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(54) **COOKING DEVICE HAVING A COOKING VESSEL AND A CERAMIC HEATER**

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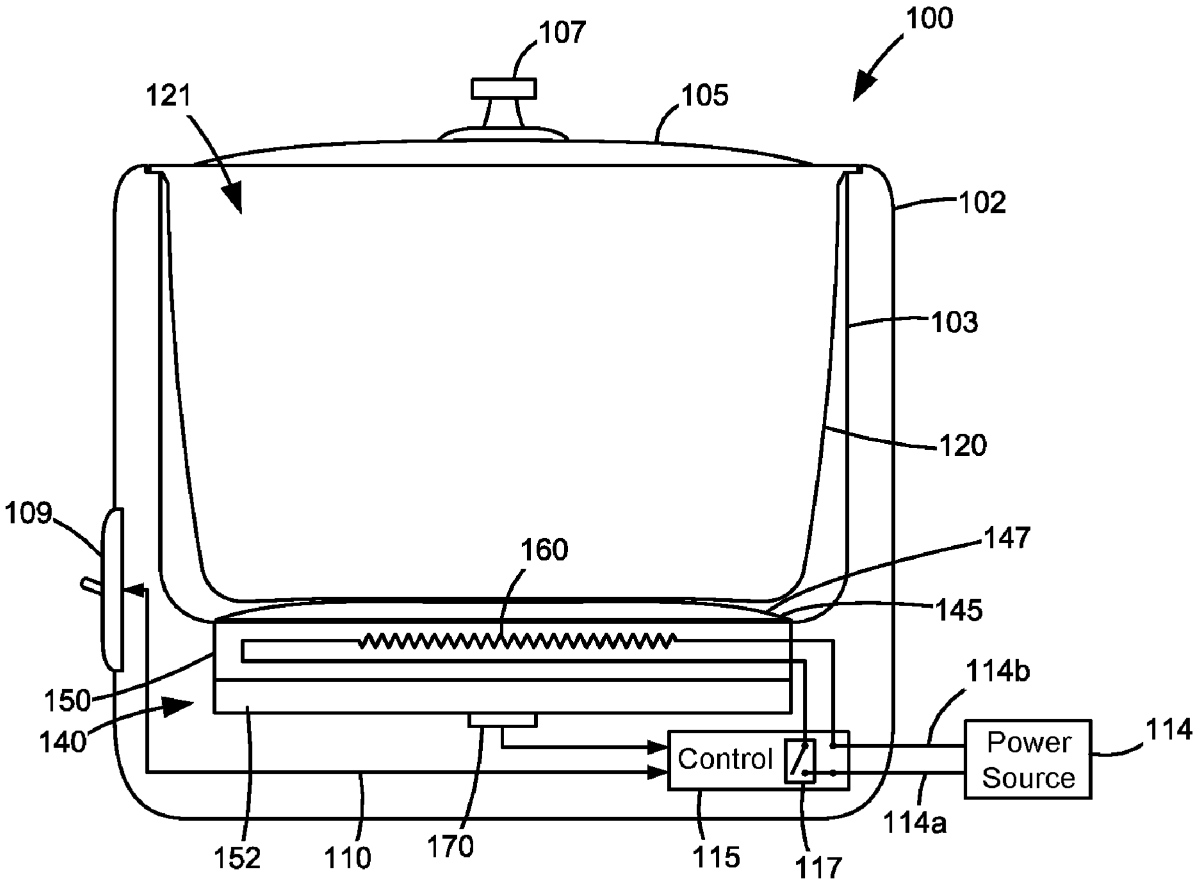
(57) **ABSTRACT**

A cooking device according to one example embodiment includes a base having a top surface positioned to contact a cooking vessel configured to hold food during cooking. The base includes a heater having a ceramic substrate and an electrically resistive trace on an exterior surface of the ceramic substrate. The heater is positioned to supply heat generated by applying an electric current to the electrically resistive trace to the top surface of the base for heating the cooking vessel to heat food in the cooking vessel. In some embodiments, the electrically resistive trace includes an electrical resistor material thick film printed on the exterior surface of the ceramic substrate. In some embodiments, the electrically resistive trace is positioned on a top surface of the ceramic substrate that faces upward toward the top surface of the base.



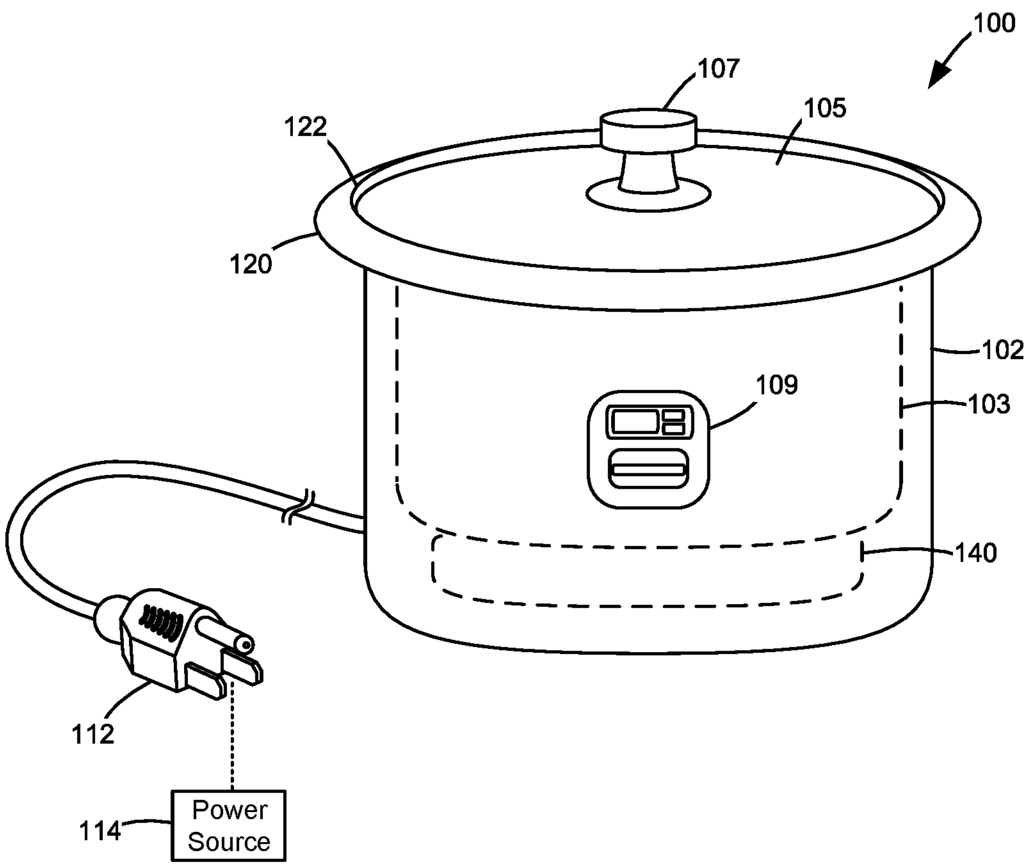


Figure 1

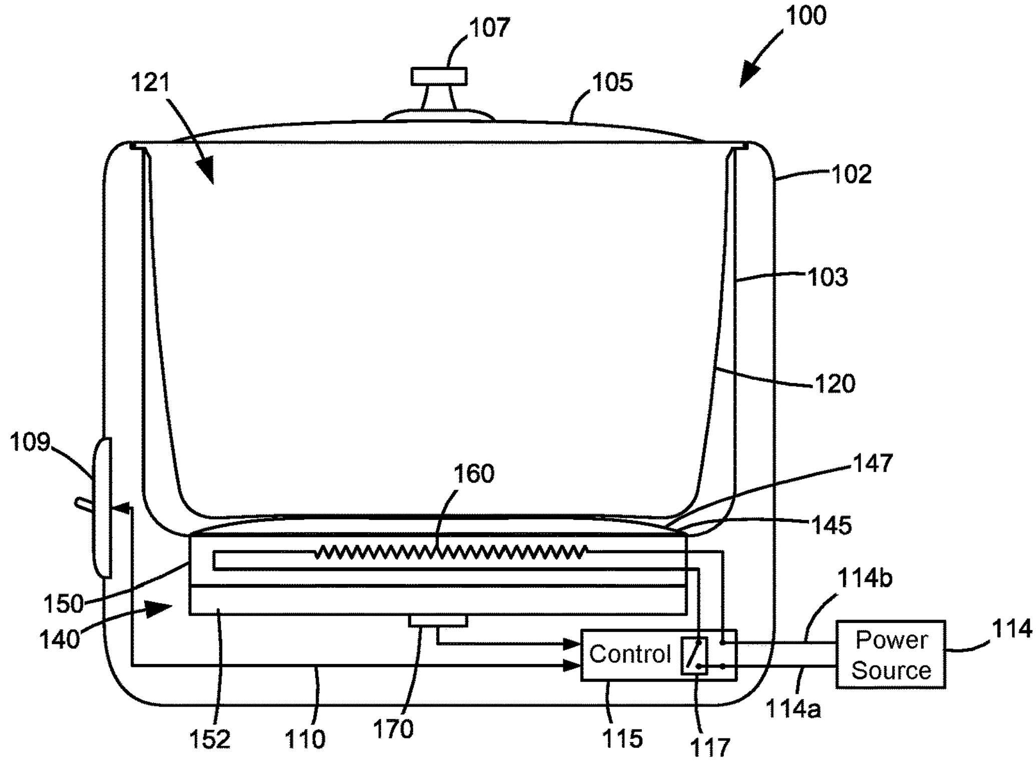


Figure 2

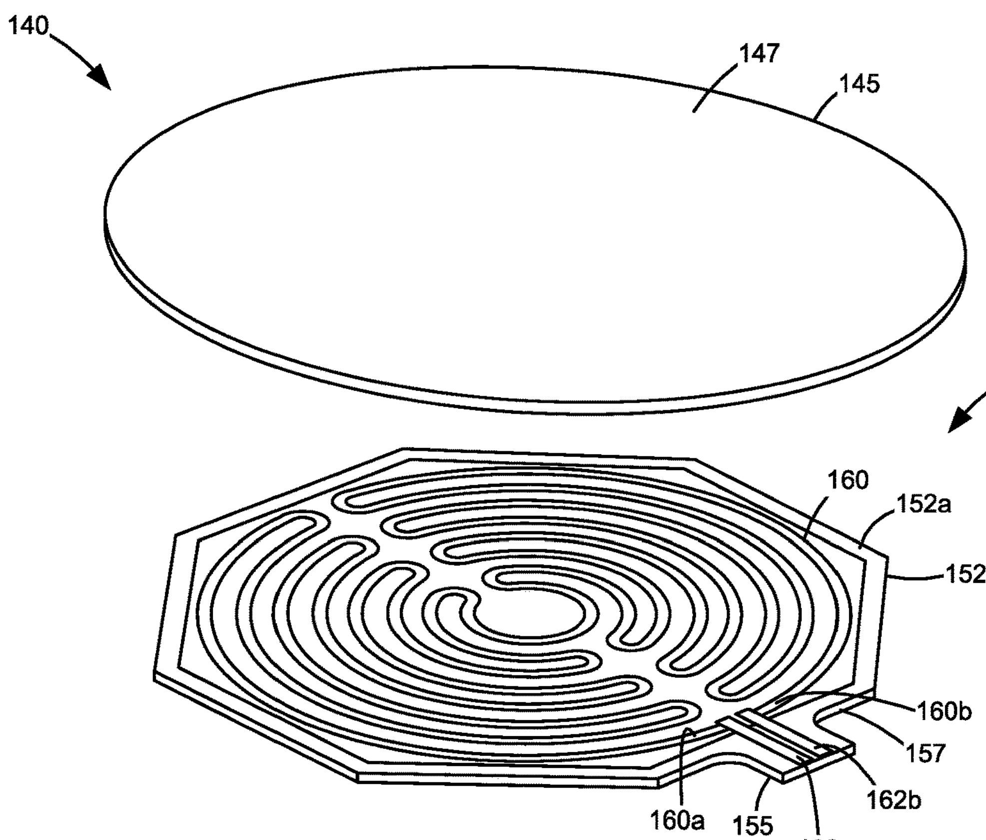


Figure 3

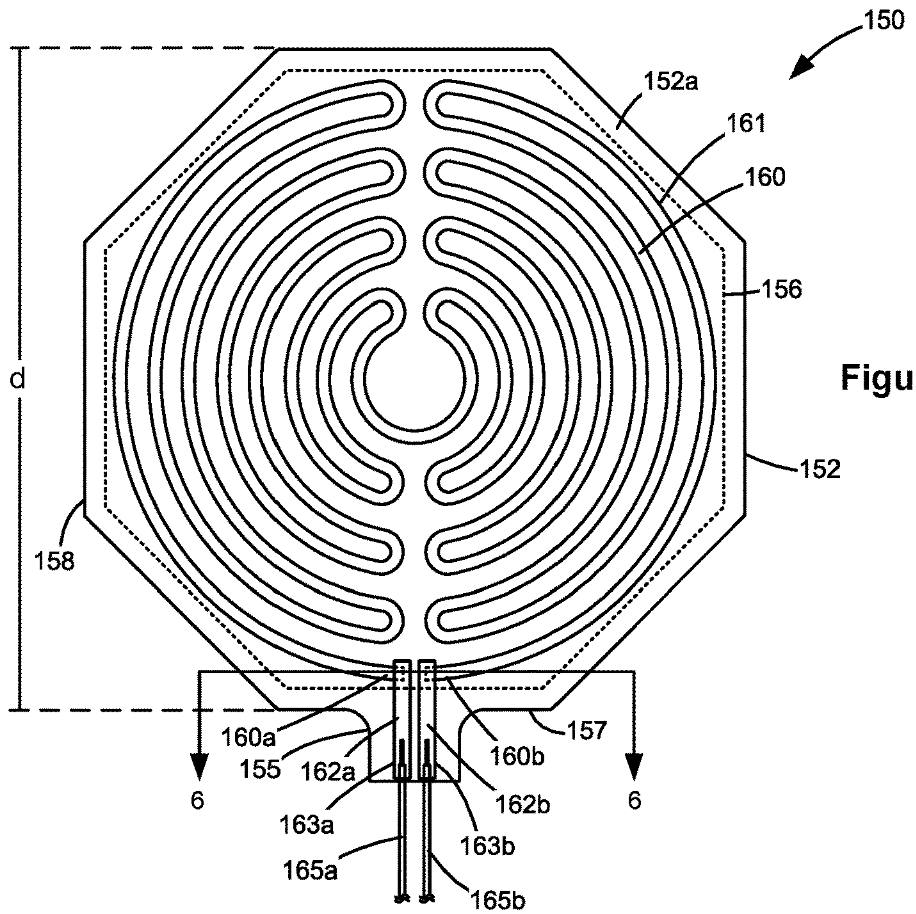


Figure 4

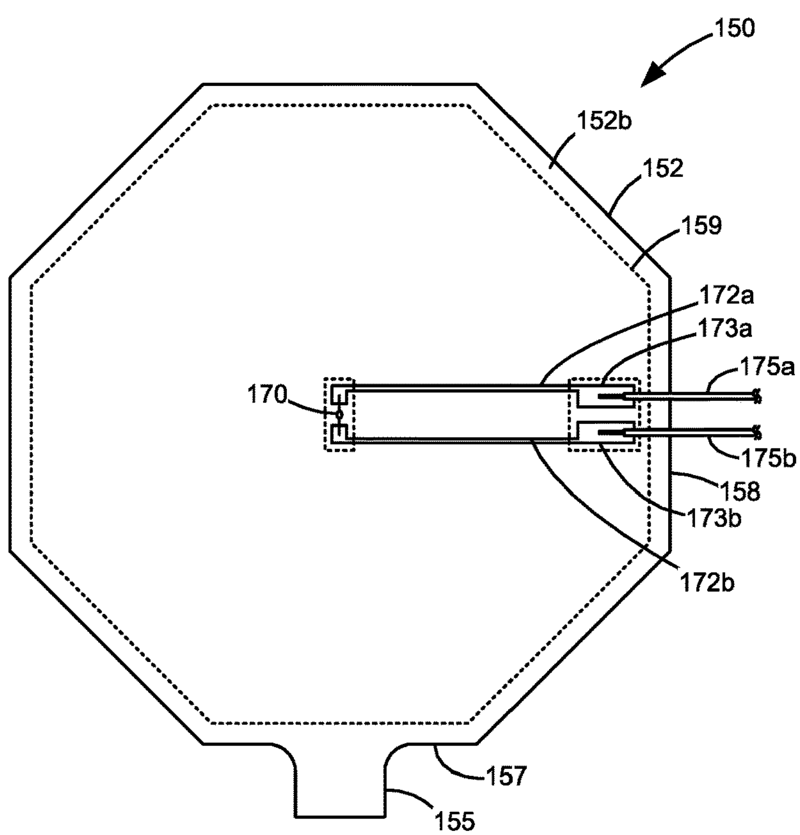


Figure 5

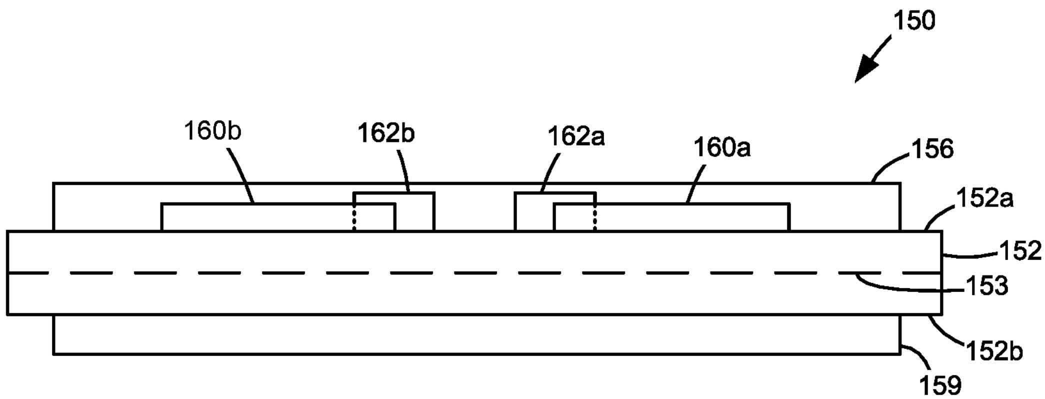


Figure 6

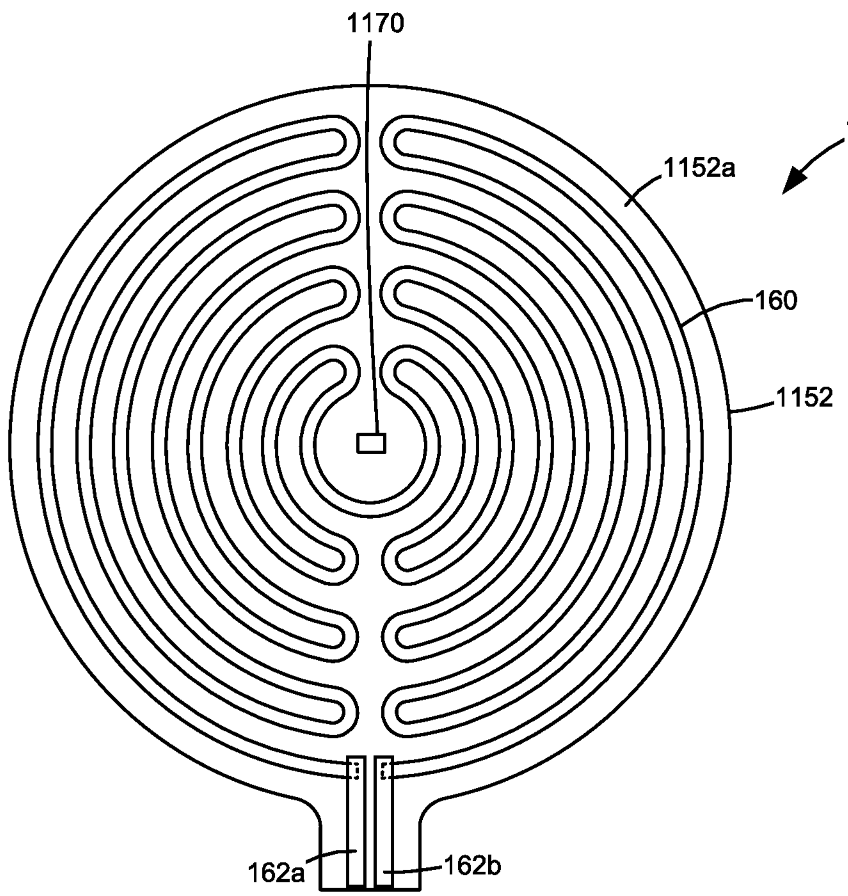


Figure 7

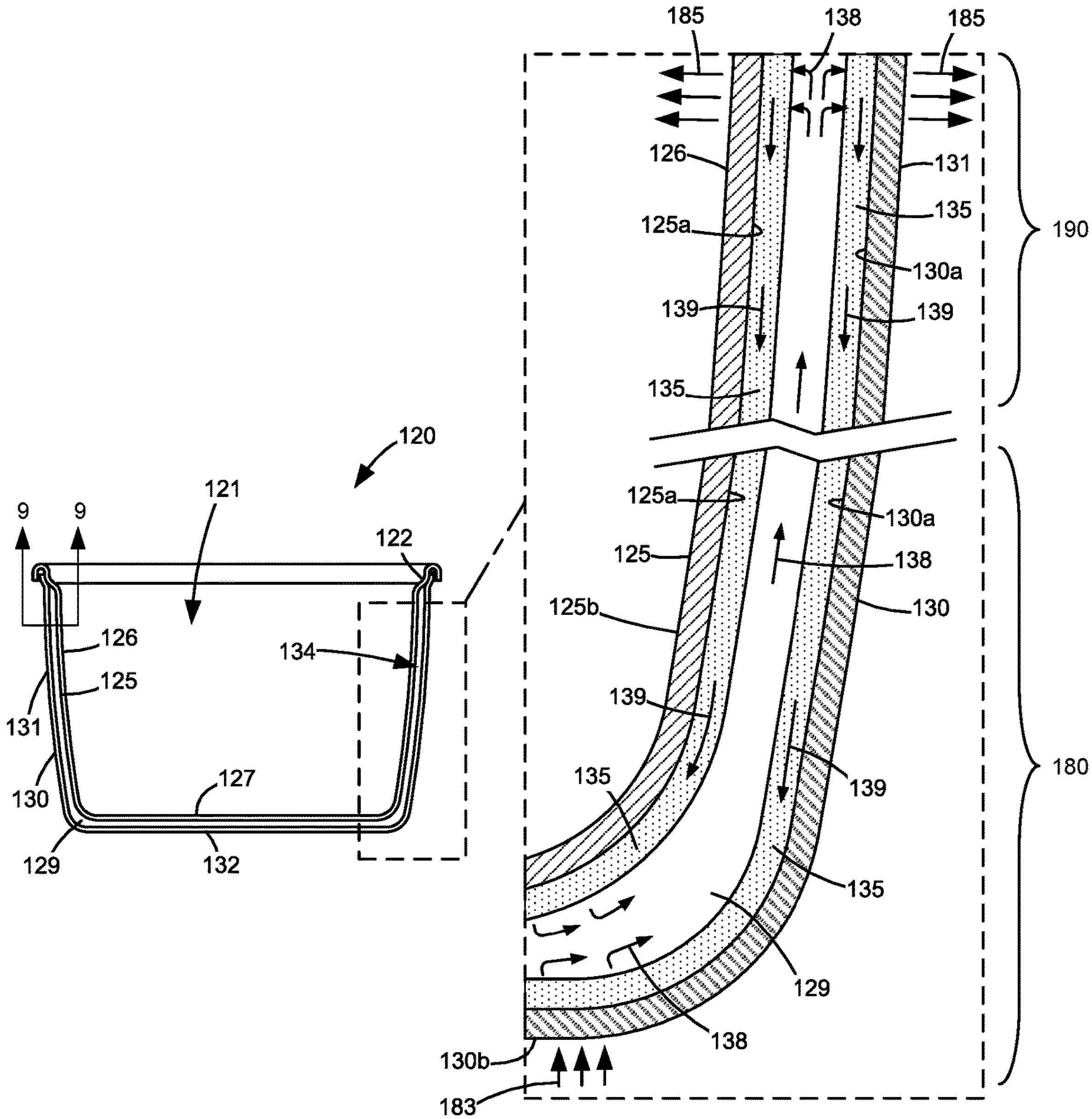

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Figure 8

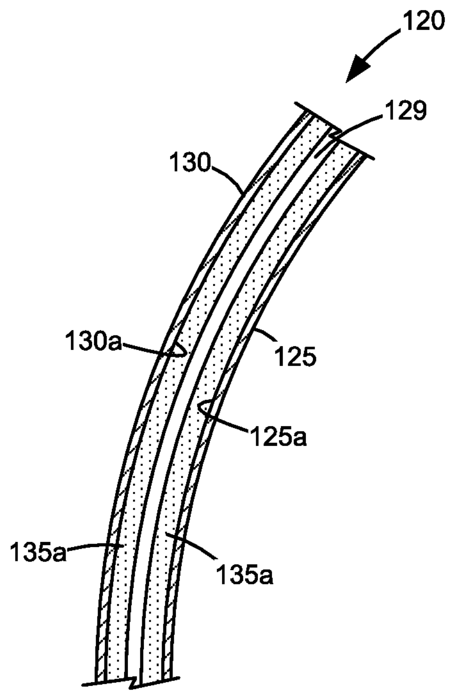

Figure 9A

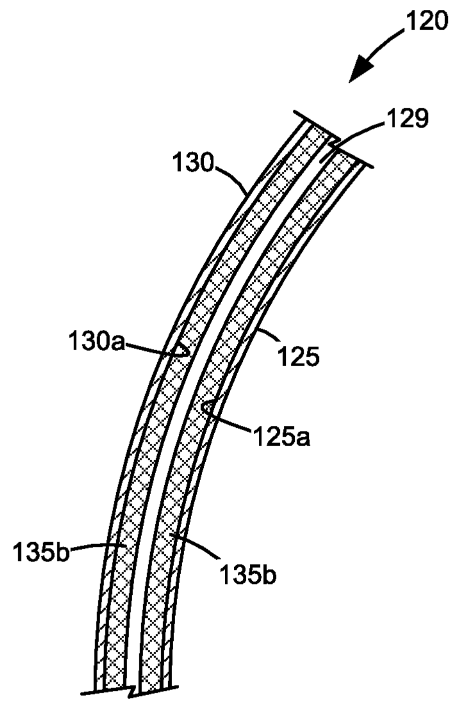

Figure 9B

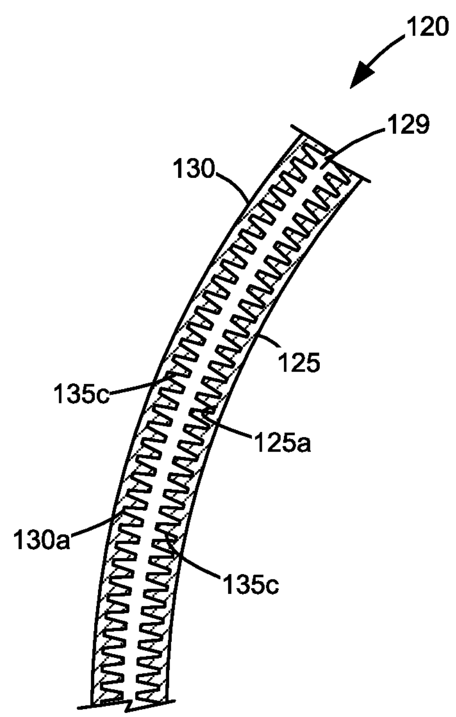

Figure 9C

COOKING DEVICE HAVING A COOKING VESSEL AND A CERAMIC HEATER

CROSS REFERENCES TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application Ser. No. 62/802,955, filed Feb. 8, 2019, entitled "Heat Pipe Cooking Vessel," the content of which is hereby incorporated by reference in its entirety.

BACKGROUND

1. Field of the Disclosure

[0002] The present disclosure relates generally to cooking devices and more particularly to a cooking device having a cooking vessel and a ceramic heater.

2. Description of the Related Art

[0003] Manufacturers of cooking devices, such as rice cookers, are continuously challenged to improve heating time and heating effectiveness. Most low-end rice cookers, for example, utilize a wire coil heater, such as nichrome wire, potted with ceramic cement inside a stainless steel sheath embedded inside a cast aluminum body. These heaters generate heat by passing electrical current through the nichrome wire. These types of heaters often suffer from long warmup and cooldown times due to the high thermal mass provided by the electrical insulation materials and the relatively large metal components. Furthermore, cooking vessels used with wire coil heaters typically have relatively low thermal mass resulting in poor distribution of heat within the cooking vessel.

[0004] Some high-end rice cookers utilize induction heaters to directly warm the cooking vessel instead of relying on convection or thermal conduction. Induction rice cookers use induction heating where current is passed through a metal coil to create a magnetic field. The cooking vessel is positioned within the magnetic field to induce electrical current in the cooking vessel which, in turn, generates heat. With induction heating, the heating temperature may be controlled by adjusting the strength of the magnetic field allowing for shorter warmup and cooldown times to be achieved. However, induction heaters are generally expensive due to the cost of the electrical materials and components, and the control systems for induction heaters are relatively complex and generally expensive as a result.

[0005] Accordingly, a cost-effective cooking device having improved thermal efficiency is desired.

SUMMARY

[0006] A cooking device according to one example embodiment includes a base having a top surface positioned to contact a cooking vessel configured to hold food during cooking. The base includes a heater having a ceramic substrate and an electrically resistive trace on an exterior surface of the ceramic substrate. The heater is positioned to supply heat generated by applying an electric current to the electrically resistive trace to the top surface of the base for heating the cooking vessel to heat food in the cooking vessel. In some embodiments, the electrically resistive trace includes an electrical resistor material thick film printed on the exterior surface of the ceramic substrate. In some embodiments, the electrically resistive trace is positioned on a top surface of the ceramic substrate that faces upward toward the top surface of the base.

[0007] Embodiments include those wherein the heater includes a thermistor that is positioned on the ceramic substrate and in electrical communication with control circuitry of the heater for providing feedback regarding a temperature of the heater to the control circuitry of the heater. In some embodiments, the thermistor is positioned on a bottom surface of the ceramic substrate that faces away from the top surface of the base.

[0008] Embodiments include those wherein the base includes a heating plate that forms the top surface of the base. The heating plate is positioned in contact with the heater to transfer heat from the heater to the top surface of the base for heating the cooking vessel to heat food in the cooking vessel. In some embodiments, the heating plate includes a domed top surface for contacting a concave bottom surface of the cooking vessel.

[0009] Embodiments include those wherein the ceramic substrate has a polygonal shape. In some embodiments, the ceramic substrate has an octagonal shape.

[0010] Embodiments include those wherein the electrically resistive trace extends in a serpentine pattern across the exterior surface of the ceramic substrate. In some embodiments, the serpentine pattern of the electrically resistive trace has a generally circular outer perimeter.

[0011] A cooking device according to another example embodiment includes a housing having a receptacle and a base positioned along a bottom of the receptacle. A cooking vessel is removably positionable within the receptacle for containing food to be cooked. The cooking vessel contacts the base when the cooking vessel is positioned within the receptacle. The base includes a heater having a ceramic substrate and an electrical resistor material thick film printed on a surface of the ceramic substrate. The heater is positioned to supply heat generated by applying an electric current to the electrical resistor material to the cooking vessel when the cooking vessel is positioned within the receptacle.

[0012] A heater for use with a cooking device according to one example embodiment includes a ceramic substrate and an electrically resistive trace thick film printed on an exterior face of the ceramic substrate. The electrically resistive trace extends in a serpentine pattern across the exterior face of the ceramic substrate from a first end of the electrically resistive trace to a second end of the electrically resistive trace. The serpentine pattern of the electrically resistive trace has a generally circular outer perimeter. The heater also includes a first electrically conductive trace electrically connected to the first end of the electrically resistive trace and a second electrically conductive trace electrically connected to the second end of the electrically resistive trace. The first and second electrically conductive traces form respective first and second terminals providing respective first and second electrical connections for completing a circuit formed by the first and second electrically conductive traces and the electrically resistive trace. Some embodiments include one or more glass layers on the exterior face of the ceramic substrate that cover the electrically resistive trace electrically insulating the electrically resistive trace. Some embodiments include a thermistor positioned on a second exterior face of the ceramic substrate that is opposite the exterior face of the ceramic substrate on which the electrically resistive trace is positioned for providing feedback

regarding a temperature of the heater to control circuitry of the heater. Embodiments include those wherein the ceramic substrate has a polygonal shape. In some embodiments, the ceramic substrate has an octagonal shape.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The accompanying drawings incorporated in and forming a part of the specification illustrate several aspects of the present disclosure and together with the description serve to explain the principles of the present disclosure.

[0014] FIG. **1** is a perspective view of a cooking device according to one example embodiment.

[0015] FIG. **2** is a schematic diagram of the cooking device according to one example embodiment.

[0016] FIG. **3** is an exploded perspective view of a heater assembly of the cooking device according to one example embodiment.

[0017] FIGS. **4** and **5** are plan views of a top surface and a bottom surface, respectively, of a heater of the heater assembly shown in FIG. **3**.

[0018] FIG. **6** is a cross-sectional view of the heater shown in FIGS. **4** and **5** taken along line **6-6** in FIG. **4**.

[0019] FIG. **7** is a plan view of a top surface of a heater according to another example embodiment.

[0020] FIG. **8** is a cross-sectional view of a cooking vessel of the cooking device employing a heat pipe according to one example embodiment.

[0021] FIGS. **9A-9C** are cross-sectional views of the cooking vessel shown in FIG. **8** taken along line **9-9** in FIG. **8** illustrating various example wick structures of the heat pipe.

DETAILED DESCRIPTION

[0022] In the following description, reference is made to the accompanying drawings where like numerals represent like elements. The embodiments are described in sufficient detail to enable those skilled in the art to practice the present disclosure. It is to be understood that other embodiments may be utilized and that process, electrical, and mechanical changes, etc., may be made without departing from the scope of the present disclosure. Examples merely typify possible variations. Portions and features of some embodiments may be included in or substituted for those of others. The following description, therefore, is not to be taken in a limiting sense and the scope of the present disclosure is defined only by the appended claims and their equivalents.

[0023] Referring now to the drawings and particularly to FIG. **1**, a cooking device **100** is shown according to one example embodiment. In the example embodiment illustrated, cooking device **100** includes a rice cooker. However, cooking device **100** may also include a pressure cooker, a steam cooker, etc. Cooking device **100** includes a housing **102**, a cooking vessel **120**, a lid **105**, a heater assembly **140**, and a user interface **109**. Housing **102** includes an upper portion having a receptacle **103** for receiving cooking vessel **120** and a lower portion within which heater assembly **140** is mounted. In the embodiment illustrated, heater assembly **140** forms a receiving base of receptacle **103** such that cooking vessel **120** contacts and rests on top of heater assembly **140** when cooking vessel **120** is positioned within receptacle **103** so that heat generated by heater assembly **140** heats cooking vessel **120**.

[0024] Cooking vessel **120** is generally a container (e.g., a bowl) having a food receptacle **121** in which food substances to be cooked, such as rice and water, are contained. That is, food receptacle **121** of cooking vessel **120** directly contacts and retains the food being cooked. Cooking vessel **120** may be composed of, for example, a metal having high thermal conductivity, such as stainless steel, aluminum or copper. Lid **105** covers the opening at a rim **122** of cooking vessel **120**. Lid **105** includes a handle **107** preferably composed of a material having low thermal conductivity to provide a safe surface for the user to hold when using lid **105**. User interface **109** is provided on a front portion of housing **102**. User interface **109** may include one or more buttons, dials, knobs, etc. for receiving user input and/or a display or indicator lights for providing information about the functioning and status of cooking device **100** to a user. Cooking device **100** also includes a power cord **112** for connecting cooking device **100** to an external power source **114**.

[0025] In one embodiment, during use, food receptacle **121** of cooking vessel **120** holds water and rice to cook, and heater **140** transfers heat to cooking vessel **120** to bring the water to boil. Once the water reaches a steady boil, the temperature of cooking vessel **120** remains generally stable. Once all of the water in cooking vessel **120** is absorbed by the rice and/or evaporated, the temperature of cooking vessel **120** tends to increase, triggering a mechanism inside cooking device **100** to either turn heater assembly **140** off or to switch to a reduced temperature warming cycle intended to keep the food in cooking vessel **120** warm.

[0026] With reference to FIG. **2**, a schematic depiction of cooking device **100** is shown according to one example embodiment. Cooking device **100** includes heater assembly **140** including a heater **150** and a heating plate **145**. Heater **150** includes a substrate **152** to which at least one resistive trace **160** is secured. Heat is generated when electrical current provided by power source **114** is passed through resistive trace **160**. When cooking vessel **120** is disposed in receptacle **103**, cooking vessel **120** contacts and rests on top of heating plate **145**. Heating plate **145** is positioned in contact with, or in very close proximity to, heater **150** in order to transfer heat from heater **150** to cooking vessel **120**. In some embodiments, thermal grease is applied between heater **150** and heating plate **145** to facilitate physical contact and heat transfer between heater **150** and heating plate **145**. In some embodiments, a gap filler (e.g., silicon gap filler) or pad (e.g., graphite gap pad) is positioned between heater **150** and heating plate **145** to facilitate heat transfer between heater **150** and heating plate **145**. Heating plate **145** is composed of, for to example, a metal having high thermal conductivity, such as forged aluminum.

[0027] Cooking device **100** includes control circuitry **115** configured to control the temperature of heater **150** by selectively opening or closing a circuit supplying electrical current to resistive trace **160**. Open loop or, preferably, closed loop control may be utilized as desired. In the embodiment illustrated, a temperature sensor **170**, such as a thermistor, is coupled to substrate **152** for sensing the temperature of heater **150** and permitting closed loop control of heater **150** by control circuitry **115**. Control circuitry **115** may include a microprocessor, a microcontroller, an application-specific integrated circuit, and/or other form integrated circuit. User interface **109** is communicatively coupled to control circuitry **115** via a communications link **110**.

[0028] In the embodiment illustrated in FIG. **2**, control circuitry **115** includes a switch **117** connected between one end of resistive trace **160** and a first terminal **114***a* of power source **114**. Switch **117** may be, for example, a mechanical switch, an electronic switch, a relay, or other switching device. The other end of resistive trace **160** is connected to a second terminal **114***b* of power source **114**. The temperature of heater **150** is controlled by measuring the temperature of substrate **152** by temperature sensor **170** held in contact with substrate **152** and feeding temperature information from temperature sensor **170** to control circuitry **115** which, in turn, controls switch **117** to selectively supply power to resistive trace **160** based on the temperature information. When switch **117** is closed, current flows through resistive trace **160** to generate heat from heater **150**. When switch **117** is opened, no current flows through resistive trace **160** to pause or stop heat generation from heater **150**. In some embodiments, control circuitry **115** may include power control logic and/or other circuitries for controlling the amount of power delivered to resistive trace **160** to permit adjustment of the amount of heat generated by heater **150** within a desired range of temperatures. For example, in some embodiments, when the temperature of heater **150** is low (e.g., under 100 degrees Celsius), heater **150** is supplied with 50% power and then gradually stepped up from 50% to 100% as the temperature of heater **150** increases.

[0029] FIG. **3** shows heater assembly **140** including heating plate **145** and heater **150** according to one example embodiment. FIG. **4** shows a top view of heater **150**, and FIG. **5** shows a bottom view of heater **150**. In the example embodiment illustrated, heating plate **145** is formed as a circular disk having a domed upper surface **147** (also shown in FIG. **2** with exaggerated scale for illustration purposes). In one embodiment, heating plate **145** has a diameter of about 162 mm, a central portion having a thickness of about 5 mm, and a circumferential edge having a thickness of about 1 mm. In other embodiments, heating plate **145** may have other shapes as long as heating plate **145** is positioned to spread heat from heater **150** across the bottom surface of cooking vessel **120**. The thermal conductivity and relative thinness of heating plate **145** result in a relatively low thermal mass, which reduces the amount of time required to heat and cool heating plate **145** and, in turn, cooking vessel **120**.

[0030] Heater **150** includes substrate **152** constructed from ceramic or the like, such as aluminum oxide (e.g., commercially available 96% aluminum oxide ceramic). Hereinafter, substrate **152** is referred to as ceramic substrate **152**. In some embodiments, heater **150** may include one or more layers of ceramic substrate **152**. Where heater **150** includes a single layer of ceramic substrate **152**, a thickness of ceramic substrate **152** may range from, for example, 0.5 mm to 1.5 mm, such as 1.0 mm. Where heater **150** includes multiple layers of ceramic substrate **152**, each layer may have a thickness ranging from, for example, 0.5 mm to 1.0 mm, such as 0.635 mm. In the embodiment illustrated, ceramic substrate **152** is octagonal in shape having an incircle diameter d of about 147 mm. However, ceramic substrate **152** may take other suitable shapes depending on the application, such as, for example, circular, hexagonal, square, etc. In general, the octagonal shape illustrated is easier to reliably manufacture on a commercial basis than, for example, a circular shape.

[0031] Ceramic substrate **152** includes a top surface **152***a* that faces heating plate **145** and a bottom surface **152***b* opposite top surface **152***a*. In the embodiment illustrated, resistive trace **160** is positioned on top surface **152***a* of ceramic substrate **152**. Resistive trace **160** includes a first end **160***a* and a second end **160***b*. In this embodiment, a pair of conductive traces **162***a*, **162***b* are also positioned on top surface **152***a*. Conductive traces **162***a*, **162***b* are connected to first and second ends **160***a*, **160***b* of resistive trace **160**, respectively. Resistive trace **160** includes a suitable electrical resistor material such as, for example, silver palladium (e.g., blended 70/30 silver palladium). Conductive traces **162***a*, **162***b* include a suitable electrical conductor material such as, for example, silver platinum. In the embodiment illustrated, resistive trace **160** and conductive traces **162***a*, **162***b* are applied to ceramic substrate **152** by way of thick film printing. For example, resistive trace **160** may include a resistor paste having a thickness of 10-13 microns when applied to ceramic substrate **152**, and conductive traces **162***a*, **162***b* may include a conductor paste having a thickness of 9-15 microns when applied to ceramic substrate **152**. Resistive trace **160** forms the heating element of heater **150**, and conductive traces **162***a*, **162***b* provide electrical connections to resistive trace **160** in order to supply an electrical current to resistive trace **160** to generate heat.

[0032] In the example embodiment illustrated, resistive trace **160** follows a serpentine pattern extending from first end **160***a* to second end **160***b* along top surface **152***a* of ceramic substrate **152**. In this embodiment, the serpentine pattern formed by resistive trace **160** has a generally circular outer perimeter **161**. Conductive traces **162***a*, **162***b* each form a respective terminal **163***a*, **163***b* of heater **150**. Cables or wires **165***a*, **165***b* are connected to respective terminals **163***a*, **163***b* in order to electrically connect resistive trace **160** and conductive traces **162***a*, **162***b* to, for example, control circuitry **115** and power source **114** in order to selectively close the circuit formed by resistive trace **160** and conductive traces **162***a*, **162***b* to generate heat. Conductive trace **162***a* directly contacts first end **160***a* of resistive trace **160**, and conductive trace **162***b* directly contacts second end **160***b* of resistive trace **160**. Conductive traces **162***a*, **162***b* both extend along an extension portion **155** of ceramic substrate **152** that extends from an edge **157** of ceramic substrate **152** in the example embodiment illustrated, but conductive traces **162***a*, **162***b* may be positioned in other suitable locations on ceramic substrate **152** as desired. Portions of first and second ends **160***a*, **160***b* of resistive trace **160** obscured beneath conductive traces **162***a*, **162***b* in FIG. **4** are shown in dotted line. In this embodiment, current input to heater **150** at, for example, terminal **163***a* by way of conductive trace **162***a* passes through, in order, resistive trace **160** and conductive trace **162***b* where it is output from heater **150** at terminal **163***b*. Current input to heater **150** at terminal **163***b* travels in reverse along the same path.

[0033] In some embodiments, heater **150** includes temperature sensor **170**, also referred to as thermistor **170**, positioned in close proximity to a surface of heater **150** in order to provide feedback regarding the temperature of heater **150** to control circuitry **115**. In the embodiment shown, thermistor **170** is positioned on bottom surface **152***b* of ceramic substrate **152**. In the example embodiment illustrated, thermistor **170** is welded directly to bottom surface **152***b* of ceramic substrate **152**. In this embodiment, heater **150** also includes a pair of conductive traces **172***a*, **172***b* that are each electrically connected to a respective terminal of thermistor **170**. Each conductive trace **172***a*, **172***b* has a distal end that forms a respective terminal **173***a*, **173***b* adjacent to an edge **158** of ceramic substrate **152**. Cables or wires **175***a*, **175***b* are connected to terminals **173***a*, **173***b* in order to electrically connect thermistor **170** to, for example, control circuitry **115** in order to provide closed loop control of heater **150**. In the embodiment illustrated, thermistor **170** is positioned at a central location of bottom surface **152***b* of ceramic substrate **152**. However, thermistor **170** and its corresponding conductive traces **172***a*, **172***b* may be positioned in other suitable locations on bottom surface **152***b* of ceramic substrate **152**.

[0034] In some embodiments, heater **150** also includes a thermal cutoff (not shown), such as a bi-metal thermal cutoff, in contact with ceramic substrate **152** and connected in series with the heating circuit formed by resistive trace **160** and conductive traces **162***a*, **162***b* permitting the thermal cutoff to open the heating circuit formed by resistive trace **160** and conductive traces **162***a*, **162***b* upon detection by the thermal cutoff of a temperature that exceeds a predetermined amount. In this manner, the thermal cutoff provides additional safety by preventing overheating of heater **150**.

[0035] FIG. **6** is a cross-sectional view of heater **150** taken along line **6-6** in FIG. **4**. As shown, heater **150** includes resistive trace **160** and conductive traces **162***a*, **162***b* formed on ceramic substrate **152**. FIG. **6** depicts a single layer of ceramic substrate **152**. However, ceramic substrate **152** may include multiple layers as depicted by dashed line **153**. In the embodiment illustrated, heater **150** includes one or more layers of printed glass **156** on top surface **152***a* of ceramic substrate **152**. In the embodiment illustrated, glass layer **156** covers resistive trace **160** and portions of conductive traces **162***a*, **162***b* in order to electrically insulate such features to prevent electric shock or arcing. The borders of glass layer **156** are shown in dashed line in FIG. **4**. In this embodiment, glass layer **156** covers resistive trace **160** and adjacent portions of ceramic substrate **152** such that glass layer **156** forms the majority of the top surface of heater **150** facing heating plate **145**. An overall thickness of glass layer **156** may range from, for example, 35-45 microns.

[0036] In the embodiment illustrated, heater **150** also includes one or more layers of printed glass **159** on bottom surface **152***b* of ceramic substrate **152** to minimize camber. The borders of glass layer **159** are shown in dashed line in FIG. **5**. In this embodiment, glass layer **159** does not cover thermistor **170** and some portions of conductive traces **172***a*, **172***b* because the relatively low voltage (in comparison with the voltages applied to resistive trace **160**) applied to such features presents a lower risk of electric shock or arcing. An overall thickness of glass layer **159** may range from, for example, 35-45 microns.

[0037] In addition to providing electrical insulation, laminating the ceramic heater of the present disclosure with glass layers **156**, **159** provides increased resistance to thermal shock. In some embodiments, heater **150** is fabricated by fiber laser scribing the perimeter of heater **150** to further increase thermal shock resistance. Fiber laser scribing tends to provide a more uniform singulation surface having fewer microcracks along the separated edge in comparison with conventional carbon dioxide laser scribing.

[0038] Heater **150** may be constructed by way of thick film printing. For example, in one embodiment, resistive trace **160** is printed on fired (not green state) ceramic substrate **152**, which includes selectively applying a paste containing resistor material to top surface **152***a* of ceramic substrate **152** through a patterned mesh screen with a squeegee or the like. The printed resistor is then allowed to settle on ceramic substrate **152** at room temperature. The ceramic substrate **152** having the printed resistor is then heated at, for example, approximately 140-160 degrees Celsius for a total of approximately 30 minutes, including approximately 10-15 mins at peak temperature and the remaining time ramping up to and down from the peak temperature, in order to dry the resistor paste and to temporarily fix resistive trace **160** in position. The ceramic substrate **152** having temporary resistive trace **160** is then heated at, for example, approximately 850 degrees Celsius for a total of approximately one hour, including approximately 10 minutes at peak temperature and the remaining time ramping up to and down from the peak temperature, in order to permanently fix resistive trace **160** in position. Conductive traces **162***a*, **162***b* are then printed on top surface **152***a* of ceramic substrate **152**, which includes selectively applying a paste containing conductor material in the same manner as the resistor material. The ceramic substrate **152** having the printed resistor and conductor is then allowed to settle, dried and fired in the same manner as discussed above with respective to resistive trace **160** in order to permanently fix conductive traces **162***a*, **162***b* in position. Glass layer(s) **156** on top surface **152***a* are then printed in substantially the same manner as the resistors and conductors, including allowing the glass layer(s) **156** to settle as well as drying and firing the glass layer(s) **156**. In one embodiment, glass layer(s) **156** are fired at a peak temperature of approximately 810 degrees Celsius, slightly lower than the resistors and conductors. Conductive traces **172***a*, **172***b* for thermistor **170** are printed on bottom surface **152***b* of ceramic substrate **152** in substantially the same manner as conductive traces **162***a*, **162***b*, and glass layer(s) **159** are printed on bottom surface **152***b* of ceramic substrate **152** in substantially the same manner as glass layer(s) **156**. Thermistor **170** is then mounted to ceramic substrate **152** in a finishing operation with the terminals of thermistor **170** directly welded to conductive traces **172***a*, **172***b*.

[0039] Thick film printing resistive trace **160** and conductive traces **162***a*, **162***b* on fired ceramic substrate **152** provides more uniform resistive and conductive traces in comparison with ceramic heaters having resistive and conductive traces printed on green state ceramic. The improved uniformity of resistive trace **160** and conductive traces **162***a*, **162***b* provides more uniform heating across heating plate **145** as well as more predictable heating of heater **150**.

[0040] While the example embodiment illustrated in FIGS. **3-5** includes heater **150** having an octagonal shape, in other embodiments, heater **150** may have other forms and shapes as desired. For example, with reference to FIG. **7**, a heater **1150** may have a circular shape according to one example embodiment. Thermistor **170** is disposed on a surface of ceramic substrate **152** opposite the surface along which resistive trace **160** is disposed in the embodiment shown in FIG. **5**, but thermistor **170** and/or its corresponding conductive traces may be disposed on the same side of ceramic substrate **152** as resistive trace **160** so long as they do not interfere with the positioning of resistive trace **160**

and conductive traces **162***a*, **162***b*. For example, in FIG. **7**, a thermistor **1170** is positioned on the same surface as resistive trace **160** (e.g., top surface **1152***a* of ceramic substrate **1152**). In some embodiments, corresponding conductive traces of thermistor **170** may be disposed on the bottom surface (opposite top surface **1152***a*) of ceramic substrate **1152** while thermistor **1170** is positioned on top surface **1152***a* thereof. In this embodiment, heater **150** may include vias that are formed as through-holes substantially filled with conductive material extending through ceramic substrate **1152** from top surface **1152***a* to the bottom surface of ceramic substrate **1152** in order to electrically connect the terminals of thermistor **1170** on top surface **1152***a* to their corresponding conductive traces on the bottom surface.

[0041] It will be appreciated that the example embodiments illustrated and discussed above are not exhaustive and that the heater of the present disclosure may include resistive and conductive traces in many different patterns and locations on ceramic substrate **152**, including to resistive traces on one or more of the exterior surfaces (top surface and/or bottom surface) of ceramic substrate **152** and/or an intermediate surface of ceramic substrate **152**, as desired. Other components (e.g., a thermistor) may be positioned on either the top surface or the bottom surface of the heater as desired, including on the same surface as the resistive traces or an opposite surface.

[0042] FIG. **8** shows a cooking vessel **120** suitable for use with heater assembly **140** according to one example embodiment. In the embodiment illustrated, cooking vessel **120** includes an inner shell **125** and an outer shell **130**. An outside surface **125***b* of inner shell **125** forms food receptacle **121** of cooking vessel **120**. Inner shell **125** and outer shell **130** have corresponding side walls **126**, **131** and corresponding bottom walls **127**, **132** separated by a gap **129** to form a dual-wall vessel. In this embodiment, bottom wall **132** of outer shell **130** has a slightly concave outside surface **130***b* that substantially matches domed upper surface **147** of heating plate **145**. The use of a heating plate **145** having a domed upper surface **147** in contact with a concave outside surface **130***b* of the bottom wall **132** of cooking vessel **120** helps reduce bowing of bottom wall **132** of cooking vessel **120** during heating in comparison with a cooking vessel having a fiat bottom surface in contact with a flat top surface of a heating plate or heater. This, in turn, helps upper surface **147** of heating plate **145** maintain consistent contact with outside surface **130***b* of the bottom wall **132** of cooking vessel **120** for heat transfer. Inner shell **125** and outer shell **130** are integrally joined or welded, e.g., at rim **122**, forming a sealed volume between inner and outer shells **125**, **130** that includes gap **129**. In some embodiments, the sealed volume is formed under reduced pressure relative to atmospheric pressure, such as a partial vacuum.

[0043] In the example embodiment illustrated, a heat pipe **134** is provided between inner and outer shells **125**, **130**, including between side walls **126**, **131** and between bottom walls **127**, **132**. In the embodiment shown, corresponding inside surfaces **125***a*, **130***a* of inner and outer shells **125**, **130** are lined with wick structures **135** containing a relatively small amount of working fluid, such as water. The wick structures **135** may be constructed from materials that allow capillary action of the working fluid within the sealed volume as discussed below. In FIGS. **9**A-**9**C, various example wick structures for use with cooking vessel **120** are illustrated. Each of FIGS. **9A-9**C is a cross-sectional view of cooking vessel **120** taken along line **9-9** in FIG. **8**. In the embodiment shown in FIG. **9**A, the wick structure includes sintered or arc sprayed metal **135***a*, such as copper or aluminum, provided on inside surfaces **125***a*, **130***a* of inner and outer shells **125**, **130**. In the embodiment shown in FIG. **9**B, a screen or wire mesh **135***b* is provided on each of the inside surfaces **125***a*, **130***a* of inner and outer shells **125**, **130** to form the wick structure. In the embodiment shown in FIG. **9**C, grooves **135***c* are formed on each of the inside surfaces **125***a*, **130***a* of inner and outer shells **125**, **130** to provide the wick structure. Each groove **135***c* extends substantially vertically along a respective side wall **126**, **131** and may continue substantially horizontally along a respective bottom wall **127**, **132**. While the example embodiments illustrated include a heat pipe **134** that includes one or more wick structures **135** and a working fluid, in other embodiments, heat pipe **134** includes a working fluid (e.g., water) contained between inner and outer shells **125**, **130**, but no wick structure.

[0044] In one embodiment, during use, the working fluid cycles between an evaporation zone **180** near or around the lower region of cooking vessel **120** that is directly heated by heating plate **145** and a condensation zone **190** around the upper region of cooking vessel **120**. In particular, as cooking vessel **120** is heated by heater assembly **140** (e.g., by outside surface **130***b* of bottom wall **132** of outer shell **130** receiving heat from heater assembly **140**) the working fluid within the evaporation zone **180** (e.g., working fluid within the wick structures **135** between bottom walls **127**, **132** of inner and outer shells **125**, **130** and between side walls **126**, **131** of inner and outer shells **125**, **130** in the lower region of cooking vessel **120**) absorbs heat **183** and changes state from liquid to vapor **138**. Driven by pressure and temperature differences between the lower (hotter) region and upper (cooler) region, vapor **138** travels from the evaporation zone **180** to the condensation zone **190** along the gap **129** between wick structures **135**. When vapor **138** arrives at the condensation zone **190**, it condenses back into liquid form releasing latent heat **185** through inner and outer shells **125**, **130** at the upper region of cooking vessel **120**. Condensed liquid **139** at the condensation zone **190** travels back to the evaporation zone **180** via wick structures **135** due to capillary action. As the vaporization and condensation cycle repeats, heat is transferred from locations near the heat source to the rest of the sealed volume of cooking vessel **120** (i.e., from between bottom walls **127**, **132** of inner and outer shells **125**, **130** to between side walls **126**, **131** of inner and outer shells **125**, **130**) resulting in an improved temperature uniformity within cooking vessel **120**.

[0045] The present disclosure provides a ceramic heater having a low thermal mass in comparison with the heaters of conventional cooking devices. In particular, a thick film printed resistive trace on a ceramic substrate provides reduced thermal mass in comparison with conventional wire coil heaters. The use of a thin heating plate, such as forged aluminum, also provides reduced thermal mass in comparison with the cast aluminum bodies of conventional wire coil heaters. The low thermal mass of the ceramic heater of the present disclosure allows the heater, in some embodiments, to heat to an effective temperature for use in a matter of seconds (e.g., less than 5 seconds), significantly faster than conventional wire coil heater cooking devices. The low thermal mass of the ceramic heater of the present disclosure also allows the heater, in some embodiments, to cool to a safe temperature after use in a matter of seconds (e.g., less than 5 seconds), again, significantly faster than conventional wire coil heater cooking devices.

[0046] Further, embodiments of the heater of the cooking device of the present disclosure operate at a more precise and more uniform temperature than conventional cooking devices because of the closed loop temperature control provided by the thermistor in combination with the relatively uniform thick film printed resistive and conductive traces. The low thermal mass of the ceramic heater permits greater energy efficiency in comparison with conventional wire coil heaters. The improved temperature control and temperature uniformity also improve the performance of the cooking device of the present disclosure. In this manner, embodiments of the cooking device of the present disclosure achieve high thermal and energy efficiency and high-end performance comparable to induction heating cooking devices, but at a greatly reduced cost in comparison with conventional induction heating cooking devices.

[0047] The present disclosure further provides a heat pipe cooking vessel for use with the ceramic heater. The heat pipe structure within the cooking vessel provides improved thermal conductivity in comparison with conventional aluminum or copper cooking vessels allowing for a more uniform temperature distribution and effective heat transfer. Coupled with the low thermal mass of the ceramic heater, the heat pipe cooking vessel provides improved temperature uniformity relative to conventional cooking devices.

[0048] While the example embodiment discussed above includes a ceramic heater used in conjunction with a heat pipe cooking vessel, it will be appreciated that the ceramic heater and the cooking vessel of the present disclosure may be used separately from each other in different heating and/or cooking applications. That is, the ceramic heater of the present disclosure may be used with a conventional cooking vessel, and the heat pipe cooking vessel of the present disclosure may be used with conventional heaters.

[0049] The foregoing description illustrates various aspects of the present disclosure. It is not intended to be exhaustive. Rather, it is chosen to illustrate the principles of the present disclosure and its practical application to enable one of ordinary skill in the art to utilize the present disclosure, including its various modifications that naturally follow. All modifications and variations are contemplated within the scope of the present disclosure as determined by the appended claims. Relatively apparent modifications include combining one or more features of various embodiments with features of other embodiments.

1. A cooking device, comprising:

a base having a top surface positioned to contact a cooking vessel configured to hold food during cooking; and

the base includes a heater having a ceramic substrate and an electrically resistive trace on an exterior surface of the ceramic substrate, the heater is positioned to supply heat generated by applying an electric current to the electrically resistive trace to the top surface of the base for heating the cooking vessel to heat food in the cooking vessel.

2. The cooking device of claim **1**, wherein the electrically resistive trace includes an electrical resistor material thick film printed on the exterior surface of the ceramic substrate.

3. The cooking device of claim **1**, wherein the electrically resistive trace is positioned on a top surface of the ceramic substrate that faces upward toward the top surface of the base.

4. The cooking device of claim **1**, wherein the heater includes a thermistor that is positioned on the ceramic substrate and in electrical communication with control circuitry of the heater for providing feedback regarding a temperature of the heater to the control circuitry of the heater.

5. The cooking device of claim **4**, wherein the thermistor is positioned on a bottom surface of the ceramic substrate that faces away from the top surface of the base.

6. The cooking device of claim **1**, wherein the base includes a heating plate that forms the top surface of the base, the heating plate is positioned in contact with the heater to transfer heat from the heater to the top surface of the base for heating the cooking vessel to heat food in the cooking vessel.

7. The cooking device of claim **6**, wherein the heating plate includes a domed top surface for contacting a concave bottom surface of the cooking vessel.

8. The cooking device of claim **1**, wherein the ceramic substrate has a polygonal shape.

9. The cooking device of claim **8**, wherein the ceramic substrate has an octagonal shape.

10. The cooking device of claim **1**, wherein the electrically resistive trace extends in a serpentine pattern across the exterior surface of the ceramic substrate.

11. The cooking device of claim **10**, wherein the serpentine pattern of the electrically resistive trace has a generally circular outer perimeter.

12. A cooking device, comprising:

a housing having a receptacle and a base positioned along a bottom of the receptacle;

a cooking vessel removably positionable within the receptacle for containing food to be cooked, the cooking vessel contacts the base when the cooking vessel is positioned within the receptacle; and

the base includes a heater having a ceramic substrate and an electrical resistor material thick film printed on a surface of the ceramic substrate, the heater is positioned to supply heat generated by applying an electric current to the electrical resistor material to the cooking vessel when the cooking vessel is positioned within the receptacle.

13. The cooking device of claim **12**, wherein the electrical resistor material is positioned on a top surface of the ceramic substrate that faces upward toward the receptacle.

14. The cooking device of claim **12**, wherein the heater includes a thermistor that is positioned on the ceramic substrate and in electrical communication with control circuitry of the heater for providing feedback regarding a temperature of the heater to the control circuitry of the heater.

15. The cooking device of claim **14**, wherein the thermistor is positioned on a bottom surface of the ceramic substrate that faces away from the receptacle.

16. The cooking device of claim **12**, wherein the base includes a heating plate that forms a top surface of the base that contacts the cooking vessel when the cooking vessel is positioned within the receptacle, the heating plate is positioned in contact with the heater to transfer heat from the heater to the cooking vessel when the cooking vessel is positioned within the receptacle.

17. The cooking device of claim **16**, wherein the heating plate includes a domed top surface and the cooking vessel includes a concave bottom surface that contacts the domed top surface of the heating plate when the cooking vessel is positioned within the receptacle.

18. The cooking device of claim **12**, wherein the ceramic substrate has a polygonal shape.

19. The cooking device of claim **18**, wherein the ceramic substrate has an octagonal shape.

20. The cooking device of claim **12**, wherein the electrical resistor material extends in a serpentine pattern across the surface of the ceramic substrate.

21. The cooking device of claim **20**, wherein the serpentine pattern of the electrical resistor material has a generally circular outer perimeter.

22. A heater for use with a cooking device, comprising:

a ceramic substrate;

an electrically resistive trace thick film printed on an exterior face of the ceramic substrate, the electrically resistive trace extends in a serpentine pattern across the exterior face of the ceramic substrate from a first end of the electrically resistive trace to a second end of the electrically resistive trace, the serpentine pattern of the electrically resistive trace has a generally circular outer perimeter; and

a first electrically conductive trace electrically connected to the first end of the electrically resistive trace and a second electrically conductive trace electrically connected to the second end of the electrically resistive trace, the first and second electrically conductive traces form respective first and second terminals providing respective first and second electrical connections for completing a circuit formed by the first and second electrically conductive traces and the electrically resistive trace.

23. The heater of claim **22**, further comprising one or more glass layers on the exterior face of the ceramic substrate that cover the electrically resistive trace electrically insulating the electrically resistive trace.

24. The heater of claim **22**, further comprising a thermistor positioned on a second exterior face of the ceramic substrate that is opposite the exterior face of the ceramic substrate on which the electrically resistive trace is positioned for providing feedback regarding a temperature of the heater to control circuitry of the heater.

25. The heater of claim **22**, wherein the ceramic substrate has a polygonal shape.

26. The heater of claim **25**, wherein the ceramic substrate has an octagonal shape.

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