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MULTILAYER CAPACITOR AND METHOD OF MANUFACTURING THE SAME

Abstract

A method of manufacturing a multilayer capacitor includes preparing a guide frame, forming at least one dielectric layer between at least two surfaces of the guide frame such that at least a portion of each side surface of the at least one dielectric layer is in contact with the at least two surfaces, forming at least one internal electrode on an upper surface of the at least one dielectric layer between at least two surfaces of the guide frame using an inkjet printing method, and separating at least two surfaces of the guide frame from the at least one dielectric layer.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is the divisional application of U.S. patent application Ser. No. 17/959,575 filed on Oct. 4, 2022, which claims the benefit of priority to Korean Patent Application No. 10-2021-0164108 filed on Nov. 25, 2021 in the Korean Intellectual Property Office, the disclosures of which are incorporated herein by references in their entirety.

BACKGROUND

1. Technical Field

[0002] The present disclosure relates to a multilayer capacitor and a method of manufacturing the same.

2. Description of Related Art

[0003] A multilayer capacitor has been widely used as a component of electronic devices such as computers, PDAS, mobile phones, and the like, as a multilayer capacitor may have a small size and high capacitance, and may be easily mounted, and a multilayer capacitor has also been used as one of components of electrical devices (including vehicles) as a multilayer capacitor may have high reliability and high strength.

SUMMARY

[0004] An aspect of the present disclosure is to provide a multilayer capacitor which may have a reduced size while retaining performance (e.g., capacitance, manufacturing costs, reliability, withstand voltage, and mounting efficiency), and a method of manufacturing the same.

[0005] According to an aspect of the present disclosure, a method of manufacturing a multilayer capacitor may include preparing a guide frame; forming at least one dielectric layer between at least two surfaces of the guide frame such that at least a portion of each side surface of the at least one dielectric layer is in contact with the at least two surfaces; forming at least one internal electrode on an upper surface of the at least one dielectric layer between at least two surfaces of the guide frame using an inkjet printing method; and separating at least two surfaces of the guide frame from the at least one dielectric layer.

[0006] According to another aspect of the present disclosure, a multilayer capacitor may include a body having a laminate structure in which at least one first internal electrode and at least one second internal electrode are alternately laminated in a first direction with at least one dielectric layer interposed therebetween; and first and second external electrodes disposed on the body and spaced apart from each other to be connected to the at least one first internal electrode and the at least one second internal electrode, respectively. A thickness of each of the at least one first internal electrode and the at least one second internal electrode, defined as $T_{sub.E}$, may be 0.25 μm or less. A first air gap may be disposed between the at least one second internal electrode and the first external electrode in a second direction. A second air gap may be disposed between the at least one first internal electrode and the second external electrode in the second direction. On one surface of the body taken in the first direction, a slope, taken in the second direction, of a portion of the one surface of the body in an overlapping portion between the at least one second internal electrode and the first external electrode in the first direction may be 01, and a slope, taken in the second direction, of a portion of the one surface of the body in an overlapping portion between the at least

one first internal electrode and the second external electrode in the first direction may be θ_2 . Then, $\{(\theta_1+\theta_2)/2\}$ may be greater than 0 degree and less than 15 degrees.

[0007] According to still another aspect of the present disclosure, a multilayer capacitor may include a body including a laminate structure in which a plurality of first internal electrodes and a plurality of second internal electrodes are alternately laminated in a first direction with at least one dielectric layer interposed therebetween; and first and second external electrodes disposed on the body and spaced apart from each other in a second direction to be connected to the plurality of first internal electrodes and the plurality of second internal electrodes, respectively. A thickness of each of the plurality of first and second internal electrodes, defined as $T_{sub.E}$, may be 0.25 μm or less. The body may further include a first side margin portion interposed between ends of the plurality of second internal electrodes and the first external electrode in the second direction, and a second side margin portion interposed between ends of the plurality of first internal electrodes and the second external electrode in the second direction. End portions of the body in the second direction may be bent downwardly in the first direction. A bent angle of an upper surface of the first side margin portion with respect to a center of one surface of the body in the first direction may be θ_1 , and a bent angle of an upper surface of the second side margin portion with respect to the center of the one surface of the body may be θ_2 . Then, $\{(\theta_1+\theta_2)/2\}$ may be greater than 0 degree and less than 15 degrees. An average distance, defined as $T_{sub.B}$, between adjacent ones of the plurality of first internal electrodes at the first side margin portion and between adjacent ones of the plurality of second internal electrodes at the second side margin portion may be less than a distance between adjacent ones of the plurality of first or second internal electrodes at a center portion of the body.

Description

BRIEF DESCRIPTION OF DRAWINGS

[0008] The above and other aspects, features, and advantages of the present disclosure will be more clearly understood from the following detailed description, taken in conjunction with the accompanying drawings, in which:

[0009] FIG. 1 is a perspective diagram illustrating a multilayer capacitor according to an example embodiment of the present disclosure;

[0010] FIG. 2 is a cross-sectional diagram taken along line A-A' in FIG. 1;

[0011] FIG. 3 is a cross-sectional diagram taken along line B-B' in FIG. 1;

[0012] FIG. 4 is a cross-sectional diagram illustrating a structure for miniaturization of a multilayer capacitor according to an example embodiment of the present disclosure;

[0013] FIGS. 5A, 5B and 5C are perspective diagrams illustrating various examples of a process of preparing a guide frame with respect to a method of manufacturing a multilayer capacitor according to an example embodiment of the present disclosure;

[0014] FIGS. 6A and 6B are perspective diagrams illustrating various examples of a process of forming at least one dielectric layer with respect to a method of manufacturing a multilayer capacitor according to an example embodiment of the present disclosure;

[0015] FIGS. 7A, 7B, 7C and 7D are perspective diagrams illustrating various examples of a process of forming at least one internal electrode with respect to a method of manufacturing a multilayer capacitor according to an example embodiment of the present disclosure;

[0016] FIG. 8 is a perspective diagram illustrating a state before a guide frame is separated from a structure (a state in which the structure is able to be compressed) in which at least one dielectric layer and at least one internal electrode are laminated with respect to a method of manufacturing a multilayer capacitor according to an example embodiment of the present disclosure;

[0017] FIG. 9A is a perspective diagram illustrating a separation process of a method of manufacturing a multilayer capacitor according to an example embodiment of the present

disclosure; and

[0018] FIG. **9B** is a perspective diagram illustrating a cutting process of a method of manufacturing a multilayer capacitor according to an example embodiment of the present disclosure.

DETAILED DESCRIPTION

[0019] Hereinafter, embodiments of the present disclosure will be described as follows with reference to the attached drawings.

[0020] These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention. It is to be understood that the various embodiments of the invention, although different, are not necessarily mutually exclusive. For example, structures, shapes, and sizes described as examples in embodiments in the present disclosure may be implemented in another example embodiment without departing from the spirit and scope of the present disclosure. Further, modifications of positions or arrangements of elements in example embodiments may be made without departing from the spirit and scope of the present disclosure. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present invention are defined only by appended claims, appropriately interpreted, along with the full range of equivalents to which the claims are entitled.

[0021] In the drawings, same elements will be indicated by same reference numerals. Also, redundant descriptions and detailed descriptions of known functions and elements that may unnecessarily make the gist of the present disclosure obscure will be omitted. In the accompanying drawings, some elements may be exaggerated, omitted or briefly illustrated, and the sizes of the elements do not necessarily reflect the actual sizes of these elements.

[0022] The terms, “include,” “comprise,” “is configured to,” or the like of the description are used to indicate the presence of features, numbers, steps, operations, elements, portions or combination thereof, and do not exclude the possibilities of combination or addition of one or more features, numbers, steps, operations, elements, portions or combination thereof.

[0023] As for the directions of a hexahedron, L, W, and T in the drawings may indicate a length direction, a width direction, and a thickness direction, respectively. The thickness direction may be a lamination direction (or a first direction) in which the dielectric layers are laminated.

[0024] In the description below, a multilayer capacitor according to an example embodiment will be described, and particularly, a multilayer ceramic capacitor (MLCC) will be described, but an example embodiment thereof is not limited thereto.

[0025] FIG. **1** is a perspective diagram illustrating a multilayer capacitor according to an example embodiment. FIG. **2** is a cross-sectional diagram taken along line A-A' in FIG. **1**. FIG. **3** is a cross-sectional diagram taken along line B-B' in FIG. **1**. FIG. **1** illustrates the body **110** from which a $\frac{1}{4}$ portion is cut out in volume to view the internal portion of the body **110**, but the actual multilayer capacitor **100** may not be cut out by $\frac{1}{4}$ in volume, and may be symmetrical with respect to the L direction, the W direction, and the T direction.

[0026] Referring to FIGS. **1**, **2** and **3**, the multilayer capacitor **100** according to an example embodiment may include a body **110**, a first external electrode **131**, and a second external electrode **132**.

[0027] The body **110** may include a laminate structure in which at least one first internal electrode **121** and at least one second internal electrode **122** are alternately laminated in a first direction (e.g., the T direction) with at least one dielectric layer **111** interposed therebetween.

[0028] For example, the body **110** may be configured as a ceramic body by baking the laminate structure. The at least one dielectric layer **111** disposed on the body **110** may be in a sintered state, and the boundary between dielectric layers adjacent to each other may be integrated such that it may be difficult to identify the boundary without using a scanning electron microscope (SEM).

[0029] For example, the body **110** may be formed as a hexahedron having both side surfaces in the length direction L, both side surfaces in the width direction W, and both side surfaces in the thickness direction T. The edges and/or corners may be rounded by being polished. However, the

shape and the dimension of the body **110** and the number of laminated dielectric layers **111** are not limited to the illustrated examples.

[0030] The thickness of the at least one dielectric layer **111** may be arbitrarily changed according to the design of capacitance of the multilayer capacitor **100**, and the dielectric layer **111** may include ceramic powder having a high dielectric constant, such as, for example, a barium titanate (BaTiO_3) powder, but an example embodiment thereof is not limited thereto. Also, various ceramic additives (e.g., MgO , Al_2O_3 , SiO_2 , ZnO), an organic solvent, a plasticizer, a binder, a dispersant, or the like, may be added to the ceramic powder according to the required configuration of the multilayer capacitor **100**.

[0031] An average particle diameter of the ceramic powder used to form the at least one dielectric layer **111** may not be limited to any particular example, and may be adjusted according to the required configuration (e.g., miniaturization and/or high capacity may be required as in a capacitor for electronic devices, or high withstand voltage properties and/or high strength may be required as in a capacitor for electrical devices), and may be adjusted to be, for example, 400 nm or less.

[0032] For example, the at least one dielectric layer **111** may be formed by forming a plurality of ceramic sheets by applying slurry including powder such as barium titanate (BaTiO_3) on a carrier film and drying the slurry. The ceramic sheet may be formed by preparing the slurry by mixing ceramic powder, a binder, and a solvent, and forming the slurry into a sheet having a thickness of several μm by a doctor blade method, but an example embodiment thereof is not limited thereto.

[0033] The at least one first internal electrode **121** and the at least one second internal electrode **122** may be formed by printing a conductive paste including a conductive metal and may be alternately exposed to one side surface and the other side surface of the body **110** in the lamination direction (e.g., the T direction) of the dielectric layers, and may be electrically insulated from each other by the dielectric layer interposed therebetween.

[0034] For example, each of the at least one first internal electrode **121** and the at least one second internal electrode **122** may be formed by a conductive paste for internal electrodes including 40 to 50 wt % of conductive metal powder having an average particle size of 0.1 to 0.2 μm , but an example embodiment thereof is not limited thereto. The conductive paste may be nickel (Ni), copper (Cu), palladium (Pd), silver (Ag), lead (Pb), or platinum (Pt), or an alloy thereof, but an example embodiment thereof is not limited thereto.

[0035] For example, an internal electrode pattern may be formed by applying the conductive paste for an internal electrode on the ceramic sheet by a printing method. The method of printing the conductive paste may be an inkjet printing method, but an example embodiment thereof is not limited thereto. For example, the body **110** may be manufactured by laminating in 200 to 300 layers of ceramic sheets on which the internal electrode pattern is printed, and pressing and baking the ceramic sheets.

[0036] Capacitance of the multilayer capacitor **100** may be proportional to an overlapping region between the at least one first internal electrode **121** and the at least one second internal electrode **122** in the lamination direction (e.g., in the T direction), may be proportional to a total number of laminated layers of the at least one first internal electrode **121** and the at least one second internal electrode **122**, and may be inversely proportional to a distance between the at least one first internal electrode **121** and the at least one second internal electrode **122**. The distance between the internal electrodes may be substantially the same as a thickness of each of the at least one dielectric layer **111**.

[0037] The multilayer capacitor **100** may have a larger capacitance for a thickness thereof as the distance between the at least one first internal electrode **121** and the at least one second internal electrode **122** decreases, whereas the withstand voltage of the multilayer capacitor **100** may be higher as the distance between the internal electrodes increases. Accordingly, the distance between the internal electrodes may be adjusted according to the required configuration (e.g.,

miniaturization and/or high capacity may be required as in a capacitor for electronic devices, or high withstand voltage properties and/or high strength may be required as in a capacitor for electrical devices). The thickness of each of the at least one first internal electrode **121** and the at least one second internal electrode **122** may also be affected by the distance between the internal electrodes.

[0038] For example, when high withstand voltage properties and/or high strength are required for the multilayer capacitor **100**, the distance between the at least one first internal electrode **121** and the at least one second internal electrode **122** may be configured to exceed twice the thickness of each of the first internal electrode **121** and the second internal electrode **122**. For example, when high withstand voltage properties and/or high strength are required for the multilayer capacitor **100**, the thickness of each of the at least one first internal electrode **121** and the at least one second internal electrode **122** may be configured to be 0.4 μm or less and the total number of layers of the internal electrodes may be configured to be 400 or more.

[0039] The first and second external electrodes **131** and **132** may be disposed in the body **110** to be spaced apart from each other so as to be connected to the at least one first internal electrode **121** and the at least one second internal electrode **12**, respectively.

[0040] For example, each of the first and second external electrodes **131** and **132** may be formed by a method of dipping in a paste including a metal component, a method of printing a conductive paste, a sheet transfer, a pad transfer method, a sputter plating method, or electrolytic plating method. For example, the first and second external electrodes **131** and **132** may include a baked layer formed as the paste is baked and a plating layer formed on an external surface of the baked layer, and a conductive resin layer may be further included between the baked layer and the plating layer. For example, the conductive resin layer may be formed as conductive particles are included in a thermosetting resin such as epoxy. The metal component may be copper (Cu), palladium (Pd), platinum (Pt), gold (Au), silver (Ag), lead (Pb), or tin (Sn), or an alloy thereof, but an example embodiment thereof is not limited thereto.

[0041] The multilayer capacitor **100** may be mounted or embedded in an external substrate (e.g., a printed circuit board), and may be electrically connected to a circuit (e.g., an integrated circuit, a processor) electrically connected to the external substrate by being connected to at least one of a wiring, a land, a solder and a bump of the external substrate through the first and second external electrodes **131** and **132**.

[0042] Referring to FIGS. **1**, **2** and **3**, the body **110** may include an upper cover layer **112**, a lower cover layer **113**, and a core region **115**, and a core region **115** may include a margin region **114** and a capacitance region **116**.

[0043] The upper and lower cover layers **112** and **113** may be disposed with the core region **115** interposed therebetween in the first direction (e.g., the T direction) and may have a thickness greater than a thickness of each of the at least one dielectric layer **111**.

[0044] The upper and lower cover layers **112** and **113** may prevent external environmental elements (e.g., moisture, plating solution, foreign substances) from permeating the core region **115**, may protect the body **110** from external impacts, and may also improve warpage strength of the body **110**.

[0045] For example, the upper and lower cover layers **112** and **113** may include a material the same as the material of the at least one dielectric layer **111** or a material (e.g., a thermosetting resin such as an epoxy resin) different from the material of the at least one dielectric layer **111**.

[0046] The capacitance region **116** may form the capacitance of the multilayer capacitor **100** by including a region between the at least one first internal electrode **121** and the at least one second internal electrode **122**.

[0047] The capacitive region **116** may including a laminate structure in which the at least one first internal electrode **121** and the at least one second internal electrode **122** are alternately laminated in the first direction (e.g., a T-direction) with the at least one dielectric layer **111** interposed

therebetween, and may have the same dimension as that of the laminate structure.

[0048] The margin region **114** may include a boundary line between the at least one first internal electrode **121** and the at least one second internal electrode **122** and a region between the surfaces of the body **110**.

[0049] The plurality of margin regions **114** may be disposed with the capacitance region **116** interposed therebetween in a second direction (e.g., W direction) perpendicular to the first direction (e.g., T direction). For example, the plurality of margin regions **114** may be formed by a method similar to the method forming the at least one dielectric layer **111** (the lamination directions may be different).

[0050] The plurality of margin regions **114** may prevent the at least one first internal electrode **121** and the at least one second internal electrode **122** from exposing to the surface of the body **110** in the second direction (e.g., W direction), such that the external environmental elements (e.g., moisture, plating solution, foreign substances) may be prevented from permeating the at least one first internal electrode **121** and the at least one second internal electrode **122** through the surface in the second direction, and reliability and lifespan of the multilayer capacitor **100** may improve. Also, the at least one first internal electrode **121** and the at least one second internal electrode **122** may efficiently expand in the second direction due to the plurality of margin regions **114**, and accordingly, the plurality of margin regions **114** may increase the overlapping region between the at least one first internal electrode **121** and the at least one second internal electrode **122**, thereby contributing to improving the capacitance of the multilayer capacitor **100**.

[0051] FIG. **4** is a cross-sectional diagram illustrating a structure for miniaturization of a multilayer capacitor according to an example embodiment.

[0052] Referring to FIG. **4**, the multilayer capacitor according to an example embodiment may include at least one first internal electrode **121** and at least one second internal electrode **122** each having a thickness $T_{sub.E}$ of 0.25 μm or less, such that the multilayer capacitor may be miniaturized. That is because, as the thickness $T_{sub.E}$ decreases, the thickness $T_{sub.D}$ of the at least one dielectric layer **111** may also decrease, and a thickness of each of the upper and lower cover layers **112** and **113** and the first and second external electrodes **131** and **132** may be reduced.

[0053] For example, a length of the miniaturized body **110** in a direction (e.g., the L direction) in which the first and second external electrodes **131** and **132** oppose each other may be less than 800 μm (e.g., 600 μm or less), and a width of the miniaturized body **110** in a direction (e.g., W direction) perpendicular to the above-mentioned direction and the first direction (e.g., T direction) may be less than 400 μm (e.g., 300 μm or less).

[0054] For example, the at least one first internal electrode **121** and the at least one second internal electrode **122** may be formed using an inkjet printing method to have a reduced thickness $T_{sub.E}$ such as 0.25 μm or less. By using the inkjet printing method, viscosity and/or the printing position of the conductive paste may be determined flexibly with precision as compared to other printing methods (e.g., screen-printing, gravure printing), such that printing resolution of the at least one second internal electrode **122** and the at least one second internal electrode **122** may improve. Reliability (e.g., connectivity, withstand voltage, or the like) of the thickness $T_{sub.E}$ of the at least one second internal electrode **122** and the at least one second internal electrode **122** may increase as the printing resolution increases.

[0055] Accordingly, when the thickness $T_{sub.E}$ of each of the at least one first internal electrode **121** and the at least one second internal electrode **122** is 0.25 μm or less, it may be highly likely that the at least one first internal electrode **121** and the at least one second internal electrode **122** may be formed using an inkjet printing method, but an example embodiment thereof is not limited thereto. For example, even when the at least one first internal electrode **121** and the at least one second internal electrode **122** have a thickness $T_{sub.E}$ of 0.25 μm or less, the internal electrodes may be formed by screen printing and/or gravure printing for rapid printing. An appropriate thickness $T_{sub.E}$ of the at least one first internal electrode **121** and the at least one second internal

electrode **122** formed by the inkjet printing method may be $0.2\text{ }\mu\text{m}$ or more and $0.25\text{ }\mu\text{m}$ or less, but an example embodiment thereof is not limited thereto

[0056] The difference in properties (e.g., a volume change rate according to baking) between the at least one dielectric layer **111** and the internal electrode may work as a limitation in improving reliability in the process of manufacturing (e.g., pressing, baking) the body **110**.

[0057] A first air gap **151** may be disposed between the at least one second internal electrode **122** and the first external electrode **131**, and a second air gap **152** may be disposed between the first internal electrode **121** and the second external electrode **132**, in the direction (e.g., the L direction) in which the first and second external electrodes **131** and **132** oppose each other.

[0058] The first air gap **151** may be at least a portion of a margin taken in the L direction for insulation between the at least one second internal electrode **122** and the first external electrode **131**, and the second air gap **152** may be at least a portion of a margin taken in the L direction for insulation between the at least one first internal electrode **121** and the second external electrode **132**.

[0059] When the first and second air gaps **151** and **152** are disposed in at least a portion of the margin taken in the L direction, the first and second air gaps **151** and **152** may reduce bottleneck in the flow in the body **110** due to the difference in properties and/or the shapes between the at least one dielectric layer **111** and the internal electrode, such that reliability (a first reliability factor) in the process of manufacturing the body **110** may improve. However, the first and second air gaps **151** and **152** of the margin taken in the L direction may increasingly consider the reliability limitation (e.g., second reliability factors such as a decrease in the withstand voltage due to a decrease in the minimum distance between the internal electrodes, breakage in the vicinity of the margin of the internal electrode taken in the L direction, possibility of mounting failure due to warpage of the body) due to a step of the margin taken in the L direction. That is, the first and second reliability factors may be traded off in terms of the margin taken in the L direction.

[0060] For example, when the at least one first internal electrode **121** and the at least one second internal electrode **122** are formed by the inkjet printing method, the inkjet printer may not print on at least a portion of the margin taken in the L direction, thereby forming the first and second air gaps **151** and **152**. Accordingly, the printing range may be reduced by the margin taken in the L direction, such that the body **110** may be formed swiftly at lower cost, even using the inkjet printing method.

[0061] A slope taken in the direction (e.g., the L direction) in which the first and second external electrodes **131** and **132** in the overlapping portion taken in the first direction (e.g., the T direction) between the at least one second internal electrode **122** and the first external electrode **131** on one surface (e.g., the upper surface) of the body **110** taken in the first direction (e.g., the T direction) may be defined as θ_1 , and a slope taken in the direction in which the first and second external electrodes **131** and **132** in the overlapping portion taken in the first direction (e.g., the T direction) between the at least first internal electrode **121** and the second external electrode **132** on one surface (e.g., the upper surface) of the body **110** taken in the first direction (e.g., the T direction) may be defined as θ_2 . As the slopes θ_1 and θ_2 decreases, the reliability limitation due to the step of the margin taken in the L direction may increase. The first and second air gaps **151** and **152** may allow the slopes θ_1 and θ_2 to be greater than 0 degree, and as the first and second air gaps **151** and **152** increase, θ_1 and θ_2 may also increase.

[0062] According to one embodiment of the present disclosure, end portions of the body **110** in the L direction may be bent downwardly in the T direction. When a portion of the body **110** interposed between ends of the at least one second internal electrode **122** and the first external electrode **131** in the L direction is defined as a first side margin portion, and a portion of the body **110** interposed between ends of the at least one first internal electrode **121** and the second external electrode **132** in the L direction is defined as a second side margin portion, and when a bent angle of an upper surface of the first side margin portion with respect to a center of the upper surface of the body **110**

in the first direction is θ_1 , and a bent angle of an upper surface of the second side margin portion with respect to the center of the upper surface of the body **110** is θ_2 , $\{(\theta_1+\theta_2)/2\}$ may be greater than 0 degree and less than 15 degrees.

[0063] In one embodiment, an average distance, defined as $T_{sub.B}$, between adjacent ones of the at least one first internal electrode **121** at the first side margin portion and between adjacent ones of the at least one second internal electrode **122** at the second side margin portion may be less than a distance between adjacent ones of the at least one first or second internal electrode at a center portion of the body **110**.

[0064] Table 1 below lists reliability (e.g., withstand voltage, breakage of internal electrode, possibility of mounting failure due to warpage of the body) according to the slopes θ_1 and θ_2 . “OK” in Reliability indicates that the reliability of the corresponding sample is higher than the reference reliability, and “NG” indicates that the reliability of the corresponding sample is lower than the reference reliability. Since the difference in reliability between samples 3 and 4 may be relative greater than the difference in reliability between other adjacent samples, the reliability between sample 3 and sample 4 may be a reference reliability. Alternatively, the reference reliability may be a criterion for determining whether a corresponding sample is defective.

TABLE-US-00001 TABLE 1 Sample No. $\{(\theta_1 + \theta_2)/2\}$ Reliability
1 1 degree OK 2 5 degrees OK 3 10 degrees OK 4 15 degrees NG 5 18 degrees NG 6 20 degrees NG

[0065] Referring to Table 1, the multilayer capacitor **100** according to an example embodiment may include the body **110** in which $\{(\theta_1+\theta_2)/2\}$ is greater than 0 degree and less than 15 degrees, and accordingly, the multilayer capacitor **100** may have a structure in which the internal electrodes having a reduced thickness $T_{sub.E}$ of 0.25 μm or less are laminated, and reliability may be secured, such that miniaturization may be implemented.

[0066] The number of laminated layers of each of the at least one first internal electrode **121** and the at least one second internal electrode **122** may be two or more, and the thickness of the at least one dielectric layer **111** in a portion overlapping a center of the body **110** in the first direction (e.g., T direction) may be defined as $T_{sub.D}$. A thickness obtained by dividing a sum of a distance between the plurality of first internal electrodes **122** between the plurality of first internal electrodes **121** and the second external electrode **132** and a distance between the plurality of second internal electrodes **121** between the plurality of first internal electrodes **121** and second external electrodes **132** by two may be defined as $T_{sub.B}$. $(T_{sub.E}+2*T_{sub.D})$ may be T_c , and may be a distance between the upper internal electrode and the lower internal electrode of the three internal electrodes adjacent to each other in a portion overlapping the center of the body **110** in the first direction (e.g., T direction).

[0067] Table 2 below lists reliability (e.g., withstanding voltage, breakage of the internal electrode, possibility of mounting failure due to warpage of the body) according to $\{T_{sub.B}/(T_{sub.E}+2*T_{sub.D})\}$. As the difference in reliability between sample 10 and sample 11 may be relatively greater than the difference in reliability between other adjacent samples, the reliability between sample 10 and sample 11 may be a reference reliability.

TABLE-US-00002 TABLE 2 Sample No. $\{T_{sub.B}/(T_{sub.E} + 2 * T_{sub.D})\}$ Reliability
7 0.95 OK 8 0.88 OK 9 0.85 OK 10 0.8 OK 11 0.74 NG 12 0.7 NG

[0068] Referring to Table 2, $T_{sub.B}$ of the multilayer capacitor **100** according to an example embodiment may be 0.8 times or more and less than 1 time of $(T_{sub.E}+2*T_{sub.D})$. Accordingly, since the multilayer capacitor **100** has a structure in which the internal electrodes having a reduced thickness $T_{sub.E}$ of 0.25 μm or less are laminated and reliability may be secured, miniaturization may be implemented.

[0069] $T_{sub.B}$ and $(T_{sub.E}+2*T_{sub.D})$ may be measured from a portion of the each of the plurality of first and second internal electrodes **121** and **122** including a 2% point from a portion (e.g., the upper surface of the capacitance region) the most adjacent to one surface (e.g., upper surface) of the body **110** in the first direction (e.g., T direction) to a portion farthest from one

surface of the body **110**.

[0070] Each of T.sub.B, T.sub.E, T.sub.D, θ_1 and θ_2 may be measured in the LT plane exposed by grinding or cutting the body **110** in the W direction such that the LT plane including a central point of the body **110** is exposed, and each of T.sub.B, T.sub.E and T.sub.D may be measured as an average value of the corresponding portion. The average value may be calculated as a value obtained by integrating a portion corresponding to each of T.sub.B, T.sub.E, and T.sub.D in the L direction and dividing the total length of the corresponding portion in the integration direction. The number of samples used for the measurement is not limited to any particular example, and may be 10 or more and 20 or less. For example, half of the sample used for the measurement may be used for the measurement of $\{(\theta_1 + \theta_2)/2\}$, and the other half may be used for the measurement of $\{T.sub.B/(T.sub.E + 2 * T.sub.D)\}$.

[0071] Each of T.sub.B, T.sub.E, T.sub.D, θ_1 and θ_2 may be measured based on an image obtained by applying the LT plane to the analysis using one of transmission electron microscopy (TEM), atomic force microscope (AFM), scanning electron microscope (SEM), optical microscopy, and surface profiler. For example, each of T.sub.B, T.sub.E, T.sub.D, θ_1 and θ_2 may be measured by visually distinguishing the corresponding portions in the image, and may be measured by distinguishing the corresponding portions by classifying pixel values of the image. Here, processing (e.g., filtering, edge detection, or the like) for the pixel values of the image may be accompanied.

[0072] Other measurement methods and/or tools appreciated by one of ordinary skill in the art, even if not described in the present disclosure, may also be used.

[0073] FIGS. 5A, 5B and 5C are perspective diagrams illustrating various examples of a process of preparing a guide frame of a method of manufacturing a multilayer capacitor according to an example embodiment.

[0074] Referring to FIGS. 5A, 5B and 5C, the method of manufacturing a multilayer capacitor according to an example embodiment may include processes **110-1a**, **110-1b**, and **110-1c** of preparing a guide frame.

[0075] Referring to FIGS. 5A, 5B and 5C, a guide frame **40** may include at least four surfaces **40a**, **40b**, **40c**, and **40d**. The at least four surfaces **40a**, **40b**, **40c**, and **40d** may surround at least one dielectric layer and/or at least one internal electrode in a later process, and at least two surfaces **40a** and **40c** among the at least four surfaces **40a**, **40b**, **40c**, and **40d** may be in contact with each side surface of the at least one dielectric layer and/or the at least one internal electrode in the subsequent processes.

[0076] For example, the guide frame **40** may be implemented in substantially the same form as that of the body, may include a material easily separated while being in contact with at least one dielectric layer and/or at least one internal electrode, and may be implemented as a formwork.

[0077] Referring to FIGS. 5A, 5B and 5C, the guide frame **40** may further include lower surfaces **40e** and **45** supporting at least one dielectric layer and at least one internal electrode. Accordingly, the guide frame **40** may further improve stability of a structure in which at least one dielectric layer and at least one internal electrode are laminated.

[0078] Referring to FIG. 5C, the lower surface **45** of the guide frame **40** may include a thermoplastic insulating material (e.g., polyethylene terephthalate (PET)), material different from that of the at least four surfaces **40a**, **40b**, **40c**, and **40d**. Accordingly, the guide frame **40** may improve stability of the structure in which at least one dielectric layer and at least one internal electrode are laminated during an additional process (e.g., compressing and baking). For example, the lower surface **45** of the guide frame **40** may be separated from the at least four surfaces **40a**, **40b**, **40c**, and **40d**.

[0079] FIGS. 6A and 6B are perspective diagrams illustrating various examples of a process of forming at least one dielectric layer of a method of manufacturing a multilayer capacitor according to an example embodiment.

[0080] Referring to FIGS. 6A and 6B, the method of manufacturing a multilayer capacitor according to an example embodiment may include processes **110-2a** and **110-2b** of forming at least one dielectric layer **11** such that at least a portion of each side surface thereof may be in contact with at least two surfaces of the guide frame **40** between the at least two surfaces.

[0081] Accordingly, since the guide frame **40** may maintain the shape of the at least one dielectric layer **11**, $\{(\theta_1+\theta_2)/2\}$ in Table 1 may be reduced to more than 0 degree and less than 15 degrees, or $\{T_{sub.B}/(T_{sub.E}+2*T_{sub.D})\}$ in Table 2 may be increased to 0.8 or more and less than 1.

[0082] Referring to FIG. 6A, the process **110-2a** of forming the at least one dielectric layer **11** may include forming the at least one dielectric layer **11** using an inkjet printing method. The inkjet printing method may be a method of spraying a dielectric material **51** in a dielectric inkjet printhead **50** while the dielectric inkjet printhead **50** moves in the L direction and the W direction. The dielectric **51** may be in a droplet state, and may be discharged through an outlet of the dielectric inkjet print head **50**.

[0083] Referring to FIG. 6B, at least one dielectric layer **11** may be implemented as a ceramic sheet in advance and may be inserted into the guide frame **40**.

[0084] FIGS. 7A, 7A, 7B, 7C and 7D are perspective diagrams illustrating various examples of a process of forming at least one internal electrode of a method of manufacturing a multilayer capacitor according to an example embodiment.

[0085] Referring to FIGS. 7A, 7A, 7B, 7C and 7D, the method for manufacturing a multilayer capacitor according to an example embodiment may include processes **110-3a**, **110-3b**, **110-3c**, and **110-3d** of forming at least one internal electrode **20** on the upper surface of at least one dielectric layer **11** between at least two surfaces of the guide frame **40** using an inkjet printing method. The at least one internal electrode **20** may be formed to have a thickness of 0.25 μm or less, but an example embodiment thereof is not limited thereto. The inkjet printing method may be a method of spraying a conductive paste **61** in an internal electrode inkjet print head **60** while the internal electrode inkjet print head **60** moves in the L direction and the W direction. The conductive paste **61** may be in a droplet state, and may be discharged through an outlet of the internal electrode inkjet print head **60**.

[0086] The forming at least one internal electrode illustrated in FIGS. 7A, 7A, 7B, 7C and 7D (**110-3a**, **110-3b**, **110-3c**, and **110-3d**) and the forming at least one dielectric layer illustrated in FIGS. 6A and 6B (**110-2a** and **110-2b**) may be alternately performed two or more times to form the plurality of internal electrodes **20** and the plurality of dielectric layers **11**.

[0087] Referring to FIG. 7A, the process **110-3a** of forming the at least one dielectric layer **11** may include, after one of the plurality of internal electrodes **20** is formed on one of the plurality of dielectric layers **11**, forming the other one of the plurality of dielectric layers **11** on one of the plurality of dielectric layers **11** while leaving a space (e.g., at least a portion of the margin taken in the L direction) in which one of the plurality of internal electrodes **20** is not formed.

[0088] The space (e.g., at least a portion of the margin taken in the L direction) in which one of the plurality of internal electrodes **20** is not formed may work as a limitation in maintaining the shape of the at least one dielectric layer **11**, but since the guide frame **40** may maintain the shape of the at least one dielectric layer **11**, $\{(\theta_1+\theta_2)/2\}$ in Table 1 may be reduced to more than 0 degrees and less than 15 degrees, or $\{T_{sub.B}/(T_{sub.E}+2*T_{sub.D})\}$ in Table 2 may increase to 0.8 or more and less than 1. Also, since the guide frame **40** may maintain the shape of the at least one dielectric layer **11**, the first and second air gaps illustrated in FIG. 4 may be formed, but the method for manufacturing a multilayer capacitor according to an example embodiment is not limited thereto.

[0089] Referring to FIG. 7B, the dielectric **51** may be sprayed from the dielectric inkjet printhead **50** to at least a portion of the space (e.g., at least a portion of the margin taken in the L direction) in which the one of the plurality of internal electrodes **20** is not formed.

[0090] Referring to FIGS. 7C and 7D, the size of the at least one internal electrode **20** for the guide frame **40** may increase. For example, the size of the at least one internal electrode **20** may increase

or the size of the guide frame **40** may decrease. Accordingly, the cutting process may not be performed.

[0091] Referring to FIG. 7D, in the process **110-3d** of forming at least one internal electrode may include forming at least one internal electrode **20** such that at least a portion of each side surface thereof may be in contact with at least two surfaces of the guide frame **40**. In example embodiments, the side margin layer may be formed on two side surfaces of at least one dielectric layer **11** after the guide frame **40** is separated, and the side margin layer may be at least a portion of the margin region **114** illustrated in FIG. 1.

[0092] FIG. 8 is a perspective diagram illustrating a state before a guide frame is separated from a structure (a state in which the structure is able to be compressed) in which at least one dielectric layer and at least one internal electrode are laminated with respect to a method of manufacturing a multilayer capacitor according to an example embodiment.

[0093] Referring to FIG. 8, the method of manufacturing a multilayer capacitor according to an example embodiment may further include an additional process **110-4** such as compressing or baking in example embodiments.

[0094] That is, before the processes illustrated in FIGS. 9A and 9B, the structure in which at least one dielectric layer **11** and at least one internal electrode are laminated may be compressed and may be baked in a first direction (e.g., T direction). In example embodiments, the laminate structure may further include an upper cover layer and/or a lower cover layer illustrated in FIG. 1.

[0095] FIG. 9A is a perspective diagram illustrating a separation process of a method of manufacturing a multilayer capacitor according to an example embodiment.

[0096] Referring to FIG. 9A, the method of manufacturing a multilayer capacitor according to an example embodiment may include a process **110-5a** of separating at least two surfaces of a guide frame from at least one dielectric layer **11**.

[0097] When the guide frame includes a lower surface, the guide frame may be configured such that at least four surfaces may be separated from a lower surface. That is, only a portion of the guide frame may be separated from the at least one dielectric layer **11**.

[0098] FIG. 9B is a perspective diagram illustrating a cutting process of a method of manufacturing a multilayer capacitor according to an example embodiment.

[0099] Referring to FIG. 9B, the method of manufacturing a multilayer capacitor according to an example embodiment may include, after the process **110-5a** of separating, a process **110-5b** of cutting the structure in which at least one dielectric layer **11** and at least one internal electrode are laminated,

[0100] For example, the laminate structure may be cut along cut-out surfaces CUT1, CUT2, and CUT3 to be divided by the number (e.g., six) of the internal electrodes **20** illustrated in FIGS. 7A and 7B.

[0101] According to the aforementioned example embodiments, the multilayer capacitor and the method of manufacturing the same may be advantageous for miniaturization for performance (e.g., capacitance, manufacturing cost, reliability, withstand voltage, and mounting efficiency).

[0102] While the example embodiments have been illustrated and described above, it will be apparent to those skilled in the art that modifications and variations could be made without departing from the scope of the present invention as defined by the appended claims.

Claims

1. A multilayer capacitor, comprising: a body including a laminate structure in which at least one first internal electrode and at least one second internal electrode are alternately laminated in a first direction with at least one dielectric layer interposed therebetween; and first and second external electrodes disposed on the body and spaced apart from each other to be connected to the at least one first internal electrode and the at least one second internal electrode, respectively, wherein a

thickness of each of the at least one first internal electrode and the at least one second internal electrode, defined as $T_{sub.E}$, is 0.25 μm or less, wherein a first air gap is disposed between the at least one second internal electrode and the first external electrode in a second direction in which the first and second external electrodes oppose each other, wherein a second air gap is disposed between the at least one first internal electrode and the second external electrode in the second direction, wherein, on one surface of the body taken in the first direction, a slope, taken in the second direction, of a portion of the one surface of the body in an overlapping portion between the at least one second internal electrode and the first external electrode in the first direction is θ_1 , wherein, on the one surface of the body in the first direction, a slope, taken in the second direction, of a portion of the one surface of the body in an overlapping portion between the at least one first internal electrode and the second external electrode in the first direction is θ_2 , and wherein $\{(\theta_1+\theta_2)/2\}$ is greater than 0 degree and less than 15 degrees.

2. The multilayer capacitor of claim 1, wherein the at least one first internal electrode includes a plurality of first internal electrodes, wherein the at least one second internal electrode includes a plurality of second internal electrodes, wherein a thickness of the at least one dielectric layer in a portion overlapping a center of the body in the first direction is defined as $T_{sub.D}$, wherein a thickness obtained by dividing a sum of a distance between adjacent ones of the plurality of first internal electrodes in an area between the plurality of second internal electrodes and the first external electrode and a distance between adjacent ones of the plurality of second internal electrodes in an area between the plurality of first internal electrodes and the second external electrode by two is defined as $T_{sub.B}$, and wherein a ratio of $T_{sub.B}$ to $(T_{sub.E}+2*T_{sub.D})$ is more than or equal to 0.8 and less than 1.

3. The multilayer capacitor of claim 2, wherein $T_{sub.B}$ and $(T_{sub.E}+2*T_{sub.D})$ are measured from a portion of the plurality of first and second internal electrodes including a 2% point of a distance from a portion most adjacent to the one surface of the body to a portion farthest from the one surface of the body in the first direction.

4. The multilayer capacitor of claim 1, wherein a length of the body in the second direction is less than 800 μm , and wherein a width of the body in a third direction, perpendicular to the first and second directions, is less than 400 μm .

5. The multilayer capacitor of claim 4, wherein $T_{sub.E}$ is 0.2 μm or more and 0.25 μm or less.

6. A multilayer capacitor, comprising: a body including a laminate structure in which a plurality of first internal electrodes and a plurality of second internal electrodes are alternately laminated in a first direction with at least one dielectric layer interposed therebetween; and first and second external electrodes disposed on the body and spaced apart from each other in a second direction to be connected to the plurality of first internal electrodes and the plurality of second internal electrodes, respectively, wherein a thickness of each of the plurality of first and second internal electrodes, defined as $T_{sub.E}$, is 0.25 μm or less, wherein the body further includes a first side margin portion interposed between ends of the plurality of second internal electrodes and the first external electrode in the second direction, and a second side margin portion interposed between ends of the plurality of first internal electrodes and the second external electrode in the second direction, wherein end portions of the body in the second direction are bent downwardly in the first direction, wherein a bent angle of an upper surface of the first side margin portion with respect to a center of one surface of the body in the first direction is θ_1 , and a bent angle of an upper surface of the second side margin portion with respect to the center of the one surface of the body is θ_2 , wherein $\{(\theta_1+\theta_2)/2\}$ is greater than 0 degree and less than 15 degrees, and wherein an average distance, defined as $T_{sub.B}$, between adjacent ones of the plurality of first internal electrodes at the first side margin portion and between adjacent ones of the plurality of second internal electrodes at the second side margin portion is less than a distance between adjacent ones of the plurality of first or second internal electrodes at a center portion of the body.

7. The multilayer capacitor of claim 6, wherein a thickness of the at least one dielectric layer at the

center portion of the body is defined as $T_{sub.D}$, and wherein a ratio of $T_{sub.B}$ to $(T_{sub.E} + 2 * T_{sub.D})$ is more than or equal to 0.8 and less than 1.

8. The multilayer capacitor of claim 7, wherein $T_{sub.B}$ and $(T_{sub.E} + 2 * T_{sub.D})$ are measured from a portion of the plurality of first and second internal electrodes including a 2% point of a distance from a portion most adjacent to the one surface of the body to a portion farthest from the one surface of the body in the first direction.

9. The multilayer capacitor of claim 6, wherein a length of the body in the second direction is less than 800 μm , wherein a width of the body in a third direction, perpendicular to the first and second directions, is less than 400 μm , and wherein $T_{sub.E}$ is 0.2 μm or more and 0.25 μm or less.
