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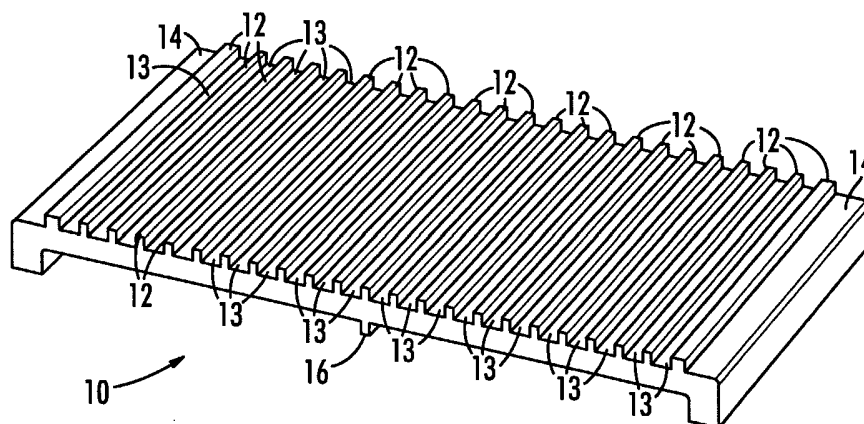
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(54) Title: LOW MASS KILN FURNITURE



(57) Abstract: Kiln furniture (10) with a porous ceramic with a density of no more than 40% of theoretical density and a sodium content of less 300 ppm. The kiln furniture also has a top surface (12) comprising ware locators (13) and shelves (14) on at least two edges wherein the shelves are below the top surface. A bottom surface (11) has ledges (15) and at least one central support (16) such that when the kiln furniture is stacked each ledge rests on a shelf and said at least one central support rests on the top surface.



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TITLE**LOW MASS KILN FURNITURE****FIELD OF THE INVENTION**

[0001] The present invention is related to kiln furniture, such as saggers, particularly
5 suited for use with electrical components. More particularly, the present invention is
directed to kiln furniture with low sodium content, low mass and structured to
accommodate stacking without spacers.

BACKGROUND OF THE INVENTION

[0002] The use of kiln furniture, or saggers, for firing ceramic materials is well
10 known. Green ceramic material is transported through a kiln in, or on, a sagger whereby
the green ceramic is sintered to form the ceramic part of choice. One common
application is the formation of ceramic electrical components and electrical insulating
components.

[0003] Dense alumina is commonly employed for formation of kiln furniture. The
15 furniture can be designed with complex geometries to compliment the shape of the ware
that is supported. Fused alumina is typically cast to near net shape and then lightly
machined to achieve the required tolerances. Other common techniques such as slip-
casting, pressing and extrusion can also be used to manufacture dense kiln furniture. In
all of these cases, it is difficult to perform a considerable amount of machining due to
20 the high density of the ceramic. Therefore, parts must be near net shape and close to the
required tolerances to minimize machining.

[0004] Current formulations of dense ceramic kiln furniture contain relatively high
levels of sodium, and other impurities. Through diligent research, these impurities have
been found to migrate to the electrical component on the furniture during firing, which
25 contaminates the part. Sodium, for example, is known to degrade the electrical
properties of some electrical components. Oxygen sensors, for example, contaminated
with sodium can display increased voltage leakage.

[0005] Dense ceramic kiln furniture is also very heavy. The high weight severely
limits automated furnace loading and leads to a host of manufacturing difficulties
30 related to hand manipulation of heavy elements. Due to the weight of the furniture,
multiple piece stacking systems are required to support the furniture and to inhibit
failure. As would be apparent, the increased amount of furniture physically limits the
amount of ware that can be transported through the kiln, thereby decreasing
productivity.

[0006] High density correlates with high thermal mass. The high thermal mass increases the amount of energy, and time, required for each heating cycle since both the ware and the furniture must be heated and cooled. The high-density furniture also must be heated slowly to prevent thermal shock. Alternatively, high strength materials must be used such that the furniture can withstand the thermal shock. If the dense furniture is damaged, it is typically catastrophic.

[0007] There has been a long felt desire for low-density kiln furniture. There has also been a long felt desire for kiln furniture that has low sodium content. As described herein, the development of low-density kiln furniture has led to unique designs which greatly reduces the total mass of kiln furniture required to support a given amount of ware in the kiln, thereby greatly increasing the overall efficiency of the firing process. Alternatively, the amount of ware fired within a given footprint can be increased, thereby greatly increasing overall efficiency of the firing process.

SUMMARY OF THE INVENTION

[0008] It is an object of the present invention to provide kiln furniture with a low density and suitable strength.

[0009] It is another object of the present invention to provide kiln furniture that can be easily manufactured by machining to final tolerance instead of by forming at near net shape.

[0010] A particular feature of the present invention is the ability to fire electrical components with minimal degradation of electrical components as typically observed.

[0011] These and other advantages, as will be realized, are provided in kiln furniture with a porous ceramic having a density of no more than 40% of theoretical density and a sodium content of less than 300 ppm.

[0012] Yet another embodiment is provided in kiln furniture with a top surface having ware locators and shelves on at least two edges wherein the shelves are below the top surface. A bottom surface is provided comprising ledges and at least one central support. When the kiln furniture is stacked, each ledge rests on a shelf and at least one central support rests on said top surface.

[0013] Yet another embodiment is provided in a process for forming kiln furniture comprising:

a) forming a monolith comprising ceramic precursor and a spacer;

- b) heating the monolith to volatilize the spacer and sinter the ceramic precursor thereby forming a porous ceramic monolith with a density of no more than 40% of theoretical density and a sodium content of less than 300 ppm;
- c) removing material from a top surface of the monolith to form ware locators, and
- 5 shelves on at least two edges wherein the shelves are below the top surface; and
- d) removing material from a bottom surface of the monolith to form ledges and at least one central support.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Fig. 1 is a perspective view of preferred kiln furniture, in the form of a
10 sagger.

[0015] Fig. 2 is a bottom view of the sagger of Fig. 1.

[0016] Fig. 3 is a side view of multiple stacked saggars as employed during use.

DETAILED DESCRIPTION OF THE INVENTION

[0017] The invention is directed to a low-density, complex-shaped ceramic kiln
15 furniture designed to compliment the shape of the ware that is supported. The improved kiln furniture comprises a low mass and high strength, thereby allowing the formation of stackable furniture without requiring spacers. The kiln furniture also has a low sodium content, thereby making the furniture particularly suitable for supporting electronic components.

20 [0018] The present invention will be described with reference to the various figures representing an integral part of the specification without limit thereto. Throughout the description, similar elements will be numbered accordingly.

[0019] Unlike prior art kiln furniture, the present invention allows for the formation of a monolith from which the kiln furniture can be machined. The ability to machine the
25 kiln furniture instead of forming near-net shapes is due to the use of low-density material. The machining can be done by water jet cutting, machining with metal or diamond tools, or any technique typically employed for machining porous ceramic. Most preferably the monolith is machined into kiln furniture by machining with diamond tools. The ability to easily machine the low-density ceramic eliminates the
30 necessity of molds and the cost associated therewith.

[0020] The monolith is preferably prepared from alumina, alumina-silica, yttria alumina zirconia, aluminum titanate, zirconium toughened alumina, zirconia, mullite, magnesia or cordierite of high purity electronic grade. Most preferably, the ceramic precursor is high purity electronic grade zirconium toughened alumina.

[0021] The ceramic precursor is combined with a volatile spacer, which, upon heating, volatilizes leaving a network of connected voids in the ceramic. The volatile spacer can be a ceramic fiberboard or individual materials such as spheres.

5 [0022] A preferred process for manufacturing the porous ceramic monolith involves forming a dough-like ceramic precursor comprising spherically shaped voids therein into the desired monolithic shape and firing as described in U.S. Pat. No. 6,773,825.

[0023] A mixture of ceramic or metal particles and pliable organic spheres is prepared into a liquid, or suspension, and the mixture is formed into a shaped article. The shaped article is dried and fired so that the particles are bonded by sintering. The organic spheres and other organic additives are volatilized. The spheres are preferably low density and more preferably hollow. The size of the voids may be preselected by selecting the appropriate polymer spheres. The porosity is also easily controlled by the number of polymer spheres added. It is most preferred that the polymer spheres are each in contact with at least two other spheres such that a network of voids is created in the monolith.

[0024] Ceramic precursors typically include a solvent, such as water, organic binders, and materials, which upon heating form a ceramic. The ceramic precursor is preferably a ceramic slurry which is thixotropic, has a reasonable degree of fluidity and a rheology such that the slurry will tend to stay in place when work is not applied to it. This is typically referred to as a high yield strength.

[0025] The article is typically dried by suitable means, such as air drying, accelerated drying at a temperature of about 100°C to 600°C for about 15 minutes to 6 hours, microwave drying or the like. After drying, the material is fired at elevated temperatures of about 1400 to 1650°C to sinter the ceramic and volatilize the organics. Firing times at or near the peak temperature for at least 5 minutes is preferred and at least 10-15 minutes is more preferred.

[0026] After sintering the monolith is machined to the desired shape.

[0027] The monolith, and kiln furniture, preferably has a density of no more than 40% of theoretical density, wherein theoretical density is the theoretical maximum density of the ceramic without voids. More preferably, the kiln monolith and subsequent kiln furniture has a density of no more than 35 % of theoretical density. Below about 10% of theoretical density the strength of the furniture is insufficient. About 10-35% of theoretical density is most preferred. For comparison purposes, dense ceramic kiln furniture typically has a density in excess of 80% of theoretical density.

[0028] The kiln furniture has low levels of impurity, thereby making them particularly suitable for use with electronic components. Previously available kiln furniture has a sodium level of 600 ppm or higher. It is preferred that the sodium level be no more than 300 ppm with lower sodium levels being more preferred. More preferably, the kiln furniture has a sodium level of 200 ppm or less and even more preferably the kiln furniture has a sodium level of 100 ppm or less.

[0029] A particular advantage of the low-density kiln furniture is the minimal impact observed during failure. Because high-density kiln furniture is inherently stronger than low-density furniture, it can withstand a greater thermal gradient without failing, but this also correlates to a significantly higher level of strain energy. Thus, when high-density kiln furniture fails, the result is usually catastrophic.

[0030] Kiln furniture of the present invention is illustrated in top perspective view in Fig. 1 and bottom perspective view in Fig. 2. The kiln furniture, represented at 10 as a sagger, comprises a bottom surface, 11, and a top surface, 12. The top surface comprises a multiplicity of ware locators, 13, in the form of depressions in the top surface, 12. It would be apparent that ware is placed in the depression and restricted from moving laterally. Shelves, 14, are formed as depressions below the surface, 12, on each side of the kiln furniture the purpose of which will be described below. The bottom of the kiln furniture comprises ledges, 15, and at least one central support, 16. When stacked each ledge, 15, rest on a shelf, 14, as seen in side view in Fig. 3. The central support, 16, rest on the top surface, 12, to support the combined weight of the furniture and ware. In one embodiment, the ledge and each central support is preferably coplanar such that when the furniture is resting on a flat surface, the weight is supported on each surface. In another embodiment, the ledge and each central support are of sufficient length to simultaneously rest on the relevant portion of a lower furniture piece such that the weight of the furniture and ware is supported. It is preferred that the width of the ledge and the width of the shelf are approximately the same such that when the ledge is resting on the shelf sideways, movement of the furniture is restricted.

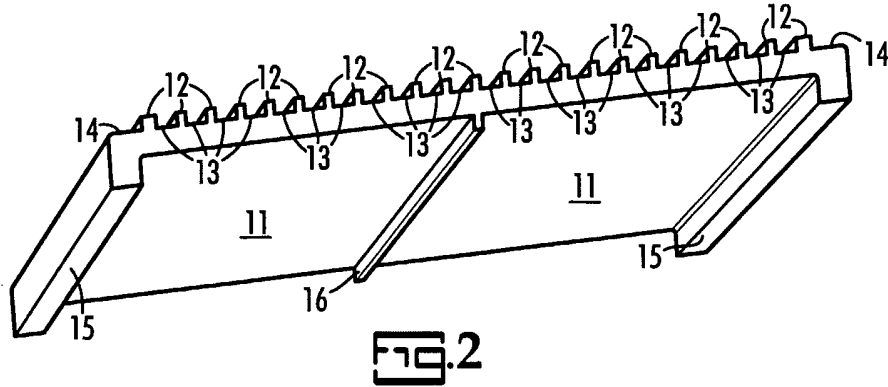
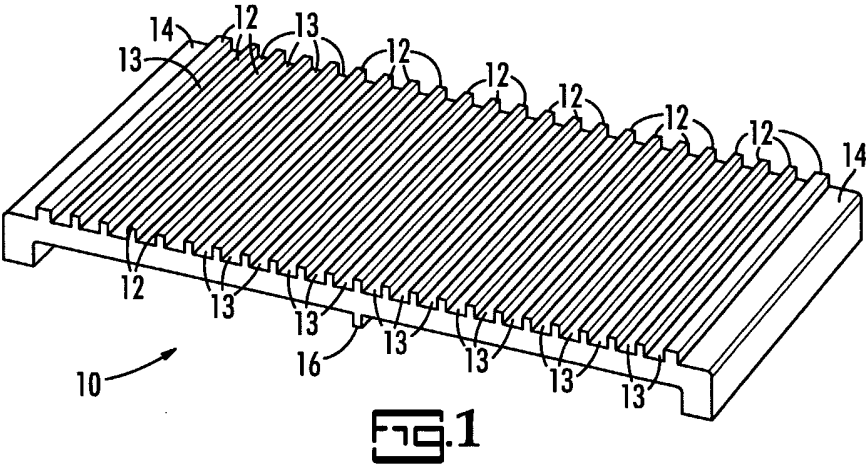
[0031] The invention has been described with particular emphasis on the preferred embodiments without limit thereto. The invention is more particularly set forth in the claims appended hereto.

Claimed is:

1. Kiln furniture comprising a porous ceramic with a density of no more than 40% of theoretical density and a sodium content of less than 300 ppm.
2. The kiln furniture of claim 1 wherein said sodium content is less than 200 ppm.
- 5 3. The kiln furniture of claim 2 wherein said sodium content is less than 100 ppm.
4. The kiln furniture of claim 1 wherein said porous ceramic is selected from alumina, alumina-silica, yttria zirconia alumina, aluminum titanate, zirconium toughened alumina, zirconia, mullite, magnesia or cordierite.
5. The kiln furniture of claim 4 wherein said porous ceramic is zirconium
10 toughened alumina.
6. The kiln furniture of claim 1 further comprising:
a top surface comprising ware locators, and shelves on at least two edges
wherein said shelves are below said top surface;
a bottom surface comprising ledges and at least one central support;
15 wherein when said kiln furniture is stacked each said ledge rest on shelf of said
shelves and said at least one central support rest on said top surface.
7. Kiln furniture comprising:
a top surface comprising ware locators, and shelves on at least two edges
wherein said shelves are below said top surface;
20 a bottom surface comprising ledges and at least one central support;
wherein when said kiln furniture is stacked each said ledge rest on shelf of said
shelves and said at least one central support rest on said top surface.
8. The kiln furniture of claim 7 comprising a porous ceramic.
9. The kiln furniture of claim 8 wherein said porous ceramic has a density of no
25 more than 40% of theoretical density.
10. The kiln furniture of claim 8 wherein said porous ceramic has a density of no
more than 40% of theoretical density.
11. The kiln furniture of claim 8 wherein said porous ceramic has a sodium content
of less than 300 ppm.
- 30 12. The kiln furniture of claim 11 wherein said sodium content is less than 200 ppm.
13. The kiln furniture of claim 12 wherein said sodium content is less than 100 ppm.
14. The kiln furniture of claim 7 wherein said porous ceramic is selected from alumina, alumina-silica, yttria zirconia alumina, aluminum titanate, zirconium toughened alumina, zirconia, mullite, magnesia or cordierite.

15. The kiln furniture of claim 14 wherein said porous ceramic is zirconium toughened alumina.
16. A process for forming kiln furniture comprising:
forming a monolith comprising ceramic precursor and a spacer;
5 heating said monolith to volatilize said spacer and sinter said ceramic precursor thereby forming a porous ceramic monolith with a density of no more than 40% of theoretical density and a sodium content of less than 300 ppm;
removing material from a top surface of said monolith to form ware locators,
10 and shelves on at least two edges wherein said shelves are below said top surface;
removing material from a bottom surface of said monolith to form ledges and at least one central support.
17. The process for forming kiln furniture of claim 16 wherein said removing material is done by machining with a diamond tool.
18. The process for forming kiln furniture of claim 16 wherein said porous ceramic monolith comprises zirconium toughened alumina.
19. The process for forming kiln furniture of claim 16 wherein said sodium content is less than 100 ppm.

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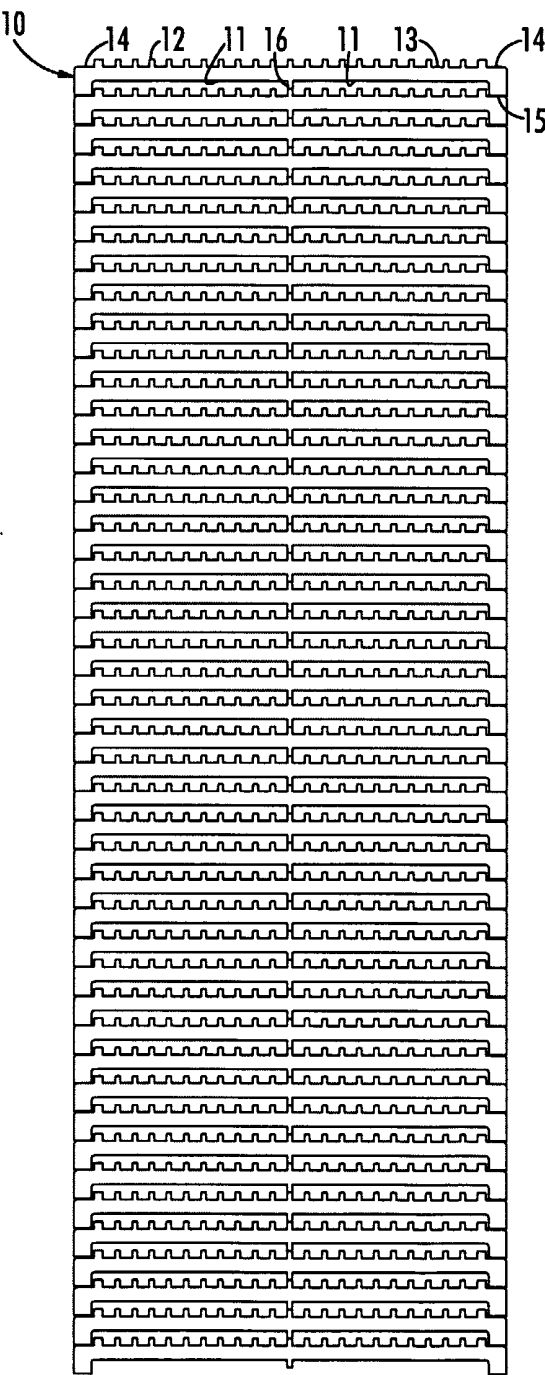


FIG. 3