apparatus comprising:

- (a) a body having a recess;
- (b) a moulding insert for insertion into the recess, the moulding insert having a moulding cavity of a size and shape for the moulding of the article; and wherein
- 30 (c) the moulding insert is of a high temperature silica-based material.

In accordance with a second preferred aspect there is provided a method for moulding an article comprising:

- (a) forming a recess in a body;
- 35 (b) forming a mould insert having a moulding cavity, the moulding insert being of high temperature silica-based material and being for insertion into the recess;
- (c) surface finishing an inner surface of the moulding cavity; and

(d) moulding the article in the moulding cavity.

5 The article may be an optical lens including a lens for digital cameras such as digital cameras incorporated into mobile telephones, personal digital assistants, computers, web cameras, and the like; and lenses uses in laser devices, measurement equipment, projectors, projector television receivers, sensor lenses, spectacle lenses, contact lenses, telescope lenses, microscope lenses, and lenses uses in medical devices.

10 The moulding insert may be formed in the recess or may be formed outside the recess and is inserted into the recess. The moulding insert may have an insert wall with an outer surface, the outer surface being a neat fit in and being supported by the recess.

15 There may be reinforcing within the moulding insert wall for providing increased structural strength to the inner surface of the moulding cavity. The reinforcing may have extensions passing through and extending beyond the moulding insert wall for providing heat conductivity from the moulding insert to the body adjacent the recess. The moulding insert wall may have a peripheral rim at an upper end thereof.

20 The apparatus may further comprise a cradle for supporting and holding the moulding insert. The cradle may be external of the moulding insert wall, follows the moulding insert wall and may be affixed to the moulding insert wall. Alternatively, the cradle may be moulded within the moulding insert wall. The cradle may comprise a plurality of bolt holes to enable the cradle to be releasably secured in the recess.

25 The cradle may comprise a plurality of equally spaced spokes extending from a lower hub to the rim of the moulding insert wall, and the cradle may be functionally connected to the extensions of the reinforcing.

30 The silica-based material may be a high-temperature glass or a high-temperature ceramic. Preferably, the silica-based material forms a smooth inner surface.

Brief Description of the Drawings

35 In order for the invention to be fully understood and readily put into practical effect there shall now be described by way of non-limitative example only preferred embodiments of the present invention, the description being with reference to the accompanying illustrative drawings in which:
Figure 1 is a perspective view of a first embodiment;
Figure 2 is a vertical cross-section along the lines and in the direction of arrows 2 – on Figure 1;

Figure 3 is a perspective view of a second embodiment;

Figure 4 is a vertical cross-sectional view along the lines and in the direction of arrows 4 – 4 on Figure 3;

Figure 5 is a perspective view of a third embodiment;

- 5 Figure 6 is a vertical cross-sectional view along the lines and in the direction of arrows 6 – 6 on Figure 5;

Detailed Description of the Preferred Embodiments

To first refer to Figure 1 there is shown a mould 10 that may in the alternative be a mould insert.

- 10 The mould 10 has a body 12 and a mould cavity 14. The mould cavity 14 is for the moulding of the article and has a size and shape required to form the article. The article may be an optical lens including lenses for digital cameras such as digital cameras incorporated into mobile telephones, personal digital assistants, computers, web cameras, and the like; and lenses uses in laser devices, measurement equipment, projectors, projector television receivers, sensor lenses, 15 spectacle lenses, contact lenses, telescope lenses, microscope lenses, and lenses uses in medical devices.

- The body 12 may include all necessary and required cooling channels and ducts (not shown). The body 12 may be made of any suitable material such as, for example, moulding steel, 20 stainless steel, or the like.

The mould cavity 14 is of, or is lined with, a different material such as a high temperature silica-based material.

- 25 Silica, also known as silicon dioxide, is the oxide of silicon. It is found in nature in several forms, including quartz and opal. Examples of silica being manufactured in several forms include glass and a colourless high purity form of glass known as fused silica. Compared to ordinary glass, fused silica is used because of its strength and high melting point. The extremely low coefficient of thermal expansion for fused silica accounts for its remarkable ability to undergo large, rapid 30 temperature changes without cracking.

- In an embodiment of the invention, the mould cavity 14 is of or is lined with silica-based glass; high temperature glass or tempered glass. By "glass" it is meant any uniform amorphous solid material, usually produced when a suitably viscous molten material cools very rapidly, thereby not 35 giving enough time for a regular crystal lattice to form. Amorphous materials are commonly prepared by rapidly cooling molten material. The cooling reduces the mobility of material's molecules before they can pack into a more thermodynamically favorable crystalline state. Glass,

in its pure form, is strong and inert material which can be formed with very smooth and impervious surfaces. These desirable properties lead to its advantage for forming or lining the moulding cavity 14 to mould articles requiring a relatively smooth surface.

- 5 Common glass is mostly amorphous silicon dioxide, which is the same chemical compound found in quartz, or in its polycrystalline form, sand. Pure silica has a melting point of about 2000 °C. An example of a suitable glass used in the present invention is high temperature borosilicate glass (such as Pyrex or Kimax) as it can withstand temperatures of up to 450 degrees Celsius permanently, or up to 500 degrees Celsius for up to 10 hours. It has high impact resistance.

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- In another embodiment of the invention, the mould cavity 14 is of or is lined with ceramics. Ceramics in its strictest sense refers to clay in all its forms. The most important of these were the traditional clays, made into pottery, bricks, tiles and the like, along with cements and glass. However, in modern day usage, by "ceramics" it is meant any product produced by the action of heat on earthy materials, for example, porcelain, in which silicon and silicates occupy a predominant position. Ceramics also include any metal oxides and inorganic non-metallic materials. A composite material of ceramic and metal is known as cermet. Historically, ceramic products have been hard, porous and brittle. Ceramic materials are usually ionic or glassy materials.

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- Ceramics include silicon nitride, boron carbide, silicon carbide, aluminium oxide, aluminium nitride, aluminium silicate, boron nitride, magnesium diboride, magnesium oxide, zinc oxide, ferrite, steatite, glass-ceramic, bricks (mostly aluminium silicates), metal ceramics (a composite material made by mixing powdered metal with powdered ceramic and sintering the mixture), uranium oxide, yttrium barium copper oxide and zirconium phosphate. [others?]

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- An example of a suitable ceramics is one that can withstand temperatures of up to 450 degrees Celsius. More preferably, a suitable ceramics is one that can withstand temperatures beyond 500 degrees Celsius. It should also have high impact resistance. The mould cavity 14 may be a separate component able to be inserted into and removed from the body 12, or may be moulded in situ in the corresponding concave recess 16 in body 12.

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- Non-crystalline ceramics, being glasses, may be shaped when either fully molten, by casting, or when in a state of toffee-like viscosity, by methods such as blowing to the mould cavity 14. For crystalline ceramics, the mould cavity 14 and the lined ceramic material may be moulded together in situ. In such a case, the dehydrated ceramic powders are mixed with water. This starts

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hydration reactions, which result in long, interlocking crystals forming around the aggregates. Over time, these result in a solid ceramic.

5 The ceramic lining may also be glazed by known methods in the art. For example, glass may be used as a glaze. [correct?]

10 Structural ceramic materials are inert, light weight, harder than metals, withstand higher temperatures and are actually stronger. When they do fracture, most high strength ceramics suffer catastrophic failure, which means there is no yield stress. Usually high density and fine grain sizes are best because this gives higher hardness and better uniformity and strength. It is best to control the porosity of the material.

15 The key to obtain high strength in structural ceramics is to increase the toughness which prevents fracture. Fracture always occurs due to high stresses at flaws or cracks. When flaws are carefully controlled, ceramics can achieve strengths 10 to 100 times higher than metals, typically at 1/3 the weight.

20 The toughness of ceramics is increased by using high aspect ratio particles (whisker or needles) or fibers to give mechanisms such as pull out, crack tortuosity, and crack bridging. Another toughening option is to add zirconia for transformation toughening or metals to allow local deformation to absorb crack tip energy. Another approach is to increase the toughness with directional void space or preferential debonding directions to allow for crack propagation without catastrophic failure (one example is in fibrous monolith composites). The strength is usually lower for this last approach, however the delayed fracture allows warning of failure, i.e. there is a yield stress.

30 Some important properties for various structural ceramics include: wear resistance, strength, hardness, fracture toughness, corrosion resistance, biocompatibility, and thermal shock resistance.

35 When the article is required to be moulded at ultrahigh-temperatures, ceramics selected from the group of diboride and carbide ceramic-matrix composites including ZrB_2/SiC , HfB_2/SiC and $\text{ZrB}_2/\text{SiC}/\text{C}$ may be used. They have a unique set of material properties including unusually high thermal conductivity, good thermal shock resistance, and modest thermal expansion coefficients that make them particularly well suited for withstanding ultrahigh-temperatures.

In yet another embodiment of the invention, the mould cavity 14 is of or is lined with a glass-ceramic mixture. This glass-ceramic is a mixture of glass and ceramic materials (mainly lithium-, silicon-, or aluminium-oxides) yielding a material that is impervious to even extreme temperature shocks. The manufacturing process is very similar to that of glass, but the melt is then made to
 5 crystallise partly. The crystalline component of the resulting material has a regular crystal structure and a negative coefficient of thermal expansion, balancing the positive coefficient of the glass, such that glass-ceramic as a whole has a thermal expansion coefficient that is very close to zero.

10 Glass-ceramic is mechanically very strong and can sustain repeated and quick temperature changes up to 800 - 1000°C.

The recess 16 is preferably of the same size and shape as the outer surface 18 of cavity 14 so that the cavity 14 is a neat fit in and is fully supported within the recess 16. By having full support
 15 for the cavity 14 in the recess 16 and thermal or physical stresses generated in or applied to the cavity 14 will be transferred at least in part to the body 12 around recess 16.

By being of high temperature ceramics, the cavity has an inner surface 22 that is relatively smooth, and will be reliable as long as the temperature and physical stress levels of the ceramics
 20 used for cavity 14 are not exceeded. Even when of ceramics, the inner surface 22 may be polished to remove any surface imperfections. [how do ceramics provide the smooth finish?]

Cavity 14 is held in recess 16 by any suitable means including a heat-conductive adhesive (not shown) and/or physical clamps (not shown) and/or by a captive nut within cavity wall 38
 25 accessible by a bolt (not shown) passing through a bolt hole in body 12. To assist in the use of clamps, the cavity 14 may have a rim 26.

Figures 3 and 4 show a second embodiment. Here the cavity 14 has reinforcing 20. The reinforcing 20 may be a suitably sized and graded mesh (as shown), reinforcing rods, or the like.
 30 The reinforcing 20 is embedded within the cavity 14 during the moulding of cavity 14. Preferably, it is approximately midway between the outer surface 18 and the inner surface 22 of cavity 14. Alternatively, the reinforcing 20 may be closer to the inner surface 22 to assist in management and distribution of thermal and physical stresses on the cavity 14.

35 Preferably, the reinforcing 20 has a plurality of extensions 24 passing through and extending beyond the outer surface 18. The extensions 24 are integral with the reinforcing 20 are to contact the inner surface of recess 16 when cavity 14 is inserted in recess 16 so as to enable

transmission of heat to body 12 around recess 16. In this way the reinforcing 20 acts as a thermal conductor to assist in conducting heat away from cavity 14, and to thus assist in cooling cavity 14. The number, length and location of extensions 24 may be as required or desired. The reinforcing may be made of a metal, preferably a metal with good heat conductivity, and good physical strength. For example, the reinforcing 20 may be made of stainless steel. The glass of the cavity 14 may be transparent, translucent, cloudy or coloured, as required or desired. If transparent or translucent, the status of the reinforcing 20 will be able to be seen through the material of cavity 14, thus being of assistance for maintenance purposes.

Figures 5 and 6 show a third embodiment where a cradle 28 is added, in addition to or as an alternative to reinforcing 20. The cradle 28 may have a continuous side wall or, as shown, have a plurality of equally-spaced ribs 30 around the cavity 14.

The ribs 30 extend upwardly from a lower hub 32 and are affixed to the outer surface 18 of the cavity 14 preferably by use of a heat-conductive adhesive. The ribs 30 follow the shape of the outer surface 18. At the upper end 34 each rib 30 passes over the rim 26 and thus may be used to secure the cavity 14 in the recess 16. Each rib 30 may have one or more bolt holes 36 to enable a bolt (not shown) to pass through body 12 and into bolt hole 36 to secure the cradle, and thus cavity 14, in recess 16. The gaps 38 between ribs 30 may be used for a heat conductive adhesive to further enhance the securing of cradle 28 and cavity 14 in recess 16. The extensions 24 are in contact with or attached to cradle 28 to allow for heat conduction from reinforcing 20 to the cradle 28 and thus to body 12. To assist such heat conduction, the cradle is preferably made of a heat conducting material such as, for example, stainless steel.

As an alternative, the ribs 30 may be formed within cavity wall 38 with there being access to bolt holes 36 through cavity wall 38.

In this way the moulding process becomes somewhat simple. The body 12 is prepared and recess 16 formed. Cavity 14 is either separately moulded, or moulded in situ, with or without reinforcing 20 and/or cradle 28. If moulded separately, it is inserted and held in place as is described above. Any necessary surface finishing for inner surface 22 may be performed before insertion, or after insertion. The mould 10 is then ready for use. Moulding cycle times and temperatures may be selected to provide the best possible result without damaging the cavity 14. This may mean lower temperatures and slightly longer cycle times, but the result should be a significant improvement over the known processes. As the high temperature silica-based material used has a smooth finish, provided all surface irregularities are removed, the resultant

moulded products should have the same or better characteristics as those moulded using known techniques.

5 Whilst there has been described in the forgoing description preferred embodiments of the present invention, it will be understood that many variations in details of design, construction or operation may be made without departing from the invention as defined in the following claims.

The Claims:

1. Apparatus for moulding an article, the apparatus comprising:
 - 5 a) a body having a recess;
 - b) a mould insert for insertion into the recess, the moulding insert having a moulding cavity of a size and shape for the moulding of the article; and wherein
 - c) the moulding insert is of a high temperature silica-based material.
- 10 2. Apparatus as claimed in claim 1, wherein the high temperature silica-based material is glass.
3. Apparatus as claimed in claim 2, wherein the high temperature glass is a borosilicate glass.
- 15 4. Apparatus as claimed in claim 1, wherein the high temperature silica-based material is ceramics.
5. Apparatus as claimed in claim 1, wherein the high temperature silica-based material is a glass-ceramic mixture.
- 20 6. Apparatus as claimed in any one of claims 1 to 5, wherein the article is an optical lens selected from the group consisting of: lenses for digital cameras including digital cameras incorporated into mobile telephones, personal digital assistants, computers, and web
- 25 cameras; lenses uses in laser devices, measurement equipment, projectors, projector television receivers, sensor lenses, spectacle lenses, contact lenses, telescope lenses, microscope lenses, and lenses uses in medical devices.
7. Apparatus as claimed in any one of claims 1 to 6, wherein the moulding insert is formed in the recess.
- 30 8. Apparatus as claimed in any one of claims 1 to 6, wherein the moulding insert is formed outside the recess and is inserted into the recess.
9. Apparatus as claimed in any one of claims 1 to 8, wherein the moulding insert has a moulding insert wall with an outer surface, the outer surface being a neat fit in and being supported by the recess.
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10. Apparatus as claimed in claim 9 further comprising reinforcing within the moulding insert wall for providing increased structural strength to the moulding cavity.

5 11. Apparatus as claimed in claim 10, wherein the reinforcing has extensions passing through and extending beyond the moulding insert wall for providing heat conductivity from the moulding insert wall to the body adjacent the recess.

10 12. Apparatus as claimed in any one of claims 9 to 11, wherein the moulding insert wall has a peripheral rim at an upper end thereof.

13. Apparatus as claimed in any one of claims 9 to 12 further comprising a cradle for supporting and holding the moulding insert.

15 14. Apparatus as claimed in claim 13, wherein the cradle is external of the moulding insert wall, follows the moulding insert wall and is affixed to the moulding insert wall.

20 15. Apparatus as claimed in claim 13, wherein the cradle is moulded within the moulding insert wall.

16. Apparatus as claimed in any one of claims 13 to 15, wherein the cradle comprises a plurality of bolt holes to enable the cradle to be releasably secured in the recess.

25 17. Apparatus as claimed in any one of claims 13 to 16, wherein the cradle comprises a plurality of equally spaced spokes extending from a lower hub to the rim of the moulding insert wall.

30 18. Apparatus as claimed in any one of claims 13 to 17 when appended to claim 10, wherein the cradle is functionally connected to the extensions of the reinforcing.

19. A method for moulding an article, the method comprising:

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- (a) forming a recess in a body;
 - (b) forming a mould insert having a moulding cavity, the moulding insert being of high temperature silica-based material and being for insertion into the recess;
 - (c) surface finishing an inner surface of the moulding cavity; and
 - (d) moulding the article in the moulding cavity.

20. A method as claimed in claim 19, wherein the high temperature silica-based material is borosilicate glass.

5 21. A method as claimed in claim 19, wherein the high temperature silica-based material is ceramics.

22. A method as claimed in claim 19, wherein the high temperature silica-based material is a glass-ceramic mixture.

10 23. A method as claimed in any one of claims 19 to 22, wherein the article is an optical lens selected from the group consisting of: lenses for digital cameras including digital cameras incorporated into mobile telephones, personal digital assistants, computers, and web cameras; lenses uses in laser devices, measurement equipment, projectors, projector
15 television receivers, sensor lenses, spectacle lenses, contact lenses, telescope lenses, microscope lenses; and lenses uses in medical devices.

24. A method as claimed in any one of claims 19 to 23, wherein the moulding insert is formed in the recess.

20 25. A method as claimed in any one of claims 19 to 23, wherein the moulding insert is formed outside the recess and is inserted into the recess.

25 26. A method as claimed in any one of claims 19 to 25 further comprising inserting reinforcing within the moulding insert wall during the mould of the moulding cavity for providing increased structural strength to the moulding cavity.