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(54) **SMART AND SAFE COOKWARE AND COOKING SYSTEM**

(57) The present invention discloses a cooking method on an induction cooktop (2) with improved cooking temperature control and safety, the cooking system (1), and smart cookware (10). The smart cookware (10) (which can be any type of pot, bowl or pan) has an integrated temperature sensor for precise temperature regulation. Further, the cookware (10) comprises its heating layer made of ferromagnetic material having Curie-point selected for safety to limit the maximum heating temperature by the induction, to prevent catching fire due to overheating and to protect the cookware (10) from overheating. The cooking method comprises additional steps for adjusting heating power according to the properties of the said ferromagnetic material with Curie-point. The cooking system comprises at least smart cooktop (2) and smart cookware (10) altogether implementing said method with improved cooking temperature control and safety.

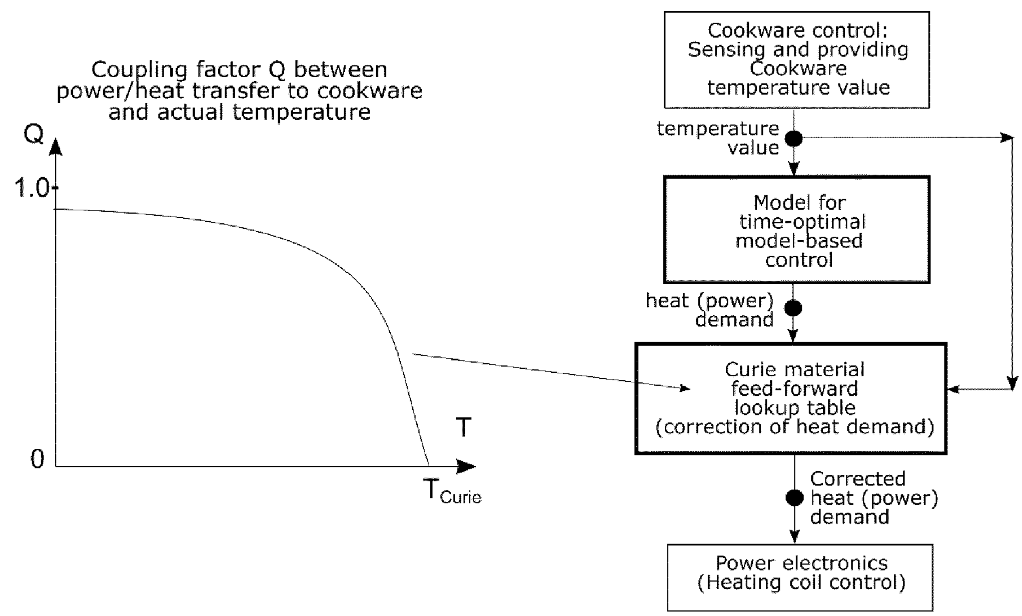

FIG. 3

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Description

TECHNICAL FIELD

[0001] The present invention relates to cookware for use on an induction cooktop that has improved temperature control and also safety. Specifically, the invention is directed to cookware with an integrated temperature sensor and induction heating bottom plain or layer made of Curie-point material for smart and safe cooking.

BACKGROUND ART

[0002] Temperature control in smart cookware is traditionally achieved by placing a temperature sensor in the pan or pot. The sensor and its electronics in the cookware are arranged to read the temperature and send its actual value to some external devices like an induction cooktop and/or a mobile smart device. The induction cooktop will utilize an algorithm to determine whether to supply or how much power to supply to the induction heating coil to achieve the desired temperature. This is also used to provide safety from overheating and burning the food. Traditionally, the cookware with a temperature sensor and other smart features employs control electronics arranged in the handle of cookware.

[0003] Smart cookware for induction cooktops usually is made with the ferromagnetic bottom layer which is heated by the cooker induction coils by inducing Eddy currents in this ferromagnetic layer, and also with the implemented temperature sensor in this ferromagnetic bottom layer, as per example in European patent applications EP1591049A1/EP2364622A3.

[0004] A sample system setup of a smart cooking system employing controlled cooktop and smart cookware with temperature sensor is disclosed in EP3489583A1 / DE102017220815B4.

[0005] The conventional cookware for induction cooktops may be designed with a special heating layer made from soft-magnetic material with Curie-point which loses its magnetics properties on a certain temperature (so-called Curie point), and this Curie-point employed to limit the maximum heating temperature of the cookware by the induction cooktop. The limiting value depends on the soft-magnetic alloy Curie point and it can be different for different types of soft-magnetic alloys. The prior art patent disclosing cookware with such soft-magnetic bottom layer is FR2689748A1 where "temperature limitation of an induction heated body, consisting (partially) of a ferromagnetic alloy, is achieved by the use of an alloy having a Curie point corresponding to the desired limit temperature. Also claimed are an induction heatable body and a cooking vessel made (partially) of the ferromagnetic alloy. Pref. the alloy has a Curie point of 230-350 deg. C and is selected from 36% Ni/64% Fe, 9% Co/18% Ni/5% Mo/68% Fe and 80% Ni/5% Mo/15% Fe. ADVANTAGE - The temperature limitation prevents deterioration of the heated body (esp. cooking vessel) and any coatings (esp. a non-stick PTFE coating) and provides the user with a reduced risk of burns during vessel handling".

[0006] Another patent US7575712B discloses that different types of soft-magnetic metal alloys are different by their Curie-point temperature, "the invention concerns a ferromagnetic alloy whereof the chemical composition comprises, in wt. %: 32.5%≦Ni≦72.5%; 5%≦Cr≦18%; 0.01%≦Mn≦4%; C≦1%; optionally one or more elements selected among Mo, V, Co, Cu, Si, W, Nb and Al, the total contents of said elements being not more than 10%, the remainder being iron and impurities resulting from preparation, the chemical composition further satisfying the following relationships: Cr-1.1Ni+23.25≦0%; 45Cr+11Ni≦1360; Ni+3Cr≧60% if Ni≧37.5; Cr≧7.5 if Ni≦37.5. The invention also concerns the use of said alloy for making heating elements for induction heated cooking appliances".

[0007] There are problems several observed in the prior art inventions. The smart cookware (a pan, pot or bowl) and cooktop systems comprising temperature sensors and temperature regulation by digital means (as in EP1591049A1/EP2364622A3) provide temperature regulation and also some safety from burning the food. However, this safety level is insufficient because there may be situations when digital temperature control fails in the application of the control module, or due to other system failures. Also, if such smart cookware having a temperature sensor would be used on a conventional induction cooktop, however, the temperature regulation will not work and, therefore, food and also the cookware can be easily overheated or even burned. The problems related with the non-smart cookware (e.g. US7575712B) having soft-metal alloy layers is that they have a single Curie point which is applicable either for safety limit (e. g. 280C) or optimal cooking temperature for some particular types of foods (e.g. 230C for optimal sear of meat). This implies that such cookware is designed either for safety but not optimal cooking temperatures or is limited to a particular type of food and only also is limited by the cooking mode.

[0008] Therefore, the present invention is a solution for smart and safe cooking kinds of foods according to different recipes by induction cooktops.

BRIEF DESCRIPTION

[0009] The present invention provides the cookware and its use in the system on an induction cooktop with improves cooking temperature control and also provides additional safety.

[0010] The invention is the smart cookware (pot, bowl, pan) having an integrated temperature sensor for precise temperature regulation and also the bottom heating layer made of soft-magnetic material having its Curie point selected for safety purpose to limit the maximum heating temperature by the induction, to prevent catching fire due to overheating and to protect the smart cookware from overheating.

[0011] The cookware is primarily invented to use smart cooking systems comprising smart cookware, smartly regulated induction cooktops and external smart devices, altogether controlling the cooking process. In the normal operation mode, the cooking temperature is regulated using the temperature sensor in the cookware, digital control module in the cooktop, and also by the application in a smart external device (e.g., smartphone). Furthermore, the system remains safe even if the digital control of the temperature failed, so-called "fail-safe" feature. This is because the bottom layer of the cookware (having soft-magnetic metal with Curie point) limits the maximum heating temperature, for example, if the cooktop with the failed control starts to heat the maximum power.

[0012] Moreover, such cookware can be used safely also on conventional induction cooktops, without danger and risk of fire (e.g. due to ignition temperature of cooking oil 340°C-370°C) and overheating the cookware itself. The cooking temperature may be regulated manually, however, the safety level is still ensured by limiting temperature on the Curie point.

BRIEF DESCRIPTION OF DRAWINGS

[0013] To understand the smart cookware with temperature regulation and "fail-safe" feature, and appreciate its practical applications, the following pictures are provided and referenced hereafter. Figures are given as examples only and in no way should limit the scope of the invention.

FIG. 1 depicts a smart and safe cooking system comprising smart and safe cookware with a thermal sensor and bottom layer comprising a material with Curie point for limiting maximal temperature and ensuring safety from overheating and catching fire.

FIG. 2 depicts a preferred embodiment of the smart and safe cookware comprising three-layer-sandwich in the bottom: the bowl (upper layer) for containing the food; the aluminum heat distribution and sensor layer - middle and thickest layer comprising the hole and the thermal sensor; the protector-bottom-layer with magnetic properties for heating by induction and Curie-point for protection.

FIG. 3 depicts dependency or coupling factor Q of heating temperature T and the heat accepted by Curie-point material, and the heat (power) regulation with the correction of heating power supply according to the lookup table for this dependency.

FIG. 4 depicts the cookware on a conventional induction hob with manual control which is safe to use also without digital thermal regulation.

DRAWINGS - Reference Numerals

[0014]

1 system for smart and safe cooking;
2 cooktop comprising means of digital control and communication means with external devices and smart cookware;
3 cooktop heater coil;
4 cooktop heater coil driver;
5 cooktop heater coil manual control;
6 module for digital control in the cooktop;
7 means of wireless communication of the cooktop with external devices and cookware;
8 thermal sensor protecting the induction coil from its own overheating;
9 handle of the cookware;
10 smart cookware comprising a thermal sensor and control electronics;
11 the bottom plain (single layer) of the smart cookware comprising a ther-mal sensor inside and made of Curie-point material;
12 the thermal sensor inside the bottom plain or layer of the cookware;
13 a hole for the thermal sensor is drilled along the bottom plain or layer of the cookware;
14 control electronics of the cookware;
15 temperature indications/values to be transmitted from the cookware to the cooktop;
16 The cookware bottom plain comprising at least three different layers: the inner layer for containing/cooking food, the middle layer for heat distribution and a thermal sensor, the outer ferromagnetic layer for induction heating with a safety Curie point;
17 The inner layer of the cookware bottom for containing and cooking food;
18 Middle layer for heat distribution and thermal sensor;
19 The outer layer of the cookware bottom plain for induction heating with a safety Curie point.

DETAILED DESCRIPTION

[0015] The present description discloses a smart and safe cooking system 1 and also smart and safe cookware 10 used with said cooking system 1 and also with any conventional induction cooktops.

[0016] **Cooking system.** The cooking system 1 is depicted in FIG. 1. It comprises at least a smart cooktop 2 having not only manual control and conventional safety means such as induction coil overheating sensor 8 but also implemented a digital control module 3 for smart control, wireless communication means 4 and other digital means for safety and pre-programmed cooking such as control applications in the digital control module 3 or external smart devices, for example, smartphones or tablets. The cooktop 2 can accept cooking temperature indications 15 from a thermal sensor 12 implemented in the cookware 10 and regulate the power of heating by the induction coil 3 according to some pre-programmed modes or cooking recipes.

[0017] The system 1 further comprises smart cookware 10 comprising inside at least a thermal sensor 8 which can provide cooking temperature indications/values to the cooktop digital control module 3 or external smart devices such as smartphones or tablets.

[0018] In general, similar cooking systems comprising cookware with sensors, a cooktop with digital control and external smart device/application are known in prior art patent applications. Still, there may be discovered essential drawbacks which are strongly advised to be solved. The digital control by external devices and cooktop modules may provide multiple measures for safety, however, digital means may fail in some conditions, for example in case of failure of the thermal sensor, stopping of the control application in the control module, etc.

[0019] The "fail-safe" feature is never too big in any kitchen, including a smart kitchen.

[0020] The idea of the present invention is to employ into the heated bottom plain 11 of the cookware 10 certain magnetic materials (alloys) having specific Curie-point temperature. Such alloys are characterized in that below their Curie-point temperature they are ferromagnetic and above the Curie-point they become paramagnetic, therefore, they are no more heated by the cooktop induction coil 3. Employing this feature in cookware and kitchen utensils is known for various purposes, like limiting heating and temperature for safety, or for optimal cooking temperature for different foods and cooking modes, e. g. in patent EP2116160B1 by Electrolux, or for other purposes. However, the Curie-point temperature of a particular material/alloy is fixed and, therefore, it helps the utensil be optimal for a narrow mode of cooking or purpose. For example, the limiting Curie-point temperature of 230°C is good for cooking meat or fish but it may not optimal for cooking an omelet or roasting vegetables, meanwhile, for fire safety, it is too reduced.

[0021] It must be noted that magnetic materials with different Curie-point temperatures and the production of such metals are also an extensive field of research. Not all properties of magnetic materials are satisfactory for kitchen applications, for example, a metal or alloy having a suitable Curie-point for limiting the temperature, however, be too much susceptible to corrosion or otherwise not suitable for the application.

[0022] In the most preferred embodiment of the system 1, there is a utility of employing not e.g. 230°C but a higher 260°C or even 280°C Curie-point material, i.e., higher than normally used in the cookware with Curie-material. The heating and digital control of the cooktop power is not as much negatively affected as if with 230°C Curie material. First, it allows to heat the utensil up to 250°C. Furthermore, the heating nearly Curie point will not slow too much, e.g. to around 200°C as if a 230°C Curie-point material was used. Thus, the higher Curie-point temperature and material make the cooking system more precise and faster reacting in a full range of required cooking temperatures, i.e., up to 250°C. On the other hand, the Curie-point temperature has to be selected for maximum safety, at most, to such temperature that cooking oil will not catch fire. The optimal range of Curie-point for safety is considered to be in the range from 250°C to 340°C, and the most preferred range is 260- 280°C. Correspondingly, the magnetic material with suitable Curie-point temperature and other properties for using it in cooking utensils has to be employed in the cookware 10 and system 1.

[0023] Another preferred embodiment of the system 1 comprises additional functions that can be implemented as options for a better performance of smart cooking system 1. In the control loop of "heated cookware 10 - thermal sensor 12 - cooktop control module 6 - heating coil 3 power" there can be added a feed-forward model of the Curie material of the utensil 10 (FIG. 3). This is helpful with a single kind of pot and/or material, i.e. adding a feed-forward model as a lookup table for a particular Curie-point material (by coupling factor Q of heat/power transfer from cooktop to cookware versus the heating temperature T) as depicted in FIG. 3. This is also helpful if several cooking vessels 10 of different types and with different Curie-point materials (e.g. 260 °C and 280°C) are used with the same system 1. In this embodiment, the temperature is measured in the pot 10 (by the thermal sensor 12 and control electronics 14). This is also helpful for a cooktops having multiple zones with differently sized heating coils, heating power and capabilities.

[0024] Then temperature values/indications are used to build up and store the feed-forward model or the lookup table as the "coupling factor" of the Curie material at this temperature as measured and stored and are a function of the induction system and this particular cookware). This model further is supplied into the control loop (so-called feed-forward correction) in a way to better estimate the power (heat) delivered to the cookware in the next time interval of the control loop (e.g., during the 1-second interval).

[0025] Such apriori knowledge about the "temperature/magnetic properties" of the Curie material of the cookware 10 can be employed as an extension to a set of predictive regulation models used for cooking control and working in aforementioned control loop "heated cookware 10 - thermal sensor 12 - cooktop control module 6 - heating coil 3 power". The other models implemented in the model-based control of the present system are:

1. The specific heat capacity of the empty cookware 10;
2. The inherent delay in the heat propagation in the bottom of the pot and temperature measurement by the sensor 12 in the cookware 10.

[0026] These parameter-models are preferably stored in the control module 14 of the cookware 10 as the specific characteristic of the particular cookware 10 type and can be transferred to the cooktop digital control module 6 when requested by the external smart device or the cooktop control module 6 itself.

[0027] The heating process with the model-based prediction is explained as follows: if the cookware 10 is shorty heated by e.g. a 2kW one-second power pulse, the cookware temperature measured by the thermal sensor 12 subsequently rises during the following 5-10 seconds, after turning off the heat source 3. The predictive "time-optimal model-based" control allows always to use the maximum available/possible power (and correspondingly, heat) that can be used to reach quickly the desired temperature of the cooking bowl 10, without risk of temperature overshoot. To keep this optimal performance and have the additional second level safety function of the Curie-point material the system 1 has:

1. To have a high as possible Curie-point temperature in the cookware 10 for not to slow down the heating. Normally, the heating begins to slow down as the temperature approaches the Curie-point.
2. To be included in the model-based predictive control of the heating and the cooking temperature.

[0028] The above two control implementation conditions provide the solution to the problem of not adversely affecting the control loop "heated cookware 10 - thermal sensor 12 - cooktop control module 6 - heating coil 3 power" because of the Curie-point material used instead of a conventional ferromagnetic material. Not mitigating this phenomenon will cause the whole cooking system 1 to be slower and/or less stable in terms of regulation theory, i.e. more oscillating with the heating temperature.

[0029] **Cookware.** In general, such principles of smart and safe cookware 10 can be applied to any type and shape vessels used on the induction cooktop: pots, bowls, pans, etc.

[0030] One preferred embodiment of smart and safe cookware 10 comprises a bottom of a single layer 11 (FIG. 1) made from a ferromagnetic material with Curie-point for heating safety (250 °C to 340°C), and the bottom layer 11 has a drilled hole 13 from the side of the bottom to the middle of the vessel 10, and the thermal sensor 12 with a wire is inserted into the hole 13. The other end of the sensor wire 12 is connected to the cookware control electronics 14 which preferably is implemented in the handle 9 or in other attachment of the cookware where the electronics 14 is least susceptible to the heat from by the ferromagnetic layer 11.

[0031] Another preferred embodiment of the cookware (FIG. 2) comprises a sandwiched bottom plain 16 with at least three layers of different metals:

- The bowl for containing the food (or upper layer) 17 made of e.g. stainless steel;
- The heat distribution layer 18 having a hole 13 and the thermal sensor 12 (the middle and thickest layer, preferably 4 mm of thickness made of e.g. aluminum, copper);
- The bottom layer 19 - the "protector" layer made of a soft-magnetic layer being heated by the induction and having Curie-point to limit the maximal temperature;

[0032] The parameter-models are preferably stored in the cookware control module 14 as a specific characteristic of the particular cookware type. It can be transferred on demand to the cooktop control module 6 when requested by an external smart device or the cooktop control module 6 itself.

[0033] It must be emphasized that said cookware 10 can be efficiently used also with conventional induction cooktops having no smart digital control for regulating power (FIG. 4). An important feature and effect of present cookware 10 are that with the thermal sensor 12 and control electronics 14 implemented inside, it can be safely used without smart regulation of coil power and heat, and without the risk that the thermal sensor 12 and electronics 14 was overheated. This is an important feature that Curie-point material does not only prevent from food burning with a smoke, a fire caused by oil ignition but also protects from overheating the cookware sensors, electronics, and other components, for example, PTFE non-sticking layers.

Claims

1. A method of smart and safe cooking by an inductance cooktop, the method comprising at least steps of

- reading an instant temperature value from the temperature sensor implemented in cookware;
- estimating power to be provided to the heating coil of the inductance cooktop for a next finite time interval;
- providing the power to the heating coil of the inductance cooktop for the next finite time interval,

characterized in that

- the heated bottom plain of the cookware comprises at least one ferromagnetic layer with Curie-point;
- the method further comprises
  - a stage of building a data model of Curie-point material and heating power coupling for a type of cookware;
  - a step of feed-forward correction of the cookware heating power according to said data model of coupling;

2. A cooking system (1), comprising at least:

- cookware (10) for an induction cooktop, the cookware comprising a temperature sensor (12) in the bottom plain or at least its layer (11) and control electronics (14) arranged to sense the

heating temperature and transfer the temperature values (15) to external control means for regulating the cooktop power;
- an induction cooktop (2) having at least one or more different heating zones and means for heating power regulation (6) according to temperature values (15) received from the temperature sensor (12) of the cookware (10);
characterized in that
- said bottom plain or layer (11) of the cookware (10) comprises at least one ferromagnetic layer with Curie-point;
- the cooking system (1) comprises a data model of Curie-point material and heating power coupling, the data model arranged for feed-foorward correction of the cookware heating power.

3. The cooking system (1) according to claim 2, **characterized in that** the thermal sensor (12) in the cookware (10) and heating power regulation (6) in the cooktop (2) are arranged to cook different foods and recipes, and the Curie-point is employed for the maximum safety of the heating temperature and cooktop heating power.

4. The cooking system (1) according to claims 2 to 3, **characterized in that** the data model of Curie-point material and heating power coupling data model is arranged during the test of a cookware (10) type and subsequently stored in the cooktop control module (6) for feed-foorward correction of the cooktop heating power adjusted for said cookware (10) type.

5. The cooking system (1) according to claims 2 to 4, **characterized in that** further, it comprises an external smart device such as smartphone or tablet with the application to control the system (1) and smart cooking with the system.

6. Smart cookware (10) for use on induction cooktops, comprising at least:

- a bottom plain or layer (11) for heating the cookware (10) by an induction cooktop;
- a temperature sensor (12) in a heated bottom plain (11) and the control electronics (14), arranged to sense the temperature and provide its values to digital control means (6) for regulating the cooktop (2) power;
characterized in that
- a bottom layer (11) for heating the cookware by an induction cooktop is made of ferromagnetic material having Curie-point for maximum heating safety.

7. The cookware (10) according to claim 6, **characterized in that** the bottom plain (16) of the cookware (10) comprises at least three layers such as:

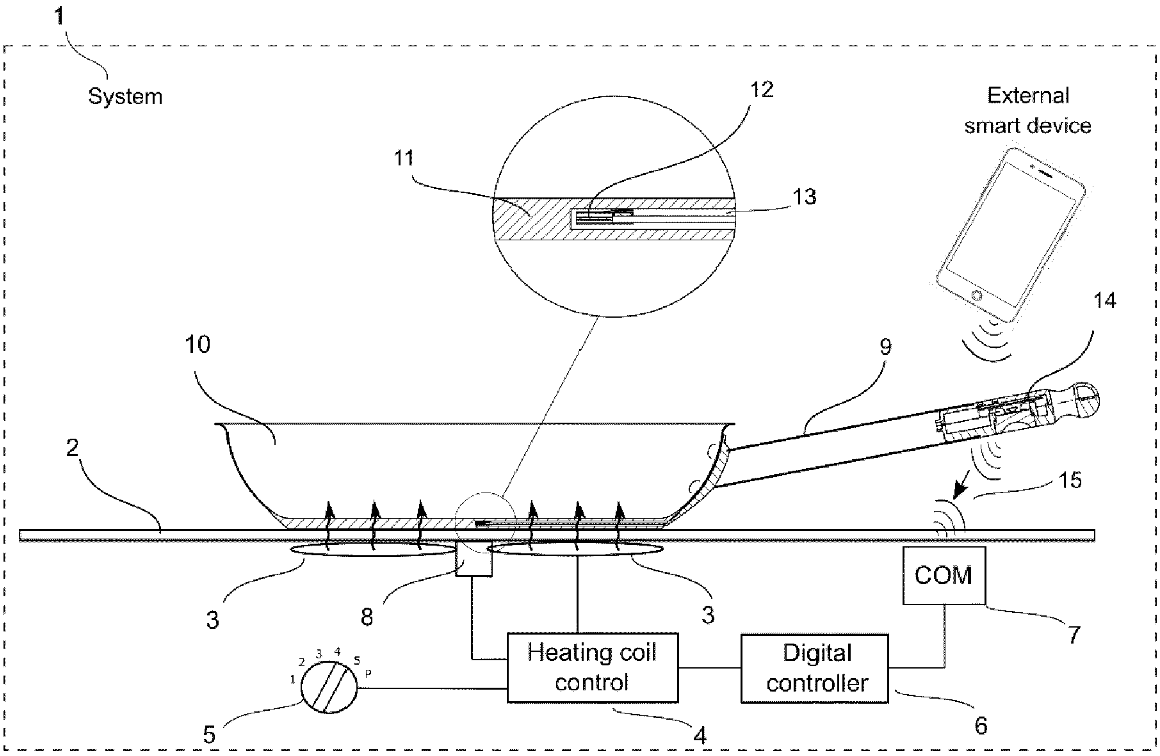
- upper layer (17) or bowl for containing the food to be cooked,
- middle or heat distribution layer (18) further comprising the hole (13) for a sensor wire (12) and thermal sensor wire (12) inserted into the hole (13).
- lower heating and protecting layer (19) having magnetic properties for induction heating and Curie-point for protecting from overheating.

8. The cookware (10) according to claims 6 to 7, **characterized in that** Curie point of the heating and protecting alloy material of the cookware (10) is selected from the range of 250°C to 340°C.

9. The cookware (10) according to claims 6 to 8, **characterized in that** it further comprises the data model of Curie-point material and heating power coupling to be stored in the control electronics (14) of the cookware.

10. The cookware (10) according to claims 6 to 9, **characterized in that** it is used within the cooking system according to claim 1.

11. The cookware (10) according to claims 6 to 10, **characterized in that** it is usable with conventional induction cooktops as conventional induction cookware.


1
System
12
External
smart device
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1 2 3 4 5 P
Heating coil
control
Digital
controller
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FIG. 1

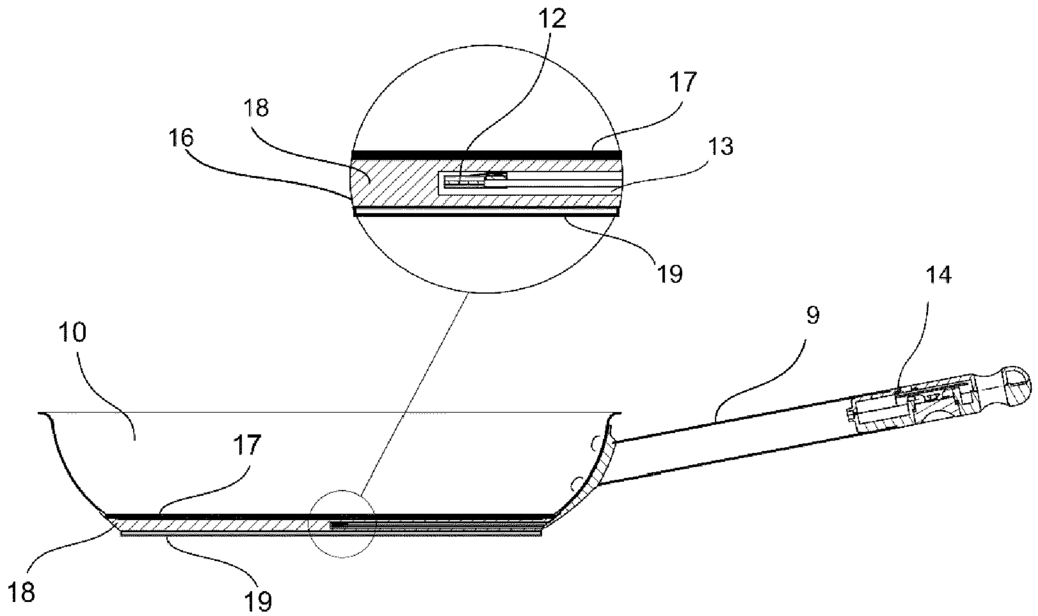
12
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FIG. 2.

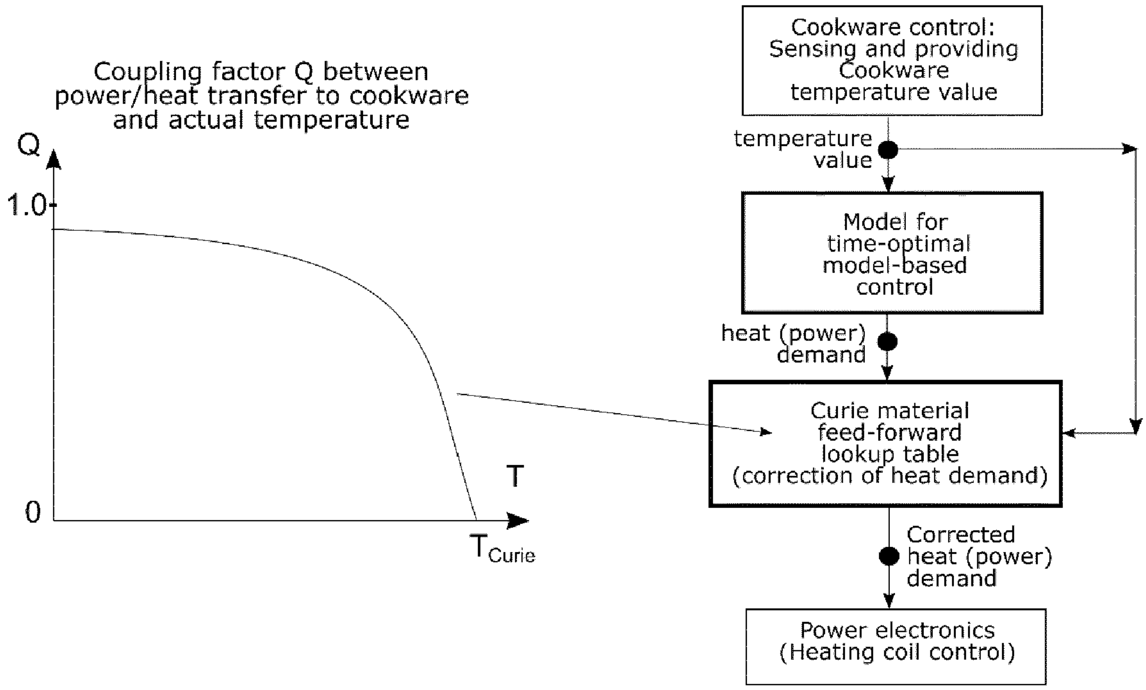
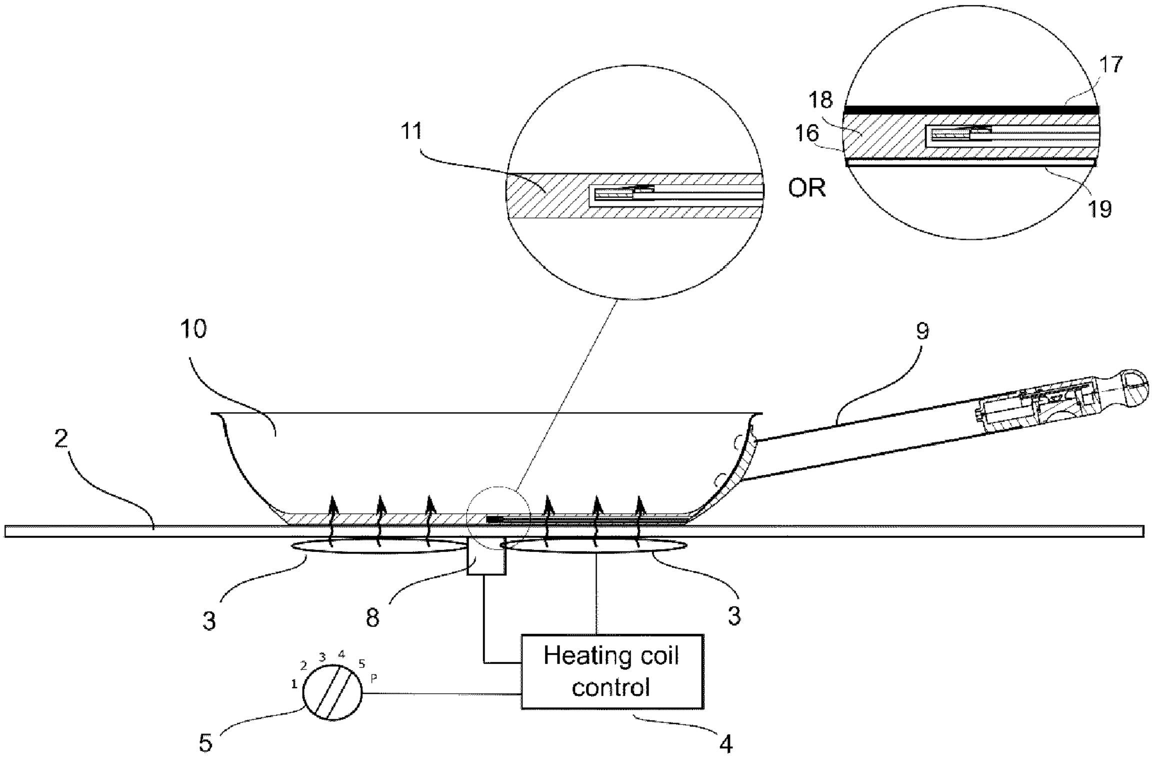

Coupling factor Q between power/heat transfer to cookware and actual temperature
Q
1.0
0
T
T_{Curie}
Cookware control: Sensing and providing Cookware temperature value
temperature value
Model for time-optimal model-based control
heat (power) demand
Curie material feed-forward lookup table (correction of heat demand)
Corrected heat (power) demand
Power electronics (Heating coil control)

FIG. 3


11
OR
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Heating coil control
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FIG. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 19 20 9679

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TECHNICAL FIELDS SEARCHED (IPC)

H05B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	19 May 2020	Garcia, Jesus

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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