US 20120186768A1

(19) United States
(12) Patent Application Publication
Sun et al.

(10) Pub. No.: US 2012/0186768 A1
(43) Pub. Date: Jul. 26, 2012

(54) **METHODS FOR FORMING FAUCETS AND FIXTURES**

(76) Inventors: **Donald Sun**, San Gabriel, CA (US); **Mark William Vilimek**, Milpitas, CA (US)

(21) Appl. No.: **13/379,634**

(22) PCT Filed: **Jun. 25, 2010**

(86) PCT No.: **PCT/US10/40102**

§ 371 (c)(1), (2), (4) Date: **Apr. 12, 2012**

Related U.S. Application Data

(60) Provisional application No. 61/269,609, filed on Jun. 26, 2009.

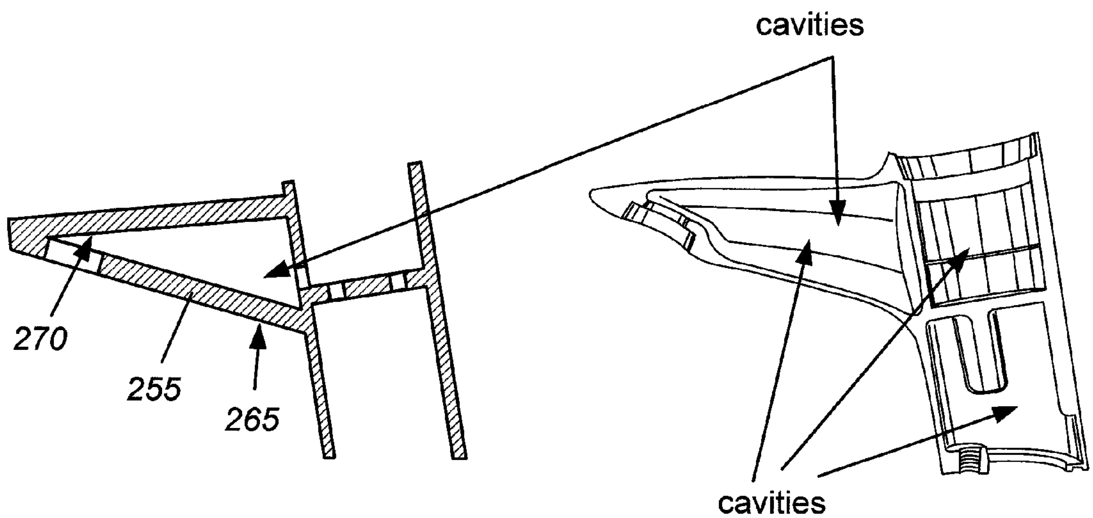
Publication Classification

(51) **Int. Cl.**
B22C 9/04 (2006.01)

(52) **U.S. Cl.** **164/23**

(57) **ABSTRACT**

This invention provides methods for forming stainless steel, single-piece, multi-chambered water faucets and fixtures with a single one-body construction. A variety of stainless steel products can be formed with a main body having an internal hollow region and a plurality of dividing chambers. The main body may be constructed using high temperature resistant ceramic cores in combination with a lost wax investment casting process. The stainless steel products formed from a single piece construction can eliminate the need for additional time-consuming manufacturing steps, such as parts welding, screw assembly, or precision press fitting. In addition, water faucets and fixtures can be provided that are substantially lead-free, non-verdigris, and non-toxic in compliance with environmental regulations and lead/toxic limits.



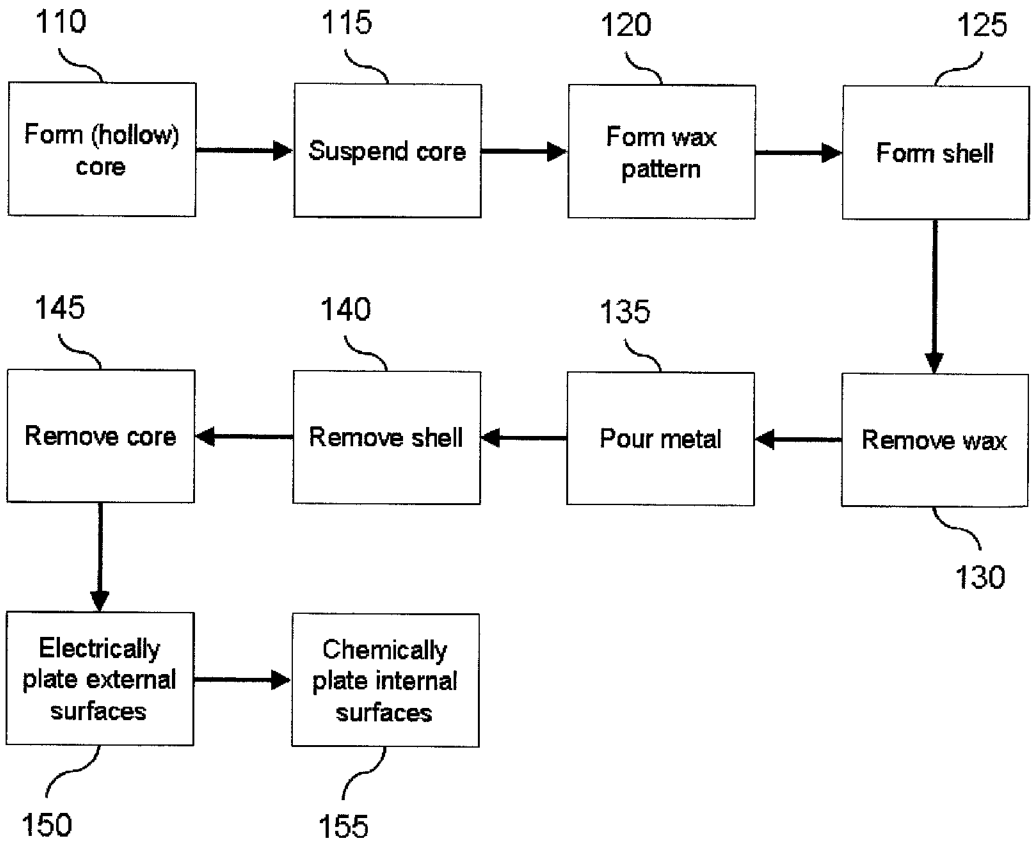

110
Form (hollow) core
115
Suspend core
120
Form wax pattern
125
Form shell
130
Remove wax
135
Pour metal
140
Remove shell
145
Remove core
150
Electrically plate external surfaces
155
Chemically plate internal surfaces

FIG. 1

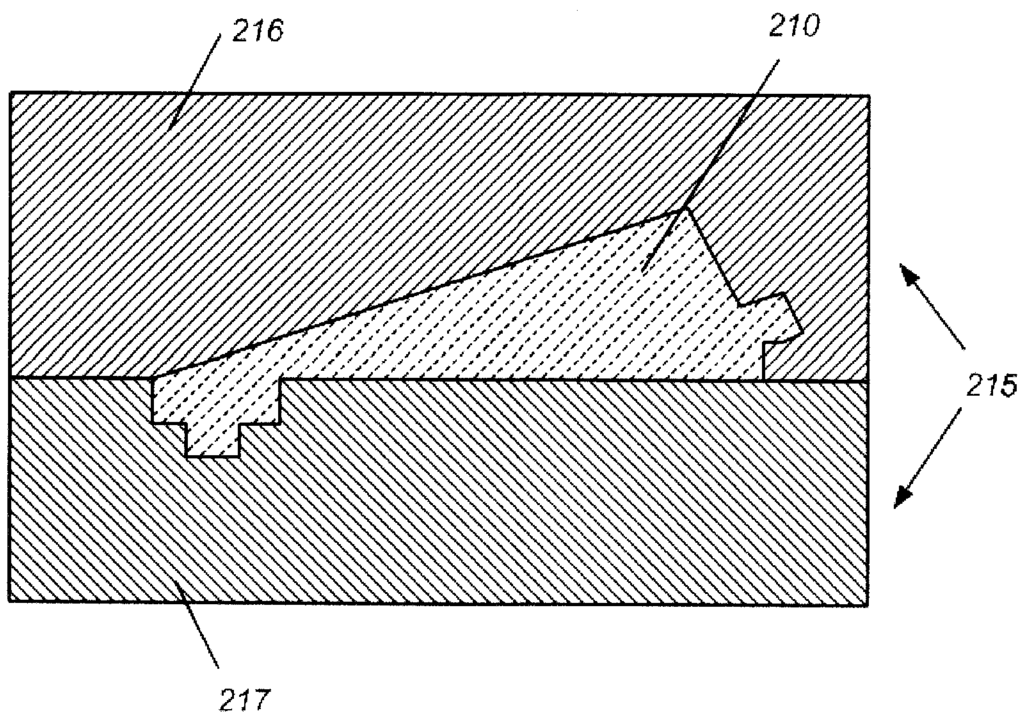


FIG. 2

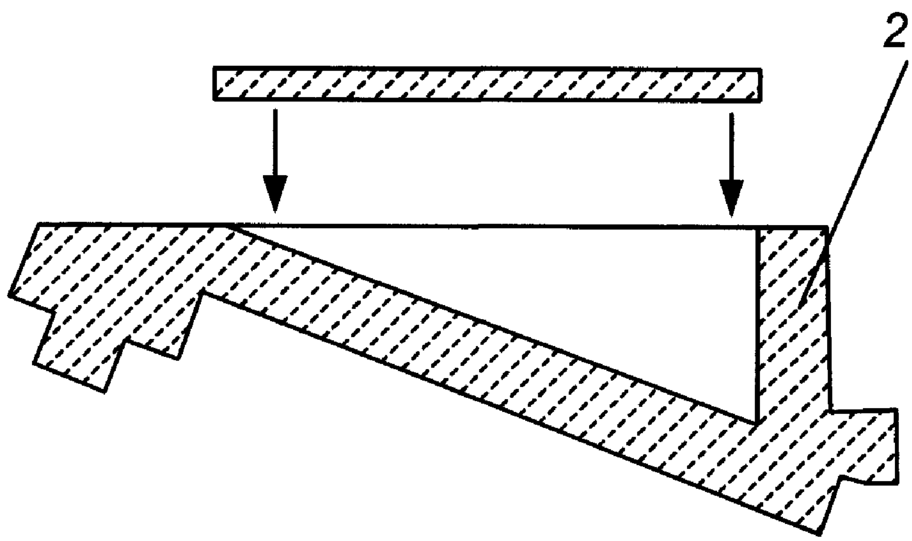


FIG. 3A

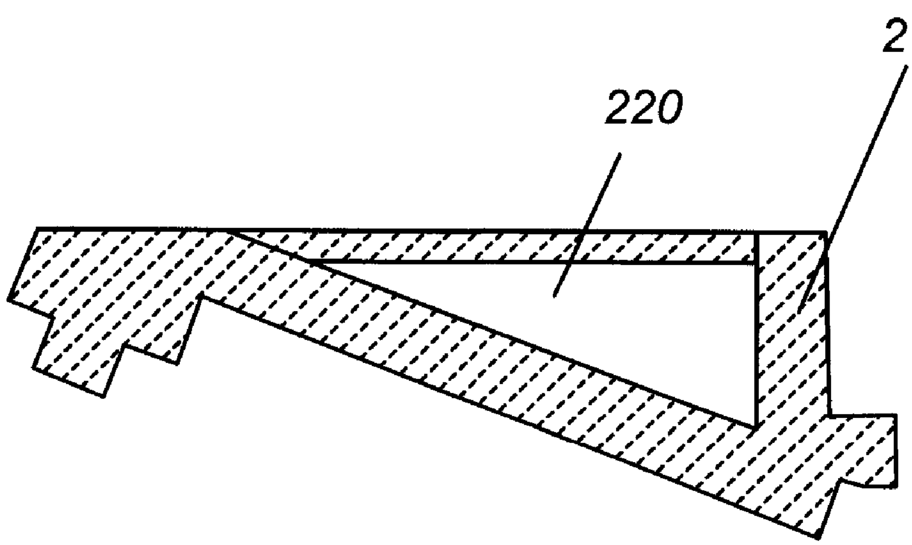


FIG. 3B

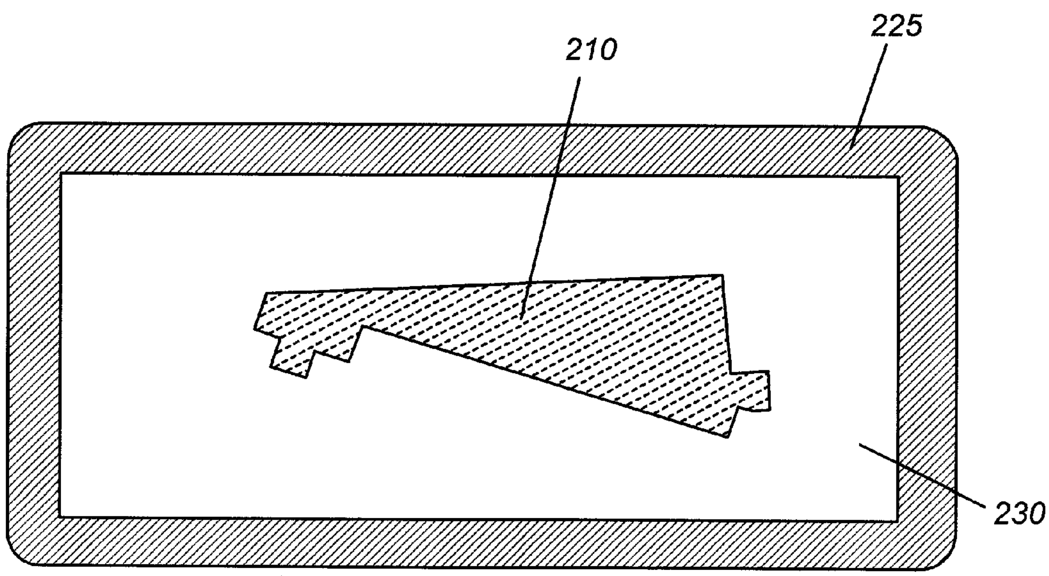


FIG. 4

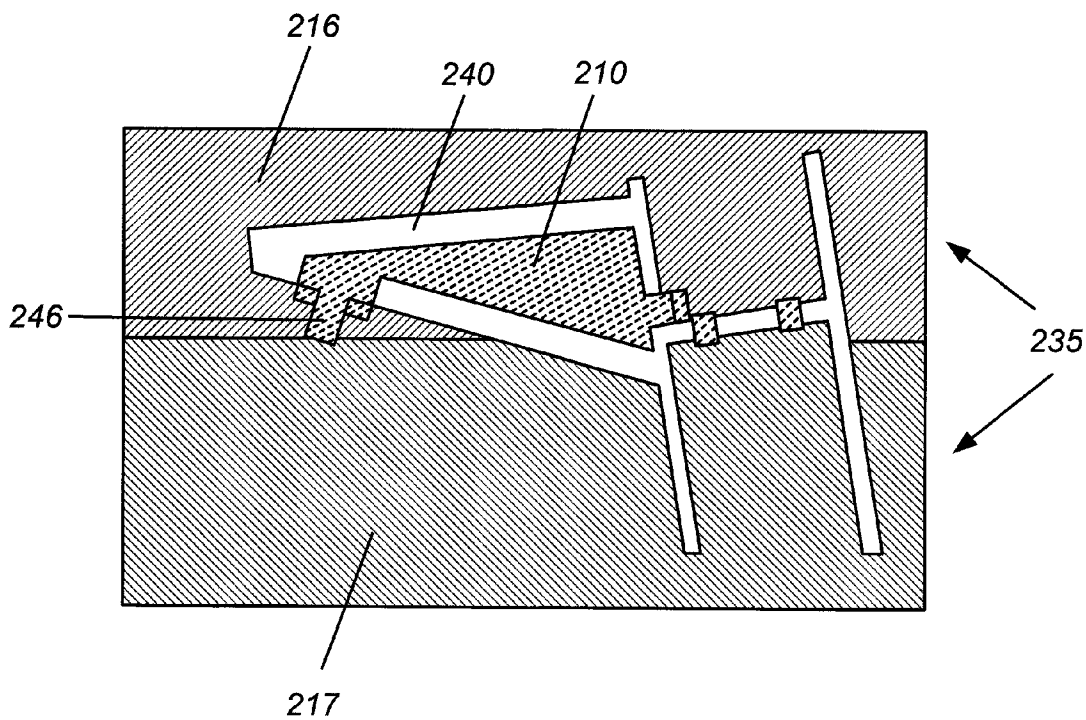


FIG. 5

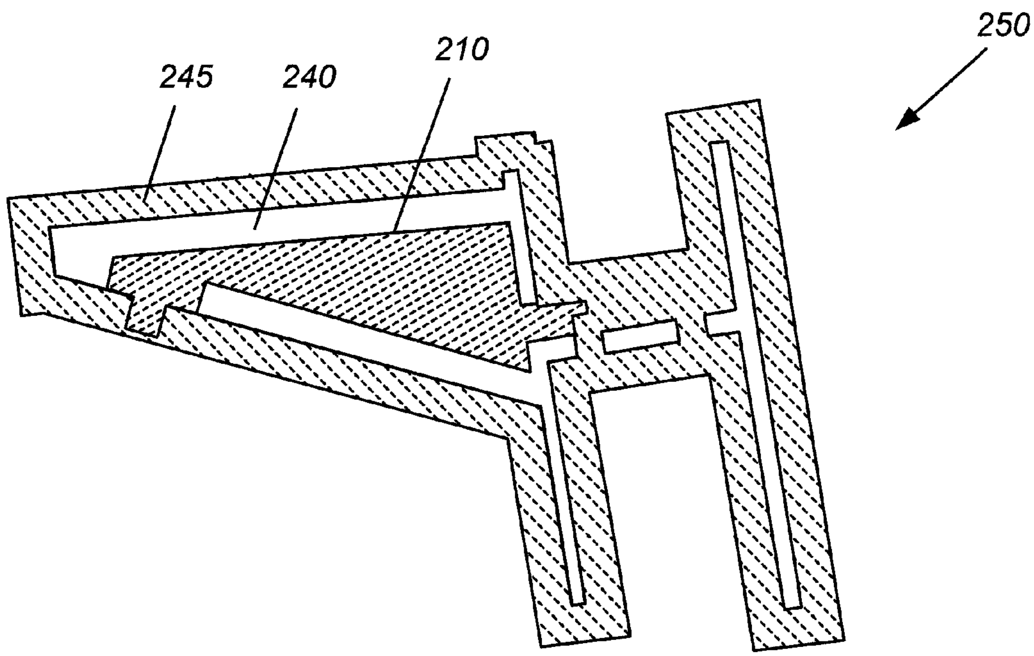


FIG. 6

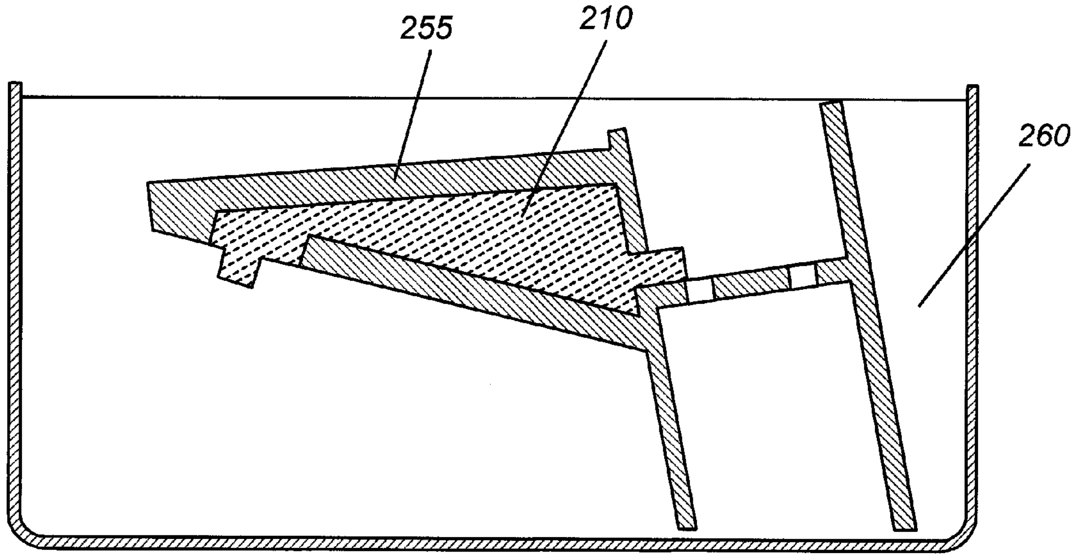


FIG. 7

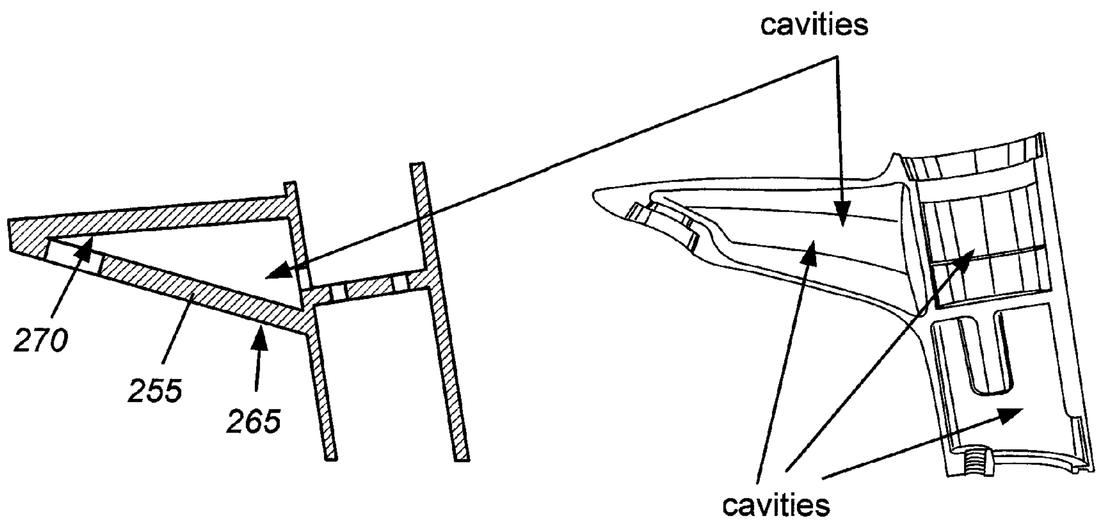


FIG. 8

METHODS FOR FORMING FAUCETS AND FIXTURES

CROSS-REFERENCE

[0001] This application claims the benefit of priority to U.S. Provisional Application No. 61/269,609 filed Jun. 26, 2009, which is incorporated by reference herein in its entirety.

FIELD OF INVENTION

[0002] The invention relates to investment casting ("IC"). More particularly, the invention relates to processes and structures formed from ceramic core patterns for lost wax investment casting that are capable of producing single-body metal structures formed with single or multiple interior chambers.

BACKGROUND

[0003] Environmental concerns around pollution and current economic development are forcing changes to the design and manufacture of water faucets that traditionally have been constructed of soft metal alloys containing lead (Pb). For more than hundred years, this traditional manufacturing process has been improved from sand casting to shell molding, even permanent mold casting. This process typically utilizes low-temperature metal alloys that require casting temperature typically under 1050° C. By using a resin sand core in this process, a hollow-center multi-chamber low-temperature alloy faucet body can be formed.

[0004] Most of the faucet bodies today are made of low-temperature alloys, which contain heavy elements such as lead (Pb), cadmium (Cd) and arsenic (As) that are both naturally occurring and part of lead element. Thus the composition of the alloy can be detrimental to humans. The internal water passage areas will contact water flow whenever the faucet is in use. Over the course of a normal life of the unit, it is cycled through repeated on/off cycles exposing the passages to air and then water accelerating the corrosion process, which enables heavy elements to leach off of the unit over its entire service life. The water flow will thus contain trace of amounts of heavy elements, bringing out traces of lead, which will subsequently mixed with the water, and the long-term use of such water to wash fruits and vegetables (or cooking of food) with trace amounts of lead will be directly or indirectly consumed and absorbed into the human body. These heavy metal elements will accumulate beyond the tolerance or load of human body and organs that will eventually lead to or cause various types of known toxic metal lead poisoning that impacts the nervous systems, mental capacity, skeletal, muscular and cardiovascular systems. These conditions are particularly harmful to young children, pregnant women and older adults. If human beings drink such water for a long or extended period of time, this will be harmful to their bodies and cause damage to their brains, nervous systems, kidneys and red blood cells. In particular, if pregnant women and children drink such water, then the consequences are unthinkably miserable.

[0005] As a result of the lead content in low-temperature metal alloys, which have been proven to cause significant harm to human beings, the State of California, the Environmental Protection Agency (EPA) in United States of America and the Restriction of Hazardous Substances (RoHS) directive in the European Union have begun to implement recently announced series of new legislations. Under new regulations, the lead content of faucets, pipelines, taps used in kitchen and drinking water system should not exceed 0.20% and 0.25%, respectively. The purpose of these provisions is to protect human drinking water that comes in contact directly or indirectly with all water delivery devices, such as pipelines, containers, plumbing and faucets, which should not contain excessive levels of heavy metal lead element. At present, the use of low-temperature metal alloy as raw material to manufacturing the faucets, such as brass faucet body materials, are mostly used in sand casting and/or shell molding. The limitation of the lead content in such brass alloy should be lower than 4% prior to Jan. 1, 2010. However, as of Jan. 1, 2010, such lead limit for brass alloy in a plumbing fixture must be less than 0.25%, as stipulated by California's AB1953.

[0006] Stainless Steel and other high temperature alloys are the obvious replacement to low-temperature but require a different manufacturing process. Investment casting is a commonly used technique for forming high-temperature metallic components having complex geometries, such as gas turbine engine components. However due to the complexity and small size of the internal passages, construction of a water faucet main body, there are many drawbacks in using current manufacturing processes and investment casting techniques to form water faucet main bodies. These include, but are not limited to, the following: the lack of a de-molding-able support to produce hollow chambers within a wax pattern; the difficulties of homogenous slurry dipping and coating when dipping to build up the layers with adequately necessary shell strength for a subsequent process of shell sintering and pouring of melted stainless steel; and the internal shell removal from or out of a casting body. Consequently such substantial limitations in various stages of an investment casting process fail to produce a sophisticated casting body constructed with the internal complexity of one or more hollow center chambers at an industrial scale with economics that matches the low-temperature alloys. For example, U.S. Patent Publication No. 2004/0221385 describes a single chamber utility faucet by using a soluble wax core. This description generally represents the current level of investment casting available today for making stainless steel utility faucets with serious limitations in the formation process which not only limits the functionality and aesthetics of the unit, but requires expensive and complex secondary processes such as welding, multiple part assembly and other steps that may introduce oxidation, corrosion, points of failure and/or un-necessary manufacturing expenses.

[0007] There is a need for water fixtures that are compliant with health regulatory standards and economic methods of their manufacture. A need further exists for stainless steel faucets that can be formed with a one-body construction and a hollow center with internal multi-chambers that are beyond the reach or capabilities of the aforementioned teachings and production methods currently available today.

SUMMARY OF THE INVENTION

[0008] The invention provides ceramic injection molding ("CIM") manufacturing processes and resulting end products that can be formed with a single one-body or one-piece construction.

[0009] A variety of products can be manufactured including multi-chambered stainless steel faucets and water fixtures. A preferable embodiment of the invention provides a stainless steel faucet formed with a main body having an internal hollow center cell with a plurality of dividing chambers. The dividing chambers may separately provide or serve as a cold-water inlet, a hot-water inlet and a mixed warm-water outlet that controls or conducts the direction of the warm-water flow. In a preferable embodiment, the main body may be constructed with hollow, under-cut, multi chambers by using one or more high temperature resistance ceramic cores during a lost wax (or lost foam) investment casting process. Once the ceramic cores are cleaned and removed or moved out of a cast, a single one-piece stainless steel faucet with a main body is thus provided and completed without additional operation. No additional time-consuming manufacturing steps, such as parts welding, screw assembly, or precision press fitting to form a final stainless steel faucet body, are required.

[0010] This invention provides methods for manufacturing a one-body construction stainless steel faucet main body with one or more hollow center, under-cut internal chambers that may have slots, holes or passageways that can separately serve as cold water inlet, hot water inlets and the warm water outlet. The passageways can also allow for directional control of warm water flow.

[0011] The manufacture process of may include the use of ceramic cores, precise positioning of the ceramic core, and one or more wax injection processes to form a complete one-body construction wax pattern with internal structures, such as multiple hollow center chambers or chambers with hollow internal portions. A wax pattern can be subjected to a pattern tree assembly process that includes one or more of the following processes: slurry dipping, coating to build up the outer shell, lost wax, shell sintering, melt stainless steel pouring to complete a hollow center, and one-body construction stainless steel faucet body after the removal of the internal ceramic cores.

[0012] In some embodiments, the wax pattern can be created from two halves. The formation of a complete wax pattern from two halves can be achieved by special design of two wax injection cavities that are used to form two half wax patterns in a single-step wax injection process. Alternatively, two separate wax injection machines or processes can be used. A first half open wax pattern can be formed and then demolded. The demolded wax pattern can be joined to a second half open wax pattern that has been previously formed. Alternatively, the demolded wax pattern can be placed into a second wax injection machine and a second half can be formed and joined to the first half. Two wax patterns can be joined by a variety of manners, for example they can be joined by thermal, ultrasonic, chemical or mechanical bonding. The patterns can be joined while the wax pattern pieces are positioned around a CIM core to form a finished wax pattern with cores pre-set into and onto the cavities of first half open wax pattern. Foam instead of wax may also be used, and subsequently, foam patterns and half foam patterns may be formed and then joined as described for wax patterns.

[0013] This invention provides for the combination of high temperature resistance ceramic cores and an investment casting process that can produce a one-body construction stainless steel faucet main body with a number of internal hollow centers, multi-chambers structure.

[0014] Another aspect of the invention provides stainless steel faucets and water fixtures that are substantially lead-free, non-verdigris, non-toxic. Such products may be manufactured to comply with EPA regulations and imposed lead/toxic limits, while also saving manufacturing costs by eliminating additional welding or machining expenses. Other aspects of the invention combine also the use of CIM processes and cores with investment casting techniques to produce a variety of products, including single body construction stainless water fixtures such as faucets that are made with less hazardous metals such as stainless steel.

[0015] In an embodiment, during wax injection process, the hollow center, under cut, internal chambers are neither demolding-able, even by a unit of metal inserts assembly, due to no supporting bridge available, nor weldable by heating a group of separate piece of wax patterns together, due to unreachable heating binding to the internal matching areas of the wax pieces that will cause gaps in between these interface area. In this particular case of a faucet body wax pattern, even the hollow center chambers are constructed without pre-set of ceramic of ceramic cores, it is virtually impossible for the zirconia slurry to be dipped and spread deep enough into and onto the internal surface of the wax pattern, neither for the zirconia sands and molichite particles, even by the power of air floating to reach into the hollow center chambers to build up an internal five or more layers of ceramic shell and to form enough shell strength after shell sintering and to hold the melted stainless steel "liquid" during pouring process. Furthermore, such formed inner ceramic shell in wet condition by slurry dipping and coating process is very difficult to be dried during shell moisture curing process because of the inner deep layers inside the wax body. Therefore the pre-set of ceramic cores with the precise positioning into and onto the top half open wax pattern is the unique process to make a finished wax pattern.

INCORPORATION BY REFERENCE

[0016] All publications, patents, and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication, patent, or patent application was specifically and individually indicated to be incorporated by reference.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The patent or application file contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawing(s) will be provided by the Office upon request and payment of the necessary fee.

[0018] A better understanding of features and advantages of the present invention will be obtained by reference to the following detailed description that sets forth illustrative embodiments, in which the principles of the invention are utilized, and the accompanying drawings of which:

[0019] FIG. **1** is a block diagram showing steps for forming a part, such as a fixture, in accordance with an embodiment of the invention;

[0020] FIG. **2** schematically illustrates a ceramic injection molded ("CIM") core in a mold, in accordance with an embodiment of the invention;

[0021] FIGS. **3**A and **3**B schematically illustrate a CIM core formed from two or more parts, in accordance with an embodiment of the invention. The CIM core of the illustrated embodiment has a hollow cavity;

[0022] FIG. **4** schematically illustrates a CIM core in a crucible filled with aluminum oxides, in accordance with an embodiment of the invention;

[0023] FIG. **5** schematically illustrates a CIM core in a tooling machine the enables the CIM core to be held in place while a wax pattern is formed around the CIM core, in accordance with an embodiment of the invention;

[0024] FIG. **6** schematically illustrates a wax (or foam) master comprising a CIM core, wax pattern and shell, in accordance with an embodiment of the invention;

[0025] FIG. **7** schematically illustrates a part, formed by investment casting methods of embodiments of the invention and having a CIM core, disposed in an alkali solution, in accordance with an embodiment of the invention; and

[0026] FIG. **8** illustrates the part of FIG. **7** with the CIM core removed, in accordance with an embodiment of the invention. The figure on the left is a schematic illustration of the figure on the right.

DETAILED DESCRIPTION OF THE INVENTION

[0027] Typically, soft metals shapes are formed using sand or die casting (carbon steel molds). Casting stainless steel using sand casting is difficult because at elevated temperatures (greater than 1475° C.) sand molds become unstable. Further, casing stainless steel using steel-on-steel (die) casting is difficult without serious deformation of the tooling components. Investment casting methods of embodiments of the invention advantageously enable the formation of stainless steel fixtures without the problems of prior art casting methods.

[0028] Methods of aspects and embodiments of the invention can be used to form fixtures, such as single-piece faucets having multiple internal chambers. Fixtures formed by methods of embodiments of the invention can be substantially non-toxic and non-verdigris, in compliance with environmental regulations and regulatory limits on toxic chemicals. Methods of preferable embodiments of the invention enable formation of faucets and fixtures that are substantially free of lead.

[0029] In embodiments of the invention, investment casting ("IC") methods are provided for forming single-piece, multicavity (or multi-chamber) faucets. Such faucets may be made of any material, such as one or more metals, including elemental metals and metal alloys (e.g., stainless steel). The multi-chamber faucet of various embodiments comprises one or more chambers for delivering water to a user.

[0030] According to methods of embodiments, one or more wax patterns are built around a core, and a shell (e.g., ceramic shell) is built around the wax pattern. Next, the wax is removed by the application of heat to the wax. The shell (also "outer shell" herein) is then heated to a predetermined casting temperature. A molten metal is then delivered to a space (also "void space" herein) between the core and the shell. In order to account for material deformation upon heating and cooling, predetermined heating and cooling rates are used.

[0031] While prior art investment casting methods enable formation of external structures, formation of internal structures (e.g., cavities, passage ways) are difficult with prior art investment casting methods. Methods of embodiments of the invention advantageously enable the formation of internal structures using a ceramic injection molded ("CIM") core that can be removed in an extraction process using chemicals that would not damage the metal casting.

[0032] In preferable embodiments of the invention, CIM cores are formed of multiple parts in order to provide cavities in the CIM cores that aid in the CIM core extraction process. In an embodiment, the CIM cores are hollow (i.e., the CIM cores are defined by an outer shell without any material toward the center of the cores). In other embodiments, the cores can be solid. In yet other embodiments, one or more hollow and one or more solid cores can be used in combination. In embodiments, once the formation of the cores is complete, the cores are placed into wax (or lost foam) masters. In an embodiment, a wax layer is formed around each core to form a wax master. The wax (or lost foam) master is then coated with a ceramic shell that forms the outer surfaces of the unit. In an embodiment, the ceramic shell is formed of zirconium silicate (or zircon).

[0033] In embodiments, the shell is formed of a first material and the CIM core is formed of a second material. In one embodiment, the first material has a higher melting point than the second material. In an embodiment, the first material is formed of zircon, silica, or a combination of zircon and silica. In another embodiment, the second material is a semi-organic material. In an embodiment, the second material is formed of zircon, silica, or a combination of zircon and silica.

[0034] The CIM cores of embodiments of the invention can be used to manufacture various fixtures, such as faucets and other parts that can replace soft metal components of various water systems, creating new types of products that are not possible to make using prior art manufacturing methods.

Method for Forming a Fixture

[0035] In an aspect of the invention, methods for forming a fixture or part are provided. The methods enable formation of single-piece, multi-cavity fixtures (e.g., faucets).

[0036] Reference will now be made to the figures, wherein like numerals refer to like parts throughout. It will be appreciated that the figures are not necessarily drawn to scale.

[0037] FIG. **1** is a process (block) diagram illustrating a method for forming a fixture, in accordance with an embodiment of the invention. While certain steps are illustrated in the process diagram, it will be appreciated that other steps could be included.

[0038] In a first step **110**, one or more ceramic injection molded ("CIM") cores are formed. The one or more CIM cores conform to internal structures of the fixture being formed. In an embodiment, the one or more CIM cores are hollow cores—i.e., the CIM cores comprise outer shells that conform to the internal structures of the fixture (e.g., faucets) being formed, but have hollow cavities. This advantageously provides savings in material costs and enables the CIM cores to be readily removed toward the end of the manufacturing process.

[0039] In preferable embodiments of the invention, CIM cores are formed of multiple parts in order to provide cavities in the CIM cores that aid in removing the CIM cores during a CIM core extraction process. CIM cores of embodiments of the invention are formed of a semi-organic material that is pressed in one or more high pressure injection molding machines. The partially-formed CIM core is then assembled and cured in a curing oven or a plurality of curing ovens if heating stages are desired. To prevent material deformation and degradation (collapsing or cracking) during heating, the CIM parts are held in crucibles, with the void space or air space between the crucibles and the CIM cores filled with aluminum oxide (e.g., Al_2O_3) that absorbs the liquids and helps hold the shape within tolerance. The curing oven aids in solidifying the cores, makes the cores dimensionally stable, and begins the oxidation process, which further aids in the extraction process. After curing of the CIM core, the CIM parts may be coated with various non-permeable coatings, depending on requirements and CIM formulas, that prevent unwanted water, wax and/or chemical intrusion during subsequent steps. In some preferable embodiments, the CIM cores may be coated with a sealant material that is water impermeable or substantially water impermeable as known by those of ordinary skill in the art. The selected material may vary according to particular formulations of the core to provide in some instances a waterproof or water resistant coating. The sealant can be a resin and/or exposy material. In some embodiments, the material can respond in a desired manner to KOH.

[0040] Next, in step **115** the one or more CIM cores formed in step **110** are suspended in a tooling apparatus, such as an injection die. In an embodiment, the injection die has an upper part and a lower part (also "upper die" and "lower die" herein) that conform to symmetrical portions of the fixture being formed. The tooling apparatus enables formation of a wax shell around the one or more CIM cores.

[0041] Next, in step **120** a wax pattern is formed around the one or more CIM cores, providing a wax master. The wax pattern can be formed by injecting the molten wax into the tooling apparatus and allowing the molten wax to fill void space between one or more walls of the tooling apparatus and the one or more CIM cores. In other embodiments of the invention, a variety of pattern materials can be used. For example, a foam pattern can be formed around the one or more CIM cores, providing a foam master. Foam pattern materials, wax pattern materials, and other pattern materials, can be manipulated similarly as described in the context of wax pattern materials herein.

[0042] In an embodiment, forming the wax pattern around the one or more CIM cores can be accomplished by assembling the one or more CIM cores in the tooling apparatus and performing a single-pass wax injection process using a timed retracting pin system. In another embodiment, the wax pattern is formed using a single-pass wax injection process and a ceramic support pin system.

[0043] In another embodiment, a sequential wax injection process is used to position individual parts of the fixture. This can be used for fixtures that have complex structures. In another embodiment, a welded wax core positioning method is used. In such a case, the CIM cores are placed into preformed wax patterns that are welded together using ultrasonic frequency welding or thermal welding. This process can be similar to the lost foam process, whereby the CIM cores are placed into foam master parts and the foam parts are fused together using glue or other means of mechanically holding parts together.

[0044] Next, in step **125** a ceramic shell is formed around the wax (or foam) master by dipping the wax (or foam) master into a ceramic slurry, forming an investment. The ceramic shell (also "shell" herein) can be formed of refractory materials, such as silica, zircon, various aluminium silicates, and alumina. Silica can be usually used in the fused silica form, but sometimes quartz can be used. Other refractory materials that can be used include molochite and chamotte. In an embodiment, the ceramic shell is formed of zircon. In another embodiment, the ceramic shell is formed of SiOx, (e.g., silica, or SiO_2). In yet another embodiment, the ceramic shell is formed of SiO_x and zircon.

[0045] Next, in step **130**, with the ceramic shell formed around the wax, the wax is removed. In an embodiment, the wax or foam is melted, leaving behind a void (also "void space" herein) in which metal can be poured to fill the void. Since the wax material can have a coefficient of thermal expansion that is greater than the ceramic (investment) material of the shell surrounding the wax, as the wax is heated it expands and induces stresses that can cause deformities in the shell. In order to minimize these stresses, the wax can be heated rapidly so that the surface of the wax can melt first and provide space for the rest of the wax to expand.

[0046] Next, at step **135**, metal is provided in the void between the shell and core. The metal can be any metal desired in the final product fixture. The metal can be an elemental metal (e.g., titanium) or a metal alloy, such as stainless steel. The metal or metal allow can have low lead content, e.g., it can have about, less than about, or up to about 4, 3, 2, 1, 0.5, 0.25, 0.2, 0.1, 0.05, 0.01, 0.005, 0.001, or 0.0001% lead content. In an embodiment, the metal is poured into the void (or the space between the one or more CIM cores and the shell). In another embodiment, vacuum casting can be used to pull the metal into the space between the core and the shell. In an embodiment, before the metal is poured, the shell material is heated to about 1000° C. or more in a burn-in process that can help stabilize the shell structure while also preventing cooling of the molten metal (thus preventing defects and shell breakage). The heating of the shell/core combination can accelerate the breakdown process of the organics in the core material to create molecular-sized pits that aid in the leaching (or core extraction) process (see below).

[0047] Next, at step **140**, the ceramic shell is removed. In an embodiment, the ceramic shell is mechanically removed via, e.g., air hammers, agitators or other tools that are capable of breaking the substantially tough material. In other embodiments, a variety of other techniques can be used to remove the ceramic shell, e.g., chemical removal or any other removal technique described herein. In an embodiment, prior to removal, the ceramic shell is allowed to cool.

[0048] The substantial toughness of the shell material makes it inapplicable for use as a CIM core material since removal of such material, if used as a core, would be difficult. In cases in which zircon is used, it might need a special environment for drying, which is difficult for small parts with internal cavities. Use of a softer material as the CIM core material aids in overcoming this problem, as the CIM core material can be removed via a passive extraction method.

[0049] Next, at step **145** the one or more CIM cores are removed. In various embodiments, after step **145** a single-piece fixture is provided. In an embodiment, step **145** provides a single-piece, multi-cavity faucet. The one or more CIM cores are removed by dipping the one or more CIM cores (and the metallic material surrounding the one or more CIM cores) into an extraction or leaching solution. In an embodiment, the extraction solution is an alkali salt solution comprising potassium hydroxide (KOH). The extraction solution can enable removal of the CIM core material in a time period between about 10 and 20 minutes. The design of the CIM core (i.e., hollow cavity) allows for greater surface area and less material to be removed, enabling a rapid extraction process. That the solution can penetrate the inner cavity of the CIM core effectively doubles the reactive surface area.

[0050] Next, at step **150**, the external surfaces of the fixture (or part) produced in step **145** are electrically plated (electroplated) to form a layer of a metallic material (metallic finish) over the external surfaces of the fixture. In an embodiment, the external surfaces are electroplated with nickel, hard chrome, or a combination of the two.

[0051] Next, at step **155**, the internal surfaces of the fixture (or part) produced in step **145** are chemically plated to form a layer of a metallic material over the internal surfaces of the fixture. In an embodiment, during step **155** a layer of nickel is formed over the internal surfaces of the fixture. The layer of nickel can have a thickness between about 1 micrometer ("micron") and 10 microns. In an embodiment, the layer of nickel has a thickness of about 3 microns.

Method for Forming a Single-Piece, Multi-Cavity Faucet

[0052] With reference to FIGS. **2-8**, a method for forming a single-piece, multi-cavity faucet is illustrated, in accordance with an embodiment of the invention. FIGS. **2-8** schematically illustrate investment casting parts and the final product (faucet) at various stages of formation.

[0053] With reference to FIG. **2**, a CIM core part **210** (also "CIM core" herein) is formed using a tooling apparatus **215** at substantially high pressures. The tooling apparatus **215** comprises a mold that has an internal structure that conforms to an internal structure of the faucet under construction. In the illustrated embodiment, the tooling apparatus **215** comprises an upper portion (mold) and a lower portion.

[0054] In some embodiments, in cases in which a faucet (or other fixture) comprises a plurality of internal structures, multiple CIM cores that correspond to a subset to of those internal structures can be used. For example, in casting a faucet, a first CIM core can be used to form a hot water inlet and a second CIM core can be used to form a water cavity where hot water and cold water mix. The number of CIM cores used to form a faucet (or other fixture) can be selected based on the complexity of the faucet being casted. The CIM cores can be used to form under-cut internal chambers or structures. The under-cut chambers or structures can have portions that protrude from the general surfaces of the faucet body and may create overhanging structures. The under-cut or overhanging structures may be about or up to about 5, 10, 20, 30, 50, 60, 70, 80, 90, or 95% of the width, length, or height of the faucet body.

[0055] The CIM core **210** of FIG. **2** can be formed from a plurality of parts, as shown in FIG. **3**A. Forming the CIM part **210** of multiple parts provides a hollow cavity **220** in the CIM part **210**, as shown in FIG. **3**B. Hollow cavities advantageously enable rapid CIM core extraction (or leaching) towards the end of the investment casting process.

[0056] With reference to FIG. **4**, the CIM core **210** shown in FIG. **2** is placed into a crucible **225** and packed with aluminum oxide particles **230** that help stabilize the CIM core **210** during a curing process. In an embodiment, the CIM core **210** is cured for about 1 to 5 days, or about 3 days.

[0057] With reference to FIG. **5**, the CIM core **210** of FIG. **2** is placed in a tooling apparatus **235** that enables the CIM core **210** to be held in place. The tooling apparatus can have an upper portion **216** and a lower portion **215**. With the CIM core **210** held in place, a wax material **240** is injected into the tooling apparatus to form a wax (or foam) master, i.e., CIM core **210** surrounded by a layer of wax **240**.

[0058] In embodiments, with the CIM core **210** held in place using ceramic pins or retracting (or retractable) fingers, wax **240** is injected into the tooling apparatus **235**. With reference to FIG. **5**, a positioning pin **246** is provided to hold the core **210** in place. In one embodiment, pressure balanced methods are used to form the wax (or foam) master. In another embodiment, with the CIM core **210** disposed in the tooling apparatus, a first layer of wax is formed around a first portion of the CIM core. A second (uncovered) portion of the CIM core is then coated with a second layer of wax. The second layer can be formed using the tooling apparatus that was used to form the first layer of wax or using another tooling apparatus. Upon forming the second layer of wax, portions of the first layer of wax can melt (or soften) and merge with the first layer of wax, thereby providing a substantially uniform layer of wax **240** around the CIM core **210**. In an embodiment, the multiple wax (or foam) parts can be merged or brought together using thermal, ultrasonic, chemical or mechanical bonding methods to form the layer of wax **240** around the CIM core **210**. One or more wax or foam masters can be joined by a tree to facilitate production. The tree with one or more wax or foam masters can be subjected to pattern tree assembly as described herein. The assembly process can include, in a desired order, coating the wax with an outer shell, curing the shell, removing wax, sintering the shell, casting the body by pouring molten stainless steel into the cast, allowing the molten steel to harden, and then removing the cast. This process can form a single-body faucet body. In some embodiments, the faucet body is made of stainless steel. The investment casting process can allow for a wide array of metals or metal alloys to be used in the formation of the faucet body, including metals or metal alloys that are low in lead content, as described herein.

[0059] With reference to FIG. **6**, the wax (or foam, if a lost-foam method is used) master having the CIM core **210** is covered with a shell **245** comprising a ceramic material, thereby forming an investment **250**. The shell can be formed by dipping in zircon or any other method of forming shells. In one embodiment, the ceramic material is zircon. In an embodiment, the ceramic material is cured after it is applied to the wax master. The curing temperature and time can be selected so as to prevent the wax material from substantially melting or expanding, which can otherwise produce deformities in the shell **245**.

[0060] Next, with the shell **245** formed around the wax **240**, the wax **240** is removed. The shell **245**, can be joined with the CIM core at one or more connection points, e.g., the positioning pin **246** shown in FIG. **5**. The wax **240** can be removed via the application of heat to the wax **240**. In an embodiment, the wax **240** is removed by rapidly heating the wax **240**. Removal of the wax **240** provides a void space (not shown) between the CIM core and the shell.

[0061] Next, with the wax **240** removed, a metallic material is provided in the void space. The metallic material can be provided by way of a melt. In an embodiment, the composition of the metallic material is selected so as to provide stainless steel between the CIM core **210** and the shell **245**.

[0062] Next, with a metallic material filling the void space between the CIM core **210** and the shell **245**, the shell **245** is mechanically removed, using, e.g., a hammer (mechanical hammer), tumblers (i.e., machines that tumble parts so that they strike each other), or a striking member, such as a striking pin. Removal of the shell provides a casted faucet with the CIM core **210**.

[0063] With reference to FIG. **7**, the casted faucet **255** having the CIM core **210** is dipped into an alkali solution **260** comprising KOH. The alkali solution can be agitated using, e.g., a motor, to faciliated the extracted CIM material to leave the cavities of the casted faucet **255**. The alkali solution breaks down the CIM material by dissolving an external portion of the CIM core **210** and, if the CIM core **210** includes an internal cavity **220** (see FIG. **3**B), by dissolving an internal portion of the CIM core **210**. If the CIM core **210** includes an internal cavity **220**, pour holes in the CIM core **210** can enable the alkali solution to enter the internal cavity **220** of the CIM core **210**.

[0064] With reference to FIG. **8**, with the CIM core **210** removed, one or more external surfaces **265** of the casted faucet **255** can be electroplated, and one or more internal surfaces **270** of the casted faucet **255** can be chemically plated. In an embodiment, chemical plating produces a layer of nickel on the one or more internal surfaces **270** of the casted faucet **255**, which can aid in preventing rust formation on the one or more internal surfaces **270**.

[0065] While preferable embodiments of the invention have been shown and described herein, it will be obvious to those skilled in the art that such embodiments are provided by way of example only. Numerous variations, changes, and substitutions will now occur to those skilled in the art without departing from the invention. It should be understood that various alternatives to aspects and embodiments of the invention described herein can be employed in practicing the invention. It is intended that the claims define the scope of the invention and that methods and structures within the scope of these claims and their equivalents be covered thereby.

What is claimed is:

1. A method of manufacturing a single-piece faucet body comprising:

forming a pattern material around one or more hollow cores,

forming a shell around the pattern material, wherein the shell and hollow core are joined at one or more locations,

removing the pattern material from the shell and hollow core, wherein the remaining shell and hollow core form an investment, and

casting the faucet body within the investment, wherein the faucet body comprises one or more internal chambers thereby forming at least a cold water inlet, a hot water inlet, and a warm water outlet.

2. The method of claim **1**, wherein the pattern is formed around a plurality of hollow cores.

3. The method of claim **1**, wherein the pattern material is wax or foam.

4. The method of claim **1**, wherein the faucet body comprises stainless steel having a lead content of less than about 0.25%.

5. The method of claim **1**, wherein the faucet body comprises one or more under-cut chambers.

6. The method of claim **1**, wherein the hollow core is formed using ceramic injection molding.

7. The method of claim **1**, wherein the shell is a ceramic material.

* * * * *