In the roll-compaction method a feedstock comprising ceramic powder and other additives [e.g. binders, dispersants, plasticisers] is forced through two counter-rotating rollers, and is compacted sufficiently to form an adherent tape.

Both methods have problems in producing large and thick tape.

The doctor blade method is difficult to use in producing thick tape due to the high binder and solvent content of the slurry which has to be removed in drying and firing. Commercial green tape rarely exceeds 1mm in thickness and 300mm in width.

The roll compaction method can produce thick tape but it is difficult to produce large sizes due to pressure limitation of the roller. In addition, roll compaction tape shows non-uniform shrinkage during sintering. For example, an alumina tape produced by roll-compaction can have a shrinkage factor of 1.15 along the rolling direction and 1.19 perpendicular to the rolling direction due to the pressure difference during roll compaction. Non-uniform shrinkage would be a major problem during the manufacturing of wafer handling devices, due to the precision dimensional control needed for wafer handling devices.

Embodiments of the present invention disclose an improved HTCC processing method to produce large and thick multilayer ceramic devices, for example a heater and chuck.

Summary of Invention

Embodiments of the present invention consist of forming sheets by dry pressing powders of the sort conventionally used in roll compaction and using these sheets to form articles by HTCC processing to a precise thickness and density.

According to a first aspect of the present invention, there is provided a method of forming one or more high temperature co-fired ceramic articles having at least one orthogonal X and Y dimension greater than 200mm and an orthogonal dimension Z less than the X and Y dimensions , comprising the steps of: forming one or more green compacts, by a process comprising dry pressing a powder comprising ceramic and organic binder to form a green compact; disposing a conductor or conductor precursor to at least one surface of at least one of the one or more green compacts to form at least one patterned green compact; assembling an insulating green material to the at least one patterned green compact to form a laminated assembly; isostatically pressing the laminated assembly to form a pressed laminated assembly; firing the pressed laminated assembly at a temperature sufficient to sinter the one or more green compacts and the insulating green material together to form a monolithic ceramic body with one or more electrically conductive electrodes embedded therein ; wherein step (e) further comprises the steps of; supporting the pressed laminated assembly on an insulting setter having at least one substantially flat surface; mounting an insulating weight having at least one substantially flat surface on the pressed laminated assembly such that the pressed laminated assembly lies between the substantially flat surface of the insulating setter and the insulating weight .

According to a second aspect of the present invention, there is provided an electrostatic chuck, comprising: a ceramic insulating base; a dielectric layer having a thickness less than 1mm, one or more electrically conductive electrodes disposed between said insulating base and said dielectric top layer; wherein the electrostatic chuck is a monolithic ceramic body having the one or more electrically conductive electrodes embedded therein; wherein the electrostatic chuck has at least one orthogonal X and Y dimension greater than 200mm and an orthogonal dimension Z less than the X and Y dimensions.

In comparison to roll compaction, dry pressing the ceramic powder formed by powder compaction on uniaxial presses provides more uniform shrinkage, thus making this technique suitable for manufacturing components that not only necessitate a high degree of dimensional tolerance but can be made to relatively large sizes or diameter, e.g. in the manufacture of electrostatic chucks.

One example of dry pressing according to one embodiment of the present invention is uniaxial pressing or die pressing or iso-pressing or a combination thereof. Co-firing the laminated assembly provides seamless bonding between the plurality of green compact so creating a monolithic insulating ceramic body with one or more electrical conductors embedded therein.

Preferably, the step of disposing a conductor or conductor precursor comprises the step of applying a metallization layer to at least one surface of at least one of the plurality of green compacts to form the at least one patterned green compact. Other examples include applying a foil to at least one surface of the green compact or even a conductor precursor such as a printing ink composed of a metal precursor on the layers, e.g. ink jet printing, which subsequently converts to a metallic conductor during firing. Where a foil pattern or wires is deposited on the layers, the application of pressure embeds the foil within the green ceramic layer so as to effectively "mould" the green ceramic around the foil pattern. To create one more holes or gaps (pathways) in the fired article such as for the purpose of providing vias or access areas in the fired part for electrical connection to the conductor or metallization layer, preferably step c) further comprises positioning one or more shapes formed from a fugitive material between at least two of the green compacts, whether either or both is patterned or not; subsequent to step d) the fugitive material is removed to leave hollow channels within the article. This removes the need to punch or drill one or more holes in the green and/or fired part respectively and thereby, reducing the number of manufacturing steps in the fabrication of the part for use as an electrostatic chuck or heater. The use of a fugitive

embodiment of the present invention, the dielectric layer is optionally fabricated form a tape cast material. Preferably, to provide uniformity in terms of shrinkage between the dielectric layer and the insulating base particularly during debinding and/or firing, preferably the dielectric layer is composed of the same green compact forming the insulating base. Fabricating the ESC from layers formed by different processes (e.g. tape casting), in particular the dielectric layer, runs the risk of differential shrinkage between the dielectric layer and the remainder of the insulating ceramic body during debinding or firing which could be due to their different binder content, different internal stresses through their particular fabrication process, leading to possible delamination of the dielectric layer from the rest of the insulating body. By fabricating the dielectric layer from the same processing technique and material as the insulating base, e.g. green compact, removes this differential shrinkage leading to a more homogenous fired part. To achieve the necessary thinness of the dielectric layer, once fired one face of the fired (monolithic) part is machined down to the required thickness necessary to interact with the metallization forming the electrodes embedded therein to create an electrostatic field when a voltage is applied to the electrodes.

In some applications of the electrostatic chuck, it is necessary to control the temperature of the substrate. Preferably, the insulating base comprises a heater, more preferably the heater comprises one or more electrical conductors forming electrical heating elements embedded therein.

In an alternative embodiment of the present invention, the high temperature co-fired ceramic article is a heater comprising an insulating ceramic body with one or more conductors forming electrical heating elements embedded therein.

When the fired laminated assembly is used as an electrostatic chuck, the exterior surface or face of the co-fired ceramic part would need to be substantially flat so as to ensure that there is maximum surface area contact between the substrate wafer and the support surface of the dielectric layer. In order to provide the flatness of the co-fired ceramic part, an embodiment of the present invention provides a method of flat firing an article comprising the steps of;

a. supporting the article on an insulating setter having at least one substantially flat surface;

CLAIMS

1. A method of forming one or more high temperature co-fired ceramic articles having at least one orthogonal X and Y dimension greater than 200mm and an orthogonal dimension Z less than the X and Y dimensions , comprising the steps of:-

a) forming one or more green compacts, by a process comprising dry pressing a powder comprising ceramic and organic binder to form a green compact;

b) disposing a conductor or conductor precursor to at least one surface of at least one of the one or more green compacts to form at least one patterned green compact;

c) assembling an insulating green material to the at least one patterned green compact to form a laminated assembly;

d) isostatically pressing the laminated assembly to form a pressed laminated assembly;

e) firing the pressed laminated assembly at a temperature sufficient to sinter the one or more green compacts and the insulating green material together to form a monolithic ceramic body with one or more electrically conductive electrodes embedded therein ; wherein step (e) further comprises the steps of;

i. supporting the pressed laminated assembly on an insulting setter having at least one substantially flat surface;

ii. mounting an insulating weight having at least one substantially flat surface on the pressed laminated assembly such that the pressed laminated assembly lies between the substantially flat surface of the insulating setter and the insulating weight .

2. The method as claimed in Claim 1, wherein said at least one surface of the setter and/or weight is/are machined substantially flat .

3. The method as claimed in Claim 1 or 2, wherein step (b) comprises the step of applying a metallization layer to at least one surface of at least one of the one or more of the green compacts to form the at least one patterned green compact

4. The method as claimed in any of the preceding Claims, in which:-

step (c) further comprises positioning one or more shapes formed from a fugitive material between at least two of the green compacts, whether either or both is patterned or not;

subsequent to step (d or e) the fugitive material is removed to leave hollow channels within the article.

5. The method as claimed in any of Claims 1 to 4, in which the articles have an orthogonal dimension Z less than 10% of the longer of the X and Y dimension.

6. The method as claimed in any of Claims 1 to 4, in which the articles have an orthogonal dimension Z less than 10% of the shorter of the X and Y dimension.

7. The method as claimed in any of Claims 1 to 6, in which the powder is a spray dried powder.

8. The method as claimed in any of the preceding Claims, wherein the insulative green material is formed by tape casting.

9. The method as claimed in any of the preceding Claims, in which the insulative green material forms an outermost layer of the laminated assembly.

10. The method as claimed in any of the preceding Claims, in which the insulative green material has a thickness less than half that of any one of the plurality of green compacts or patterned green compacts.

11. The method as claimed in any of the preceding Claims, in which the orthogonal X and Y dimensions are both 300mm or more.

12. The method as claimed in any of the preceding Claims, in which both orthogonal X and Y dimensions are both 450mm or more.

13. The method as claimed in any of the preceding claims, wherein the one or more electrodes is a continuous unperforated metal conductor.

14. An electrostatic chuck, comprising:

a ceramic insulating base;

a dielectric layer having a thickness less than 1mm,

one or more electrically conductive electrodes disposed between said insulating base and said dielectric top layer; wherein the electrostatic chuck is a monolithic ceramic body having the one or more electrically conductive electrodes embedded therein ;

wherein the electrostatic chuck has at least one orthogonal X and Y dimension greater than 200mm and an orthogonal dimension Z less than the X and Y dimensions.

15. The electrostatic chuck as claimed in claim 14, in which at least one orthogonal X and Y dimension is 300mm or more.

16. The electrostatic chuck as claimed in claim 14 or 15, in which the insulating based comprises a heater.

17. The electrostatic chuck as claimed in any of the Claims 14 to 17, in which one or more electrical conductors is/are embedded within the insulating base.

18. The electrostatic chuck as claimed in any of ther claims 14 to 17, in which the insulating base and/or the dielectric layer is a material selected from the group consisting of alumina, titania, zirconia, and alloys containing any of the foregoing.

19. The electrostatic chuck as claimed in any of the claims 14 to 18, in which the one or more electrical electrodes is material selcted from the group consisting of platinum, palladium, gold, tungsten, molybdenum, niobium, tantalum, and alloys of any of the foregoing.

20. The electrostatic chuck as claimed in any of the claims 14 to 19, in which the dielectric layer has a thickness of substantially less than 0.5mm or less than 0.25mm, or less than 0.1mm.