

Method of Stacking Ceramic Green Sheets

BACKGROUND OF THE INVENTION

Field of the Invention

5 The present invention relates to a method of stacking ceramic green sheets, and more specifically, it relates to a method of stacking ceramic green sheets, which is carried out for manufacturing a multilayer ceramic electronic component.

10 Description of the Background Art

 In order to manufacture a multilayer ceramic electronic component such as a multilayer ceramic capacitor, for example, it is necessary to stack ceramic green sheets.

15 Such ceramic green sheets are advantageously minimized in thickness for attaining large electrostatic capacitance in a multilayer ceramic capacitor, for example. Thus, distances between internal electrodes can be reduced and the number of layers of such internal
20 electrodes can be increased in a prescribed dimensional range.

 In order to stack such thin ceramic green sheets, the so-called transfer technique is advantageously employed. According to this transfer technique, a ceramic green
25 sheet is lined with a proper back film and compression-

bonded in this state to other ceramic green sheets which are already stacked with each other so that the former is transferred to the latter, and thereafter the back film is separated from the as-transferred ceramic green sheet.

5 In order to obtain a multilayer ceramic capacitor through the aforementioned transfer technique, two methods are typically carried out as follows:

 (1) A ceramic green sheet which is formed on a back film and internal electrode films which are formed on
10 another back film are alternately transferred.

 (2) As shown in Fig. 4, internal electrode films 2 are provided on a back film 1 and a ceramic green sheet 3 is formed on this back film 1 to cover the internal
15 electrode films 2, so that the internal electrode films 2 and the ceramic green sheet 3 are integrally transferred. Alternatively, a ceramic green sheet 3 is formed on a back film 1 and internal electrode films 2 are provided on the ceramic green sheet 3 as shown in Fig. 5, so that the
20 ceramic green sheet 3 and the internal electrode films 2 are integrally transferred.

 However, the aforementioned method (1) is inferior in productivity since the internal electrode films and the ceramic green sheet are alternately transferred, and hence this method has been merely applied to specific items. On
25 the other hand, the method (2) is excellent in

productivity since the internal electrode films 2 and the ceramic green sheet 3 are already integrated with each other to facilitate handling.

In the aforementioned transfer technique,
5 transferability of the ceramic green sheets depends on effective action of a binder contained in the ceramic green sheets, sufficient smoothness of the surface of the ceramic green sheet which is brought into contact with already stacked ceramic green sheets to be transferred
10 thereto, and the like.

On the surface 4 of the ceramic green sheet 3 which is formed on the back film 1 as shown in Fig. 4 or 5, however, ceramic particles are arranged so random that the sheet surface is irregularized with insufficient
15 smoothness. Thus, adhesiveness provided by the surface 4 of the ceramic green sheet 3 may be reduced to cause defective transfer. This problem also arises in the aforementioned method (1). Particularly in the method (2), however, the ceramic green sheet 3 is provided with
20 the internal electrode films 2 on either surface, and hence such internal electrode films 2 are necessarily interposed between two ceramic green sheets which are brought into contact with each other in a transfer step. As to adhesive strength, that between the ceramic green
25 sheet and the internal electrodes is inferior to that

between ceramic green sheets. Thus, the
aforementioned problem of reduction in adhesive
strength caused by drying of the surface 4 of the
ceramic green sheet 3 is particularly serious in the
method (2).

In order to obtain a miniature multilayer ceramic
capacitor having large capacitance, on the other hand,
it is necessary to reduce the ceramic green sheets in
thickness, as hereinabove described. In this case,
however, defects such as pinholes are so increased
that the defective rate of the as-completed multilayer
ceramic capacitors is increased.

The aforementioned problems may arise not only in
multilayer ceramic capacitors but in general
multilayer ceramic electronic components which are
manufactured through steps including that of stacking
ceramic green sheets.

SUMMARY OF THE INVENTION

Accordingly, it is desired to provide a method of
stacking ceramic green sheets, which can solve the
aforementioned problems.

According to one aspect of the present invention,
there is provided a method of stacking ceramic green
sheets, said method comprising the steps of:
preparing first and second back films; forming a
ceramic green sheet on said first back film;

transferring said ceramic green sheet from said first back film to said second back film while directing an outward surface of said ceramic green sheet being formed on said first back film toward said second back film; and transferring said ceramic green sheet from said second back film to other ceramic green sheets, being already stacked with each other, while directing said outward surface of said ceramic green sheet being held by said second back film to said already stacked ceramic green sheets.

In advance of the aforementioned step of transferring the ceramic green sheet from the first back film to the second back film, a patterned functional material film such as an internal electrode film may be formed on the second back film so that the functional material film is transferred with the ceramic green sheet which is transferred to the already stacked ceramic green sheets from the second back film.

According to another aspect of the present invention, there is provided a method of stacking ceramic green sheets, said method comprising the steps of: preparing first and second back films; forming a first ceramic green sheet on said first back film; providing a patterned functional material film and forming a second ceramic green sheet on said second

back film; bringing said first and second ceramic green sheets into contact with each other for transferring said first ceramic green sheet from said first back film to said second ceramic green sheet; and transferring said first and second ceramic green sheets and said functional material film to other ceramic green sheets being already stacked with each other while directing an outward surface of said first ceramic green sheet being held by said second back film toward said already stacked ceramic green sheets.

An advantage of the present invention is that an adhesive surface of the ceramic green sheet to be transferred to the already stacked ceramic green sheets is defined by a surface which is exposed by separation of the first back film, whereby excellent smoothness is attained. In addition, heat and pressure can advantageously be applied to the ceramic green sheet through the first and second back films when the ceramic green sheet is transferred from the first back film to the second back film. Therefore, it is possible to improve adhesiveness between the ceramic green sheets for stacking the ceramic green sheets by a transfer technique. Thus, reliability in transfer can be improved and the pressure to be applied for such transfer can be reduced.

Further, it is possible to advantageously

annihilate pinholes which may be contained in the ceramic green sheet by applying heat and pressure to the ceramic green sheet which is held between the first and second back films, thereby reducing the defective rate of multilayer ceramic electronic components obtained by stacking such ceramic green sheets. Particularly when first and second ceramic green sheets are held between the first and second back films, such defectives are further removed.

10 When the second back film is provided with a functional material film such as an internal electrode film so that the functional film is integrated with the ceramic green sheet to be stacked, it is possible to improve stacking efficiency.

15 According to another aspect of the present invention, there is provided a method for preparing a ceramic green sheet for transfer to a stack of ceramic green sheets comprising defining the surface of one face of the ceramic green sheet by contact with and separation from a first backing sheet; and providing a second backing sheet on the other face of the ceramic green sheet.

25 Advantageously, the step of defining the surface of one face of the ceramic green sheet may comprise: forming the ceramic green sheet on the first backing layer; and transferring the ceramic green sheet to the

second backing layer by contacting the exposed face of the ceramic green sheet with the second backing sheet and separating the first backing sheet from the face opposite to the exposed face.

5 The above and further features of the present invention are set forth with particularity in the appended claims and will become clearer from consideration of the following detailed description of embodiments of the invention given with reference to
10 the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a sectional view showing a step of transferring a ceramic green sheet 13 from a first back film 11 to a second back film 12, which is
15 included in an embodiment of the present invention;

Fig. 2 is a sectional view showing a step of transferring the ceramic green sheet 13 from the second back film 12 to already stacked ceramic green sheets 13a, which is carried out after the step shown
20 in Fig. 1;

Fig. 3 is a sectional view showing a step corresponding to that shown in Fig. 1, which is included in another embodiment of the present invention;

Fig. 4 is a sectional view showing a conventional back film 1 which is provided with internal electrode films 2 thereon and a ceramic green sheet 3 formed on the back film 1; and

Fig. 5 is a sectional view showing a conventional back film 1 provided with a ceramic green sheet 3 thereon, and internal electrode films 2 formed on the ceramic green sheet 3.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Figs. 1 and 2 illustrate an embodiment of the present invention.

As shown in Fig. 1, first and second back films 11 and 12 having smooth surfaces are employed in this embodiment. These back films 11 and 12 are made of polyethylene terephthalate, for example. The back films 11 and 12 are preferably surface-treated with a mold release agent, in order to facilitate smooth separation of a ceramic green sheet as described below.

A ceramic green sheet 13 is formed on the back film 11. On the other hand, patterned functional material films 14 are formed on the second back film 12. The functional material films 14 are patterned by

photoetching, for example.

Then, an outward surface of the ceramic green sheet 13 provided on the first back film 11 is directed to the second back film 12 so that the ceramic green sheet 13 is brought into contact with the second back film 12, and the first and second back films 11 and 12 and the ceramic green sheet 13 are passed through a pair of rolls 15 and 16 in this state, as shown in Fig. 1. The rolls 15 and 16 are adapted to heat and pressurize the ceramic green sheet 13 through the back films 15 and 16.

The back films 11 and 12 and the ceramic green sheet 13 being passed through the rolls 15 and 16 are cooled and then passed through another pair of rolls 17 and 18, so that the first back film 11 is thereafter separated from the ceramic green sheet 13. Thus, the ceramic green sheet 13 is transferred from the first back film 11 to the second back film 12. An outward surface of the ceramic green sheet 13 being held by the second back film 12, i.e., a surface 19 exposed by the separation of the first back film 11, has excellent smoothness which compares with that of the back film surface.

Fig. 2 shows a method of stacking the ceramic green sheet 13 which is held by the second back film 12 in the aforementioned manner.

The second back film 12 holding the ceramic green

sheet 13 is guided onto a stage 20. A stacking apparatus 21 is arranged to face the stage 20. This stacking apparatus 21 is approachable to and separable from the stage 20 as a whole. The stacking apparatus 21 has a compression bonding head 22 and cutting blades 23 which are provided around the same. The cutting blades 23 are vertically displaceable with respect to the compression bonding head 22. The stage 20 and/or the compression bonding head 22 contains a heater.

Fig. 2 shows a plurality of ceramic green sheets 13a, which are already stacked with each other, in a space enclosed by the cutting blades 2 on the compression bonding head 22. The outward surface 19 of the ceramic green sheet 13 which is held by the second back film 12 is directed toward the already stacked ceramic green sheets 13a and the stacking apparatus 21 is downwardly moved toward the stage 20, whereby the ceramic green sheet 13 is cut by the cutting blades 23 and compression-bonded to the already stacked ceramic green sheets 13a. The outward surface 19 which is compression-bonded to the already stacked ceramic green sheets 13a has excellent smoothness as hereinabove described, whereby a strong compression bonding state can be attained.

Then, the stacking apparatus 21 is again separated from the stage 20, so that the ceramic green sheet 13

enclosed by the cutting blades 23 is transferred from the second back film 12 to the already stacked ceramic green sheets 13a.

5 The step shown in Fig. 2 is repeated a required number of times, to obtain a laminate for a multilayer ceramic electronic component.

10 In the aforementioned embodiment, the functional material films 14 may not be formed on the second back film 12 but the aforementioned method may be applied to transfer of a ceramic green sheet in a method of alternately transferring a ceramic green sheet and functional material films, similarly to the conventional method (1).

15 Fig. 3 shows another embodiment of the present invention. Referring to Fig. 3, elements corresponding to those shown in Fig. 1 are denoted by similar reference numerals, to omit redundant description.

20 In this embodiment, a second ceramic green sheet 24 is formed on a second back film 12, in addition to functional material films 14. When these elements are passed through a pair of rolls 15 and 16, therefore, a first ceramic green sheet 13 is brought into contact with the second ceramic green sheet 24. After passage through another pair of rolls 17 and 18, a first back film 11 is
25 so separated that the first ceramic green sheet 13 is

transferred from the first back film 11 to the second ceramic green sheet 24.

The ceramic green sheets 13 and 24 thus held by the second back film 12 are guided onto the stage 20 in place of the ceramic green sheet 13 held by the second back film 12 as shown in Fig. 2, and stacked similarly to the aforementioned embodiment.

It is also possible for the ceramic green sheets to be stacked by an apparatus other than that shown in Fig. 2.

Examples of methods of stacking ceramic green sheets embodying the present invention are now described.

Example 1

As shown in Fig. 1, a ceramic green sheet 13 was formed on a first back film 11 by slurry of nonreducing dielectric ceramic mainly composed of barium titanate. On the other hand, a metal film of nickel was formed on a second back film 12 and patterned by photoetching, to form functional material films 14 for serving as internal electrode films for a multilayer ceramic capacitor.

Then, the step shown in Fig. 1 was carried out to transfer the ceramic green sheet 13 from the first back film 11 to the second back film 12.

Then the ceramic green sheet 13 was stacked with the functional material films 14 by thermocompression bonding

as shown in Fig. 2, and the as-obtained laminate was further cut into dimensions for providing a single multilayer ceramic capacitor. Thereafter this substance was fired and then provided with external electrodes, to
5 prepare a multilayer ceramic capacitor.

Example 2

An operation similar to that in Example 1 was carried out except that a second ceramic green sheet 24 was formed on a second back film 12 as shown in Fig. 3, to prepare a
10 multilayer ceramic capacitor.

Comparative Example

Similarly to the second back film 12 employed in Example 1, a back film provided with patterned functional material films of nickel was prepared. This back film was
15 coated with slurry which was similar to that employed in Example 1 for forming a ceramic green sheet, and dried.

The ceramic green sheet held by the back film was subjected to steps similar to those in Example 1, to prepare a multilayer ceramic capacitor.

20 The ceramic green sheets were 10 μm in thickness in Example 1 and Comparative Example, while each of the first and second ceramic green sheets 13 and 24 was 5 μm in thickness in Example 2.

As to Examples 1 and 2 and Comparative Example,
25 transferability levels of the ceramic green sheets were

evaluated under various pressures applied for stacking the ceramic green sheets. Table 1 shows the results.

Table 1

Pressure	Example 1	Example 2	Comparative Example
180 kg/cm ²	A	A	A
150 kg/cm ²	A	A	A
120 kg/cm ²	A	A	B
90 Kg/cm ²	A	A	C
70 Kg/cm ²	B	B	C

A: nondefective in transfer

B: partially defective in transfer

C: extremely defective in transfer

It is understood from Table 1 that Examples 1 and 2 were superior in transferability to Comparative Example.

Then, initial defective rates (short-circuit factors) of the multilayer ceramic capacitors were investigated as to Examples 1 and 2 and Comparative Example. Table 2 shows the results.

Table 2

	Short-Circuit Factor
Example 1	2/200
Example 2	0/200
Comparative Example	6/200

5 It is understood from Table 2 that the short-circuit factors were reduced in Examples 1 and 2 as compared with Comparative Example, while the short-circuit factor was particularly remarkably reduced in Example 2. It is 10 presumable that the short-circuit factor was reduced in each of Examples 1 and 2 as compared with Comparative Example since pinholes in the ceramic green sheets were removed by the heat and pressure applied in the step of 15 transferring the ceramic green sheet from the first back film 11 to the second back film 12 while the short-circuit factor was further reduced in Example 2 as compared with Example 1 due to an effect attained by the superposition of two ceramic green sheets.

20 Although the present invention has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the scope of the present invention being limited only by the terms of the appended 25 claims.



CLAIMS:

1. A method of stacking ceramic green sheets, said method comprising the steps of:

preparing first and second back films;

5 forming a ceramic green sheet on said first back film;

transferring said ceramic green sheet from said first back film to said second back film while directing an outward surface of said ceramic green sheet being formed on said first back film toward said
10 second back film; and

transferring said ceramic green sheet from said second back film to other ceramic green sheets, being already stacked with each other, while directing said outward surface of said ceramic green sheet being held
15 by said second back film to said already stacked ceramic green sheets.

2. A method of stacking ceramic green sheets in accordance with claim 1, wherein said step of
20 transferring said ceramic green sheet from said first back film to said second back film includes a step of applying heat and pressure to said ceramic green sheet through said first and second back films while holding said ceramic green sheet between said first and second



back films.

3. A method of stacking ceramic green sheets in accordance with claim 1 or 2, further comprising a step of forming a patterned functional material film on said second back film in advance of said step of transferring said ceramic green sheet from said first back film to said second back film, said functional material film being transferred with said ceramic green sheet in said step of transferring said ceramic green sheet from said second back film.

4. A method of stacking ceramic green sheets in accordance with claim 3, wherein said functional material film includes a conductor material film.

5. A method of stacking ceramic green sheets, said method comprising the steps of:

preparing first and second back films;

forming a first ceramic green sheet on said first back film;

providing a patterned functional material film and forming a second ceramic green sheet on said second back film;

bringing said first and second ceramic green sheets into contact with each other for transferring



said first ceramic green sheet from said first back film to said second ceramic green sheet; and

transferring said first and second ceramic green sheets and said functional material film to other ceramic green sheets being already stacked with each other while directing an outward surface of said first ceramic green sheet being held by said second back film toward said already stacked ceramic green sheets.

6. A method of stacking ceramic green sheets in accordance with claim 5, wherein said step of transferring said first ceramic green sheet from said first back film to said second ceramic green sheet includes a step of applying heat and pressure to said first and second ceramic green sheets through said first and second back films while holding said first and second ceramic green sheets between said first and second back films.

7. A method of stacking ceramic green sheets in accordance with claim 5 or 6, wherein said second ceramic green sheet is formed after said functional material film is provided in said step of providing said functional material film and forming said second ceramic green sheet on said second back film.



8. A method of stacking ceramic green sheets in accordance with any of claims 5, 6 or 7, wherein said functional material film includes a conductor material film.



9. A method for preparing a ceramic green sheet for transfer to a stack of ceramic green sheets comprising:
defining the surface of one face of the ceramic green
5 sheet by contact with and separation from a first backing sheet; and
providing a second backing sheet on the other face of the ceramic green sheet.

10. A method according to claim 9 wherein the step of
10 defining the surface of one face of the ceramic green sheet comprises the steps of:
forming the ceramic green sheet on the first backing layer; and
transferring the ceramic green sheet to the second
15 backing layer by contacting the exposed face of the ceramic green sheet with the second backing sheet and separating the first backing sheet from the face opposite to the exposed face.

11. A method according to claim 9 wherein the ceramic
20 green sheet comprises first and second ceramic green sheet sub-layers each formed on a respective backing sheet and wherein the step of defining the one face of the ceramic green sheet comprises contacting the exposed surfaces of the first and second ceramic sub-

layers and separating the backing sheet from one of the first and second ceramic sub-layers.

12. A method according to any one of claims 9, 10 or 11 wherein a patterned film is disposed between one of the first and second backing sheets and an adjacent face of the ceramic green sheet.

13. A method for stacking ceramic green sheets comprising the steps:

providing a ceramic green sheet by the method of claim 9 or any claim dependent thereon;

10 transferring the ceramic green sheet to a predetermined location by contacting the exposed face of the ceramic green sheet with the predetermined location and removing the second backing layer.

14. A method substantially as hereinbefore described with reference to Figure 3 of the drawings.

15. A method substantially as hereinbefore described with reference to Figures 1 and 2 of the drawings.

