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-1-

METHOD AND APPARATUS FOR FIRING CERAMIC COMPACT

BACKGROUND OF THE INVENTION

1. Field of the Invention

5 The present invention relates to a method and apparatus for firing ceramic compacts used in electronic parts.

2. Description of the Related Art

10 In mass production of ceramic electronic parts and the like, green ceramic compacts are generally fired using a batch firing apparatus 1a such as set forth in Figure 4. Figure 4 is a cross-sectional view of the batch firing apparatus 1a, provided with a furnace 2a having a firing space 3a for green ceramic compacts therein. The furnace 2a comprises a furnace wall 4a including a ceiling and a side wall, a stage 10a as a hearth, a heater 5a provided along the furnace wall 4a in the furnace 2a, a
15 gas inlet pipe 6a and a gas outlet pipe 7a provided in the ceiling of the furnace. Further, a lift 9a is provided under the stage 10a for raising and lowering the stage 10a. The furnace 2a is supported by legs 11a.

20 In the firing process of green ceramic compacts using the firing apparatus 1a, a casing 8a including many green ceramic compacts is put on the stage 10a and placed in the firing space 3a in the furnace 2a. The firing space 3a is heated with the heater 5a to fire the green ceramic compacts while supplying a given gas through the gas inlet and outlet pipes 6a and 7a. After the furnace 2a is cooled to a predetermined temperature, the stage is lowered with the lift 9a to remove the fired ceramic compacts. ✓

25 Since cooling in the furnace 2a of the ceramic compacts, which is fired at a high temperature, to room temperature requires a long time period, it is proposed in order to achieve faster cooling that the stage 10a be lowered with the lift 9a while the fired ceramic compacts have a high temperature be cooled by direct exposure to the open air.

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REPLACED SHEETS SG

- ☒ Description : paged1 to paged6
- ☒ Claim(s) : paged7 to paged9
- ☒ Drawing(s) : paged10 to paged4
- ☒ Abstract : paged10 to paged10

-3-

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1A is a longitudinal sectional view of an apparatus for firing a ceramic compact in accordance with an embodiment of the present invention, and Figure 1B is a horizontal sectional view taken from line A-A of Figure 1A;

5 Figure 2 is a longitudinal sectional view for illustrating the cooling step of the fired ceramic compact in the apparatus set forth in Figure 1;

Figure 3 is a longitudinal sectional view for illustrating the step for removing the fired ceramic compact from the apparatus set forth in Figure 1; and

10 Figure 4 is a longitudinal sectional view of a prior art apparatus for firing a ceramic compact.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will now be illustrated with reference to the embodiments set forth in the drawings.

15 Figure 1A is a longitudinal sectional view of a batch firing apparatus 1 as an embodiment in accordance with the present invention, and Figure 1B is a horizontal sectional view taken from line A-A of Figure 1B. A heater 5 set forth in Figure 1A is omitted in Figure 1B.

20 The firing apparatus 1 includes a furnace 2 and a firing tube 14 which is provided on the ceiling of the furnace 2 and has a firing space 3 for firing a ceramic compact. The furnace includes a furnace wall 4 including a ceiling and a side wall, a hearth comprising a first stage 10 and a second stage 12, a heater 5 provided in the furnace 4 along the inner firing tube 14, a gas inlet pipe 6 and a gas outlet pipe 7. The first stage 10 is located in the center of the furnace 2 and the second stage 12 is a
25 ring tightly provided along the periphery of the first stage 10 without openings to seal in the heat during a firing. The first and second stages 10 and 12 move independently from each other.

30 The gas inlet and outlet pipes 6 and 7 are provided in the ceiling of the firing tube 14. The composition of the gas used depends on what characteristics are desired in the fired ceramic compacts. The firing tube 14 is provided in the furnace 2 so as

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-4-

to have a given space 13 between the furnace wall 4 and the side wall of the firing tube 14. The top end of the firing tube 14 is tightly fixed to the ceiling of the furnace 2 by a sealing means. A casing 8 containing a green ceramic compact is loaded on the first stage 10 and is enclosed by the bottom end of the firing tube 14 and the first stage 10 so as to not form a gap between them. The firing tube 14 is formed from a highly heat-conductive material, for example, alumina and silicon carbide. Silicon carbide is preferably used due to its high heat conductivity and high mechanical strength. The first and second stages 10 and 12 of the hearth are provided with lifts 9 and 15 so that the first and second stages 10 and 12 can rise and fall independently of each other. The furnace 2 is supported by legs 11.

Next, a method for firing a green ceramic compact using the apparatus 1 set forth above will be illustrated with reference to Figures 1 and 2.

The casing 8 containing many green ceramic compacts is loaded on the first stage 10 and placed in the firing tube 14 in the furnace 2 by means of the lift 9. The casing 8 is thereby enclosed in the firing space 3 in the firing tube 14. The second stage 12 is also raised by means of the lift 15 so as to close the furnace 2. Then, the heater 5 is energized to heat the firing space 3, and a given gas is fed through the gas inlet and outlet pipes 6 and 7 to fire the green ceramic compacts.

After firing, the second stage 12 is lowered along the X direction set forth in Figure 2 by means of the lift 15 while still enclosing the firing tube 14. The space 13 between the furnace wall 4 and the firing tube 14 is exposed to open air by an opening formed by such movement of the second stage 12 and thus the firing tube 14 is directly exposed to open air. Thus, the fired ceramic compacts, as well as the firing tube 14, are cooled by open air introduced through the opening. In order to shorten the cooling time, cool air may be fed passed the outside of the firing tube 14 with a fan. The fired ceramic compacts are cooled to around room temperature in such a manner.

Then, the first stage 10 is lowered along the X direction set forth in Figure 3 by means of the lift 9, the casing 8 containing the fired ceramic compacts is unloaded from the first stage 10, and the fired ceramic compacts are removed from the casing 8.



-5-

In the method for firing green ceramic compacts, the firing space atmosphere is considerably homogeneous even when open air is introduced in the furnace 2 to rapidly cool the fired ceramic compacts. Thus, electronic parts made of such ceramic compacts exhibit stable and excellent electric characteristics. The firing space 3 in the firing tube 14 may be enclosed to an extent that the atmosphere in the firing space 3 is not disturbed by open air introduction in the furnace 2.

The firing method in accordance with the present invention will be explained in more detail with reference to a monolithic ceramic capacitor of 100 nF capacitance having a length of 1.6 mm, a width of 0.8 mm and a thickness of 0.8 mm. Using the firing apparatus 1 set forth above having a firing tube 14 made of silicon carbide, an aluminum casing containing many green ceramic compacts was loaded onto the first stage 10. The green ceramic compacts were fired in the firing tube 14 at a maximum firing temperature of 1,300 °C, and then the inside of the furnace 2 was cooled as is. Then, the second stage was lowered to introduce open air into the furnace 2. The fired ceramic compacts were, thereby, cooled from 1,000 °C to room temperature at a cooling rate of approximately 10 °C/min. The first stage 10 was lowered, the casing 8 was unloaded from the first stage 10, and the fired ceramic compacts were removed from the casing 8. Monolithic ceramic capacitors were obtained in such a manner.

For comparison, green ceramic compacts were fired as in set forth above with the prior art apparatus 1a set forth in Figure 4, the stage 10a was lowered at a high temperature of 1,000 °C to directly expose the fired ceramic compacts to open air, and the fired ceramic compacts were cooled at a cooling rate of 10 °C/min. Prior art monolithic ceramic capacitors were obtained in such a manner.

Each 100 of the monolithic ceramic capacitors obtained by the methods in accordance with the present invention and based on the prior art were subjected to evaluation of change in electrostatic capacitance. As a result, it was found that the monolithic ceramic capacitors obtained from the prior art method have a high change variance (CV) value in electrostatic capacitance of 13.8%, whereas the monolithic ceramic capacitors obtained from the method in accordance with the present invention have a low change variance (CV) value of 4.9%.

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-6-

Accordingly, the atmosphere of the firing space 3 in the firing tube ~~10~~¹⁴ can be stably and rapidly cooled without disturbance by the open air. ✓

The firing apparatus 1 in accordance with the present invention is not limited to the embodiments set forth above and thus can be modified within the scope of the present invention. For example, although the stage 12 is vertically movable in the
5 embodiments set forth above, a horizontally movable stage may also be used.

The shapes of the furnace and the firing space are not limited to being cylindrical as shown in Figure 1, and other shapes such as a prism or other rectilinear shapes may be employed. The shape of the firing tube 14 is also not limited to a
10 cylinder, and may be, for example, prismatic or other rectilinear shape. Moreover, the first stage 10 and the second stage 12 are not limited to being circular and a circular ring, and may be, for example, rectangular and a rectangular ring, respectively. The second stage 12 may have an appropriate shape independent of the shape of the first stage 10 as long as the second stage 12 is provided so as to tightly
15 close the casing 8.

Although the casing 8 loaded on the first stage 10 is made of alumina in the embodiments set forth above, other materials such as zirconia may be also used.

Further, the method and apparatus of the present invention are applicable to any ceramic electronic parts formed by firing green ceramic compacts other than
20 monolithic ceramic capacitors.

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-7-

WHAT IS CLAIMED IS:

1. A method for firing a green ceramic compact comprising the steps of:
placing a casing containing a green ceramic compact into a firing tube
made of a highly heat-conductive material so as to substantially enclose said casing;
5 firing said green ceramic compact in a furnace;
cooling the fired ceramic compact by directly exposing the outer
surface of said firing tube to open air; and
removing said casing from said firing tube.
- 10 2. A method in accordance with claim 1, further comprising the step of
providing said firing tube in said furnace.
3. A method in accordance with claim 1, wherein said placing step
includes the steps of placing said casing containing a green ceramic compact on a first
15 movable stage and moving said first stage into contact with said firing tube so as to
substantially enclose said casing.
4. A method in accordance with claim 1, wherein said firing step includes
the step of moving a second stage into contact with walls of said furnace so as to
20 substantially close said casing to open air.
5. A method in accordance with claim 4, wherein said cooling step further
includes moving said second stage out of contact with said walls of said furnace to
directly expose the outer surface of said firing tube to open air.
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6. A method in accordance with claim 1, wherein said removing step
further includes the steps of moving a first movable stage out of contact with said
firing tube and removing said casing from said first stage.

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-8-

7. A method in accordance with claim 3, wherein said removing step further includes the steps of moving said first stage out of contact with said firing tube and removing said casing from said first stage.

- 5 8. A firing apparatus for firing a green ceramic compact, comprising:
a furnace; and
a firing tube ~~in said furnace with a given space from the side wall of~~ ✓
~~said furnace~~, said firing tube capable of being loaded with a casing containing said ✓
green ceramic compact so as to substantially close said casing, said firing tube having
10 a space for firing said casing therein.

9. A firing apparatus in accordance with claim 8, wherein said furnace is provided with a hearth comprising a first movable stage.

- 15 10. A firing apparatus in accordance with claim 8, wherein said furnace is provided with a hearth comprising a first stage and a second stage, each being independently movable.

- 20 11. A firing apparatus in accordance with claim 8, wherein said firing tube is provided in said furnace.

12. A firing apparatus in accordance with claim 8, wherein said firing tube includes a highly heat-conductive material.

- 25 13. A firing apparatus in accordance with claim 8, wherein said firing tube ~~in said furnace~~ is at a given space from a side wall of said furnace. ✓

14. A firing apparatus in accordance with claim 8, wherein a top of said firing tube is fixed to a ceiling of said furnace.

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-9-

15. A firing apparatus in accordance with claim 9, wherein a bottom of said firing tube in said furnace is designed to contact said first stage so as to substantially enclose said casing.

- 5 16. A firing apparatus in accordance with claim ¹¹ (8) wherein said firing tube in said furnace is at a given space from the side wall of said furnace, a top of said firing tube is fixed to a ceiling of said furnace, a bottom end of said firing tube is capable of being placed on said first stage so as to substantially enclose said casing, said firing tube having a space for firing said green ceramic compact therein and
10 being formed from a highly heat-conductive material. ✓

17. A firing apparatus in accordance with claim 8, wherein said second stage is movable to close said furnace to open air.

- 15 18. A firing apparatus for a green ceramic compact comprising ~~the steps of:~~ a furnace provided with a hearth comprising a first stage and a second stage, each being independently movable; and
a firing tube provided in said furnace with a given space from a side wall of said furnace, a top of said firing tube being fixed to a ceiling of said furnace,
20 a bottom end of said firing tube being placed on said first stage loaded with a casing containing said green ceramic compact so as to substantially close said casing, said firing tube having a space for firing said green ceramic compact therein and being formed from a highly heat-conductive material. ✓

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