

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
28 February 2008 (28.02.2008)

PCT

(10) International Publication Number
WO 2008/024861 A2

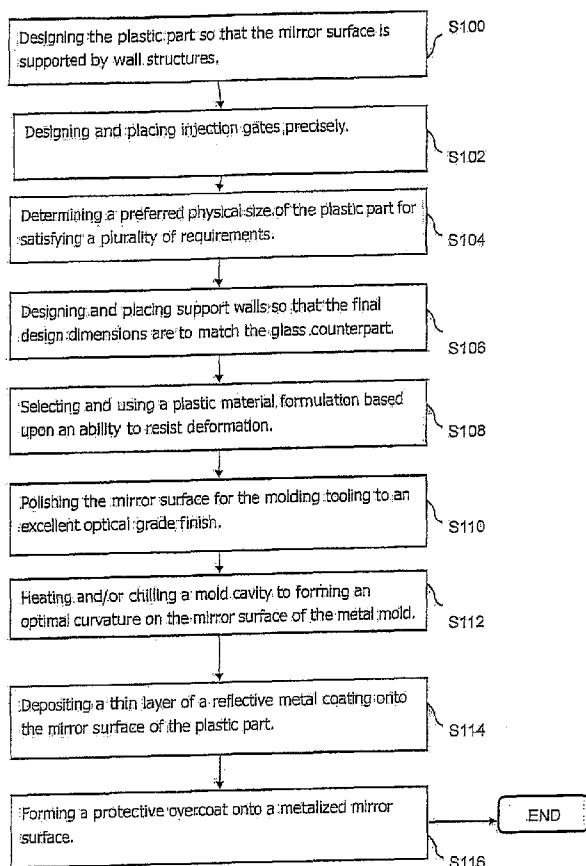
- (51) International Patent Classification:
B29D 11/00 (2006.01)
- (21) International Application Number:
PCT/US2007/076554
- (22) International Filing Date: 22 August 2007 (22.08.2007)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
60/839,740 23 August 2006 (23.08.2006) US
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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: LOW-COST PLASTIC SPHERICAL MIRROR



(57) Abstract: A method for fabricating a plastic spherical mirror is disclosed. First, a plastic part with a mirror surface supported by a plurality of wall structures is designed. Next, a metal mold including mold for forming the plastic part according to the above design specification is provided. A mirror surface of the metal mold is polished to an A1 optical grade finish. The metal mold is heated and chilled to form a curvature of the mirror surface of the metal mold. A plastic material formulation is selected and heated until a melt thereof is obtained. The melt is injected into the mold of the metal mold and the injected melt in the mold is cooled to form the plastic part. A thin layer of a reflective metal coating is deposited on the mirror surface of the plastic part and a protective overcoat is formed on the reflective metal coating.

WO 2008/024861 A2



Published:

- *without international search report and to be republished upon receipt of that report*

LOW-COST PLASTIC SPHERICAL MIRROR

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the priority benefit of the US provisional application serial No. 60/839,740, filed on August 23, 2006. All disclosure of this US provisional application is incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention generally relates to a spherical mirror. More particularly, the present invention relates to a low-cost plastic spherical mirror.

Description of Related Art

[0002] Glass has been the conventional material of choice for use as a spherical mirror. One of the most important reasons is because plastics technologies were not developed as they are today. In other words, the tools and materials were not available as they are today. The metal mold tolerances and the resulting parts can be specified and held in tens of thousandth of an inch. Materials used today are more sophisticated; the plastics are able to emulate the thermal stability and durability similar to that of glass, and to endure the type of operating conditions in the past that only glass could have tolerated.

[0003] Glass spherical mirrors are expensive because of the secondary operations needed to prepare the mirror surface after it is heat formed or slumped to shape. These secondary operations include annealing, grinding and polishing. The annealing process is used to strengthen the glass so that it is strong enough to undergo the grinding and polishing operation, as well as adding the additional strength needed to resist

breakage during usage. The grinding and polishing stages are necessary because of the limits of the tolerance capabilities of glass forming molds and the physical nature of glass.

[0004] Unfortunately, the grinding and polishing stages require a considerable amount of manual processing for producing a finished product; therefore, they are often considered semi-automated processes.

[0005] In addition, glass spherical mirrors also have the serious drawbacks of breakage, heavy weight, difficulty in mounting the mirror and expensive shipping costs. To overcome the limitations and drawbacks of glass, a low-cost version of the glass spherical mirror was developed but it did not provide an acceptable surface finish, was still very heavy and the resulting cost reductions were not comparable to plastic spherical mirror. Clearly, what is needed is a method and system for manufacturing a plastic spherical mirror to reduce the weight of a spherical mirror to approximately one-third that of glass, and for making a low-cost plastic spherical mirror of comparable performance to a glass spherical mirror.

SUMMARY OF THE INVENTION

[0006] The present invention provides a method and system for manufacturing a low-cost plastic spherical mirror of comparable performance as that of a high quality glass spherical mirror.

[0007] In an embodiment of the present invention, plastic injection molding is used for manufacturing a plastic part for a low-cost plastic spherical mirror. The plastic injection molding method is able to yield higher tolerance, improved process control, and high reproducibility.

[0008] The metal mold for plastic injection molding is able to hold a tight tolerance for a general envelope dimension of a mirror. The spherical radius tolerance is also to be held at a tight tolerance. The aforementioned tolerances are comparable to that of the glass spherical mirrors.

[0009] A plurality of plastic material formulations have been developed in which a plurality of performance criteria relating to material strength, thermal stability, water absorption, mold shrinkage, material flow into the mold, UL recognition, manufacturing considerations, surface density, lubricant content, and scratch resistance may be satisfied. The selection of the plastic material formulation may be based on the metal mold and part testing results.

[0010] Vacuum metallization or vacuum deposition may be used for depositing a reflective mirror coating for use as the mirror surface of the spherical mirror. The metal deposited on the plastic surface preferably has a thickness of several microns. The metallization phase is performed and then a protective overcoat is spray coated onto the metalized surface. The vacuum metalized part has improved quality because of the improved quality control of the surface of the plastic material that is being coated by means of the ability to minimize the amounts of flaws on the surface of the plastic part resulting from the molding process.

[0011] A method for fabricating a plastic spherical mirror according to an embodiment of the present invention includes the following steps.

(a) The plastic part is designed so that a mirror surface is supported for the prevention of distortion or twisting, and for satisfying a plurality of optical performance requirements.

(b) The plastic injection gates are precisely placed for ensuring the elimination of remnants or knit lines created by plastic resin flow.

(c) A preferred physical size of the plastic part for satisfying a plurality of optical performance requirements and physical design requirements is selected.

(d) A plurality of support walls are formed and strategically placed in the plastic part.

(e) A plastic material formulation is selected so that it is specifically designed to resist deformation.

(f) the tool may also be made from a preferred grade steel having a preferred polish finish;

(g) The metal mold is heated and or chilled to form an optimal curvature on a mirror surface.

(h) A thin layer of a reflective metal coating is deposited onto the mirror surface of the plastic part.

(i) A protective overcoat is formed onto a metalized mirror surface.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The above and other features and advantages of the present invention will become more apparent by describing in detail exemplary embodiments thereof with reference to the attached drawings.

[0013] FIG. 1 illustrates an embodiment of a method for fabricating a plastic part for the plastic spherical mirror in accordance with the present invention.

[0014] FIG. 2 illustrates an embodiment of a trimmed plastic part for a plastic spherical mirror in accordance with the present invention.

[0015] FIG. 3 illustrates another embodiment of a method for fabricating a plastic spherical mirror in accordance with the present invention.

[0016] FIG. 4 illustrates a plastic part fabricated by an injection molding process in accordance with the present invention.

DETAILED DESCRIPTION

[0017] The present invention will now be described with reference to the accompanying drawings, in which exemplary embodiments of the invention are shown. The invention may, however, be embodied in many different forms and should not be construed as being limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the concept of the invention to those skilled in the art.

[0018] In the drawings, whenever the same element reappears in subsequent drawings, it is denoted by the same reference numeral.

[0019] For the sake of convenience of understanding, some key terms and phrases are first presented.

[0020] A “plastic material formulation” may comprise a homopolymer, a thermoplastic, a copolymer, a polymer blend, a thermoset, a polymer blend, any one of the above material containing performance additives, fillers, or fibers, or any other similar types of polymer material formulations.

[0021] The “deposition of a reflective metal coating over the mirror surface of the plastic part” may be accomplished by vacuum deposition, spin coating, spraying, vacuum metallization, sputtering, or any other similar process capable of depositing the reflective metal coating on the order of several microns.

[0022] “Low-cost” may be defined as a favorable cost differential as compared to glass of the same dimensional configuration for use as spherical mirrors.

[0023] A "glass counterpart" is defined to be a glass spherical mirror of the same dimensional configuration and possesses equivalent functionalities as that of the plastic spherical mirror.

[0024] As used herein, the words "may" and "may be" are to be interpreted in an open-ended, non-restrictive manner. At minimum, "may" and "may be" are to be interpreted as definitively including structure or acts recited.

[0025] In an embodiment of the present invention, a plastic injection molding process is used for fabricating the plastic part 20 of a plastic spherical mirror. In the present embodiment of the present invention, the plastic injection molding process is capable of providing a dimensional tolerance of +/- .0001 inch for a parabolic plastic mirror that ranges from a diameter of from about five inches to about 36 inches, in certain preferred embodiments of the present invention. Although the tooling for the plastic injection molding process is relatively expensive, the cost per each plastic part 20 manufactured is however very low. A plurality of complex geometries is reproducible using the plastic injection molding process according to an embodiment of the present invention and may be limited only by the manufacturability of a metal mold.

[0026] In an embodiment of the present invention, a metal mold's final finish may be implemented by means of machining and polishing or other similar finishing methods capable of producing an adequate finish quality, such as an A1 grade or a grade that is considered as the finest finish available for a plastic part 20.

[0027] In the embodiment of the present invention, using the plastic injection molding process, plastic parts up to about 36 inches in length may be produced. The procedures used in the plastic injection molding process are well known in the art; and therefore, detail description thereof is shall not be discussed herein.

[0028] In the present embodiment, a metal mold for plastic injection molding process is able to provide plus or minus .030 inch tolerance for a general envelope dimension and a spherical radius tolerance of plus or minus .05% for the plastic part. The aforementioned tolerances are comparable to the glass spherical mirrors. The metal mold is able to hold a tolerance of about +/- .0001 inch.

[0029] In an embodiment of the present invention, a plurality of plastic material formulations 50 may each be used for fabricating the plastic spherical mirror 10 in which a plurality of performance criteria are satisfied, such as material strength, thermal stability, water absorption, mold shrinkage, material flow into the mold, UL recognition, manufacturing considerations, surface density, lubricant content, and scratch resistance.

[0030] In an embodiment of the present invention, the plastic material formulations 50 may comprise one of the following: optical-grade polycarbonate, natural-grade polycarbonate, UV-grade polycarbonate, polyetherimide, glass-filled grade polyetherimide, PMMA (acrylic), and other comparable plastic materials having similar performance criteria. The selection of the plastic material formulation 50 may be based on the degree of precision for the mold tooling as well as experimental results from part testing.

[0031] In an embodiment of the present invention, a vacuum metallization or a vacuum deposition process may be used for coating a metal layer over the mirror surface 40 of the trimmed plastic part 25 as illustrated in FIG. 2 or the plastic spherical mirror treated with an evaporated metal vapor. The thickness of the metal deposited on the plastic surface is preferably about four to eight microns. The metalizing phase is followed by a spray coating of a protective overcoat on a metalized mirror surface 45. The metalized plastic part 30 that has been vacuum metalized may possess improved quality because of improved quality control of the surface of the plastic material that is

being coated by means of minimizing of the amount of flaws that are on the plastic surface resulting from the molding process. Furthermore, the metallization is to have an excellent adhesion with respect to the mirror surface 40 of the underlying plastic part 20.

[0032] Referring to FIG. 1, a method for fabricating the plastic spherical mirror, in which the plastic part 20 of relatively thin thickness holds its form/shape after being heated and cooled, may include a plurality of the following steps:

PART DESIGN

[0033] (a) designing the plastic part 20 so that the mirror surface 40 is supported for preventing distortion or twisting by designing a plurality of wall structures onto the entire edge of a mirror edge (S100);

(b) designing and placing a plurality of injection gates precisely with the intent of ensuring the elimination of remnants or knit lines created by plastic resin flow (S102);

(c) determining a preferred physical size of the plastic part 20 for satisfying a plurality of optical performance requirements and physical design requirements (S104);

(d) designing and placing a plurality of support walls in the plastic part 20 so that the final design dimensions of the plastic part 20 matches that of a glass counterpart (S106);

MATERIAL SELECTION

[0034] (e) selecting a plastic material formulation based upon an ability to resist deformation according to a plastic part 20 quality specification (S108);

MOLD TOOLING PROCESSING

[0035] (f) polishing a mirror surface of the metal mold to an excellent optical grade finish (S110);

(g) heating and/or chilling the mold cavity to form an optimal curvature on the mirror surface of the metal mold (S112);

MIRROR FORMATION

[0036] (h) depositing a thin layer of a reflective metal coating on the mirror surface 40 of the plastic part 20 (S114); and

(i) forming a protective overcoat onto the metalized mirror surface (S116).

[0037] Referring to FIG. 2, an embodiment of a trimmed plastic part 25 for use for a plastic spherical mirror in accordance with the present invention is illustrated.

[0038] Referring to FIG. 3, in another embodiment of the present invention, a method for producing the plastic spherical mirror 10, in which the plastic part 20 of a relative thickness sufficient to hold its form/shape after being heated and cooled, may include a plurality of the following steps:

PART DESIGN

[0039] (i) designing the plastic part 20 so that the mirror surface of the plastic part 20 is supported for preventing distortion or twisting by designing a plurality of ejector pins, for example, 28 ejector pins around the edge of the plastic part 20 serving to allow for part removal from the metal mold without distorting the surface geometry or damaging the mirror surface 40 finish (S200);

(ii) designing a plurality of plastic injection gates and placing the

plastic injection gates precisely and evenly in the plastic part (S202);

(iii) determining a preferred physical size of the plastic part 20 for satisfying a plurality of optical performance requirements and physical design requirements (S204);

(iv) designing and placing a plurality of support walls strategically in the plastic part 20 (S206);

MATERIAL SELECTION

[0040] (v) selecting an optical-grade polycarbonate, polyetherimide, or PMMA (acrylic) as the plastic material formulation for use as the plastic spherical mirror (S208);

MOLD TOOLING PROCESSING

[0041] (vi) polishing the mirror surface of the metal mold to an A1 finish, wherein the metal is fabricated using a high grade steel (S210);

(vii) heating and/or chilling a mold cavity to form an optimal curvature on the mirror surface of the metal mold (S212);

MIRROR FORMATION

[0042] (viii) depositing a thin layer of a reflective metal coating onto the mirror surface 40 of the plastic part 20 using vacuum metallization or vacuum deposition at preferably a thickness of, four to eight microns (S214);

(ix) spray coating a protective overcoat on the metalized mirror surface of the plastic part 20 (S216); and

FINISHED PART INSPECTION

[0043] (x) maintaining sphericity on the mirror surface 40 of the plastic spherical mirror at a tolerance of +/- 0.05% (S218).

[0044] Referring to FIG. 4, a plastic part 20 directly after injection molding process in accordance with another embodiment of the present invention is illustrated. The ejector pins 50 are disposed around the edge of the plastic part 20 to allow part removal from the metal mold without distorting the surface geometry or damaging the mirror surface 40.

[0045] It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the present invention without departing from the scope or spirit of the invention. In view of the foregoing, it is intended that the present invention cover modifications and variations of this invention provided they fall within the scope of the following claims and their equivalents.

What is claimed is:

Claim 1: A method for fabricating a plastic spherical mirror, comprising:
designing a plastic part with a mirror surface supported by a plurality of wall structures;
providing a metal mold including mold for forming the plastic part according to the design specification provided in step (a);
polishing a mirror surface of the metal mold to an A1 optical grade finish;
heating and or chilling the metal mold to form a curvature of the mirror surface of the metal mold;
depositing a thin layer of a reflective metal coating on the mirror surface of the plastic part; and
forming a protective overcoat on the reflective metal coating.

Claim 2: The method of claim 1, further comprising:
designing and placing a plurality of injection gates; and
determining a physical size of the plastic part.

Claim 3: The method of claim 1, further comprising:
designing and placing a plurality of support walls in the plastic part so that final design dimensions of the plastic part match with that of a glass counterpart.

Claim 4: The method of claim 1, wherein the plastic material formulation is selected based upon satisfying a plurality of performance criteria relating to material strength, thermal stability, water absorption, mold shrinkage, material flow into the

mold, UL recognition, manufacturing considerations, surface density, lubricant content, and scratch resistance.

Claim 5: The method of claim 1, wherein the plastic material formulation is selected from the group consisting of an optical-grade polycarbonate, a natural-grade polycarbonate, a UV-grade polycarbonate, a polyetherimide, a glass-filled grade polyetherimide, and a PMMA (acrylic).

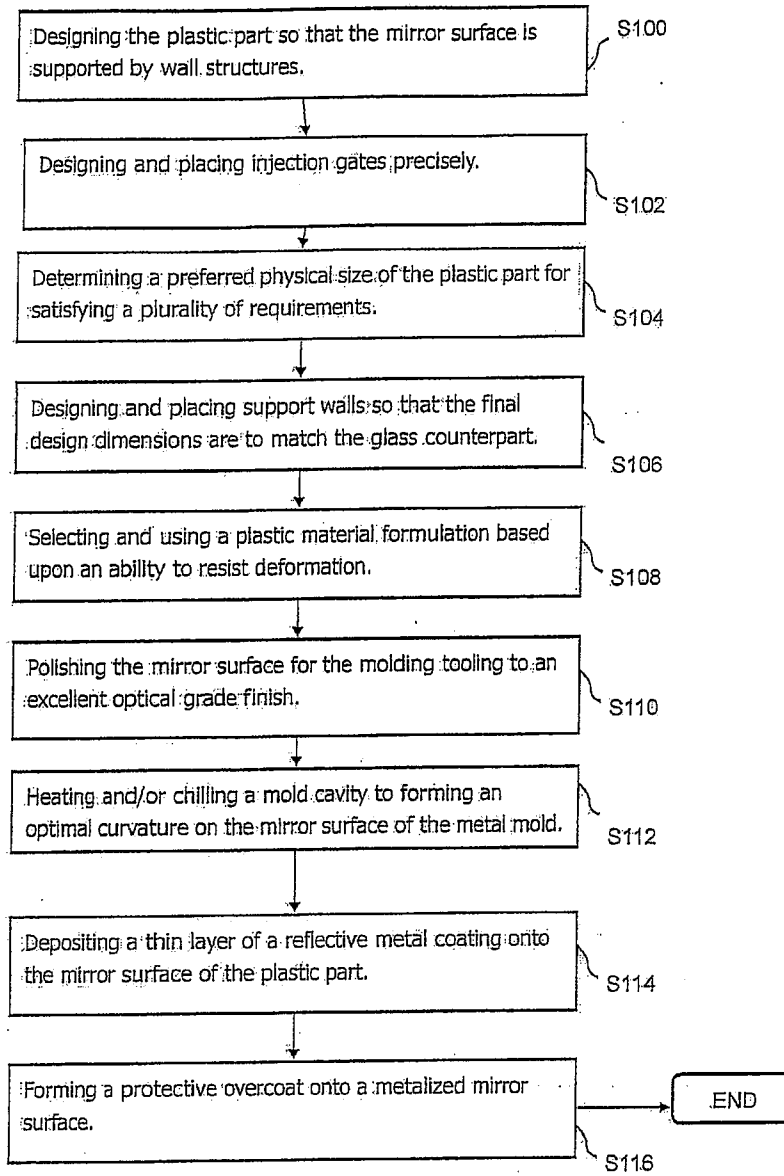


FIG. 1

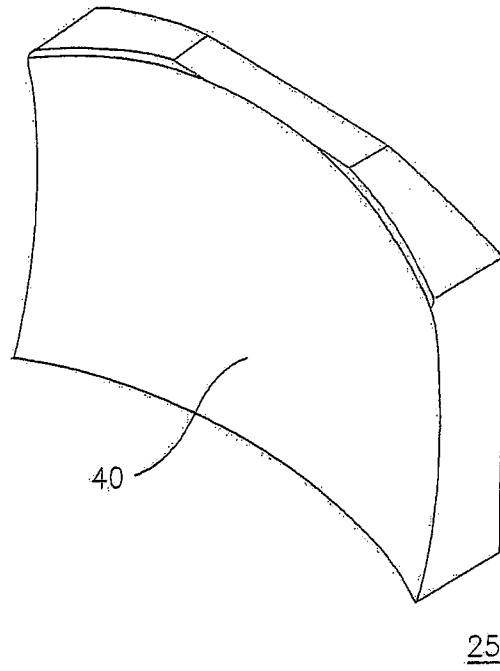


FIG. 2

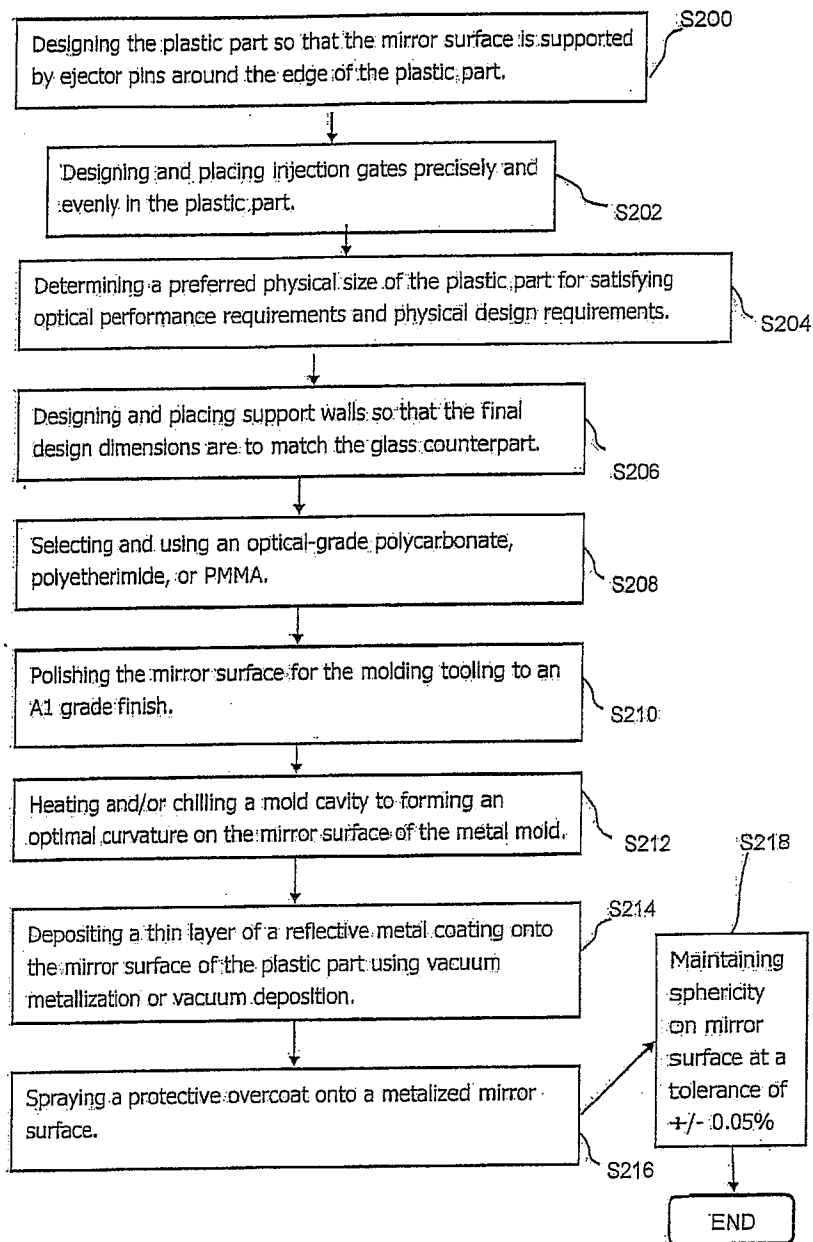


FIG. 3

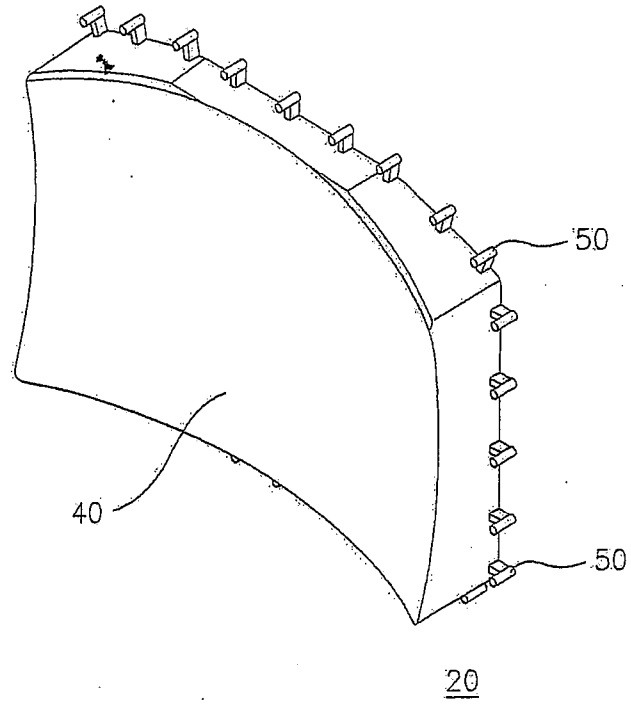


FIG. 4