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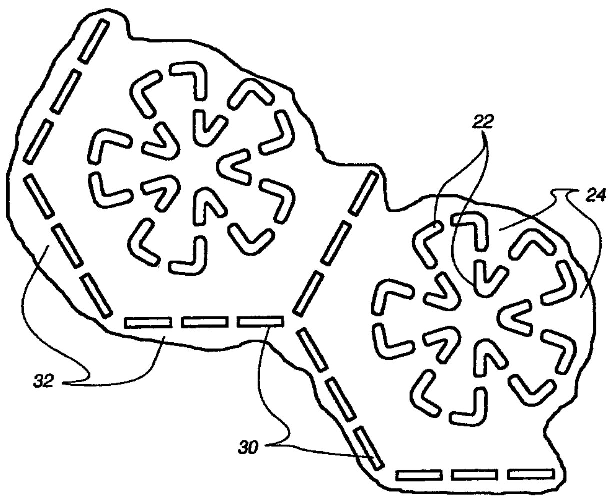
(54) Title: ABUSE-TOLERANT METALLIC PACKAGING MATERIALS FOR MICROWAVE COOKING



(57) Abstract: An abuse-tolerant microwave food packaging material includes repeated sets of metallic foil (22) or high optical density evaporated material segments (24, 30) disposed on a substrate (34). Each set of metallic segments (24, 30) is arranged to define a perimeter having a length equal to a predetermined ratio of the operating, or effective wavelength of a microwave oven (78). The repeated sets of segments act both as a shield to microwave energy and as focusing elements for microwave energy when used in conjunction with food products yet remaining electrically safe in the absence of the food products.

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ABUSE-TOLERANT METALLIC PACKAGING MATERIALS FOR MICROWAVE COOKING

BACKGROUND

The present invention relates to an improved microwave-interactive cooking package. In particular, the present invention relates to high efficiency, safe and abuse-tolerant susceptor and foil materials for packaging and cooking microwavable food.

Although microwave ovens have become extremely popular, they are still seen as having less than ideal cooking characteristics. For example, food cooked in a microwave oven generally does not exhibit the texture, browning, or crispness which are acquired when food is cooked in a conventional oven.

A good deal of work has been done in creating materials or utensils that permit food to be cooked in a microwave oven to obtain cooking results similar to that of conventional ovens. The most popular device being used at present is a plain susceptor material, which is an extremely thin (generally 60 to 100Å) metallized film that heats under the influence of a microwave field. Various plain susceptors (typically aluminum, but many variants exist) and various patterned susceptors (including square matrix, "shower flower", hexagonal, slot matrix and "fuse" structures) are generally safe for microwave cooking. However, susceptors; do not have a strong ability to modify a non-uniform microwave heating pattern in food through shielding and redistributing microwave power. The quasi-continuous electrical nature of these materials prevents large induced currents (so limiting their power reflection capabilities) or high electromagnetic (E-field) strengths along their boundaries or edges. Therefore their ability to obtain uniform cooking results in a microwave oven is quite limited.

Electrically "thick" metallic materials (e.g., foil materials) have also been used for enhancing the shielding and heating of food cooked in a microwave oven. Foil materials are much thicker layers of metal than the thin metallized films of susceptors. Foil materials, also often aluminum, are quite effective in the prevention of local overheating or hot spots in food cooked in a microwave by redistributing the heating effect and creating surface browning and crisping in the food cooked with microwave energy. However, many designs fail to meet the normal consumer safety requirements by either causing fires, or creating arcing as a result of improper design or misuse of the material.

The reason for such safety problems is that any bulk metallic substance can carry very high induced electric currents in opposition to an applied high electromagnetic field under microwave oven cooking. This results in the potential for very high induced electromagnetic field strengths across any current discontinuity (e.g., across open circuit joints or between the package and the wan of the oven). The larger the size of the bulk metallic materials used in the package, the higher the potential induced current and induced voltage generated along the periphery of the metallic substance metal. The applied E-field strength in a domestic microwave oven might be as high as 15kV/m under no load or light load operation. The threat of voltage breakdown in the substrates of food packages as well as the threat of overheating due to localized high current density may cause various safety failures. These concerns limit the commercialization of bulk foil materials in food packaging.

Commonly owned Canadian Patent No. 2196154 offers a means of avoiding abuse risks with aluminum foil patterns. The structure disclosed addresses the problems associated with bulk foil materials by reducing the physical size of each metallic element in the material. Neither voltage breakdown, nor current overheat will occur with this structure in most microwave ovens, even under abuse cooking conditions. Abuse cooking conditions can include any use of a material contrary to its intended purpose including cooking with cut or folded material, or cooking without the intended food load on the material. In addition, the heating effectiveness of these metallic materials is maximized through dielectric loading of the gaps between each small element which causes the foil pattern to act as a resonant loop (albeit at a much lower Q-factor (quality factor than the solid loop). These foil patterns were effective for surface heating. However, it was not recognized that a properly designed metallic strip pattern could also act to effectively shield microwave energy to further promote uniform cooking.

Commonly owned U.S. Patent Application Serial No. 08/037,909 approaches the problem differently by creating low Q-factor resonant circuits by patterning a susceptor substrate. The low Q-factor operation described in U.S. Patent Application Serial No. 08/037,909 provides only a limited degree of power balancing.

SUMMARY OF THE DISCLOSURE

The present invention relates to an abuse-tolerant microwave packaging material which both shields food from microwave energy to control the occurrence of localized overheating in food cooked in a microwave, and focuses microwave energy to an adjacent food surface.

Abuse-tolerant packaging according to the present invention includes a continuously repeated first set of microwave-interactive metallic segments disposed on a microwave-safe substrate. Each first set of metallic segments define a perimeter equal to a predetermined ratio of an operating wavelength of a microwave oven. The metallic segments can be foil segments, or may be segments of a high optical density evaporated material.

In a first embodiment, the perimeter defined by the metallic segments is approximately equal to a ratio of an operating effective wavelength of a domestic microwave oven. In a second embodiment, the perimeter defined by the metallic segments is approximately equal to one-half the operating wavelength of a microwave oven.

Each segment in the first set is spaced from adjacent segments so as to create a (DC) electrical discontinuity between the segments. Preferably, each first set of metallic segments define a five-lobed flower shape. The five-lobed flower shape promotes uniform distribution of microwave energy to adjacent food by distributing energy from its perimeter to its center.

Preferably, abuse-tolerant packaging according to the present invention includes a repeated second set of spaced metallic segments which enclose each first set of metallic segments and define a second perimeter which is approximately equal to a ratio of an operating microwave resonant wavelength.

A third embodiment of abuse-tolerant packaging according to the present invention includes, in addition to the second set of metallic segments, a repeated third set of spaced metallic segments which enclose each second set of metallic segments and define a perimeter approximately equal to a ratio of an operating microwave wavelength.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram of a pattern repeated in a first embodiment of the present invention;

FIG. 2 is a sectional view of a microwave packaging material according to the present invention;

FIG. 3 is a diagram of a pattern repeated in a second embodiment of the present invention;

FIG. 4 is a diagram of a pattern repeated in a third embodiment of the present invention;

FIG. 5 is a diagram of a sheet of microwave packaging material according to a third embodiment of the present invention; and

FIG. 6 is diagram of a quasi-shielding wall according to the present invention.

DETAILED DESCRIPTION

For a better understanding of the invention, the following detailed description refers to the accompanying drawings, wherein preferred exemplary embodiments of the present invention are illustrated and described.

The present invention relates to an abuse-tolerant, high-heating-efficiency metallic material used in microwave packaging materials. This abuse-tolerant material redistributes incident microwave energy so as to increase reflection of microwave energy while maintaining high microwave energy absorption. A repeated pattern of metallic foil segments can shield microwave energy almost as effectively as a continuous bulk foil material while stiff absorbing and focusing microwave energy on an adjacent food surface. The microwave metallic segments can be made of foil or high optical density evaporated materials. High optical density materials include evaporated metallic films which have an optical density greater than one (optical density being derived from the ratio of light reflected to light transmitted). High optical density materials generally have a shiny appearance, whereas thinner metallic materials, such as susceptor films have a flat, opaque appearance. Preferably, the metallic segments are foil segments.

The segmented foil (or high optical density material) structure prevents large induced currents from building at the edges of the material or around tears or cuts in the material, thus diminishing the occurrences of arcing, charring or fires caused by large induced currents and voltages. The present invention includes a repeated pattern of small metallic segments, wherein each segment acts as a heating element when under the influence of microwave energy. In the absence of a food (dielectric) load, this energy generates only a small induced current in each element and hence a very low field strength close to its surface.

Preferably, the power reflection of the abuse-tolerant material is increased by combining the material in accordance with the present invention with a layer of conventional susceptor film. In this configuration, a high surface heating environment is created through the additional excitement of the susceptor film due to the composite action of food contacting the small metallic segments. When the food contacts the metallic segments of the abuse-tolerant material according to the present invention, the quasi-resonant characteristic of perimeters defined by the metallic segments can stimulate stronger and more uniform cooking. Unlike a full sheet plain susceptor, the present invention can stimulate uniform heating between the edge and center portion of a sheet of material to achieve more uniform heating effect. The average width and perimeter of the pattern of metallic segments will determine the effective heating strength of the pattern and the degree of abuse tolerance of the pattern. However, the power transmittance directly toward the food load through an abuse-tolerant metallic material according to the present invention is dramatically decreased, which leads to a quasi-shielding functionality. In the absence of food contacting the material, according to the present invention, the array effect of the small metallic segments still maintains a generally transparent characteristic with respect to microwave power radiation. Thus, the chances of arcing or burning when the material is unloaded or improperly loaded are diminished.

Preferably, each metallic segment has an area less than 5 mm^2 and the gap between each small metallic strip is larger than 1 mm. Metallic segments of such size and arrangement reduce the threat of arcing which exists under no load conditions in average microwave ovens. When, for example, food, a glass tray, or a layer of plain susceptor film contacts the metallic segments, the capacitance between adjacent metallic segments will be raised as each of these substances has a dielectric constant much larger than a typical substrate on which the small metal segments are located. Of these materials, food has the highest dielectric constant (often by an order of magnitude). This creates a continuity effect of connected metallic segments which then work as a low Q-factor resonate loop, power transmission line, or power reflection sheet with the same function of many designs that would otherwise be unable to withstand abuse conditions. On the other hand, the pattern is detuned from the resonant characteristic in the absence of food. This selectively tuned effect substantially equalizes the heating capability over a fairly large packaging material surface including areas with and without food.

Turning to the drawing figures, FIGS. 1-3 show three respective embodiments of patterns of metallic foil segments according to the present invention. In a first embodiment in accordance with the present invention shown in FIG. 1, a first set of spaced bent metallic segments 22 define a first perimeter, or loop 24. According to the present invention, the length of the perimeter is preferably approximately equal to a multiple of one-half an operating wavelength of a microwave oven (i.e., 0.5λ, 1λ, 1.5λ and so on). The perimeter of a set of segments can be other ratios of the operating wavelength. In the first embodiment, the perimeter 24 is approximately equal to one full operating wavelength of a microwave oven. Preferably the metallic segments 22 are arranged to define a five-lobed flower shape seen in each of the respective embodiments shown in FIGS. 1-3. The five-lobed flower arrangement promotes the even distribution of microwave energy to adjacent food. Metallic segments defining other shapes such as circles, ovals, polygonal shapes and so on are within the scope of the present invention.

Preferably, each first set of metallic segments 22 is accompanied by an enclosing second set of straight metallic segments 30. The second set of metallic segments 30 also preferably define a second perimeter 32 having a length approximately equal to the operating wavelength of a microwave oven. The sets of metallic segments 24, 30 are arranged to define a pattern (not shown in FIG. 1, but described later in connection with FIG. 5), which is continuously repeated to create a desired quasi-shielding effect. Preferably, the outer set of segments (the second set of segments 30 in the first embodiment) define the hexagonal second perimeter 32 with a shape which allows each set of metallic segments 30 to be nested with adjacent second sets of metallic segments 30. Nested arrays of resonant hexagonal loops are described in commonly owned U.S. Patent Application Serial No. 60/037,907 and are discussed in more detail in reference to FIG. 5. The hexagon is an excellent basic polygon to select due to its ability to nest perfectly along with its high degree of cylindrical symmetry. The first and second sets of metallic segments are repeated on a substrate to create the patterned material of the present invention.

The sets of metallic segments 24, 30 can be formed on a microwave transparent substrate by conventional techniques known in the art. One technique involves selective demetalization of aluminum having a foil thickness and which has been laminated to a polymeric film. Such demetalizing procedures are described in commonly assigned U.S. Patent Nos. 4,398,994, 4,552,614, 5,310,976, 5,266,386 and 5,340,436, the disclosures of which are herein incorporated by reference. Alternately, the metallic segments may be formed on a susceptor film (i.e., a metallized polymeric film) using the same techniques. Segments of high optical density evaporated materials can be produced by similar etching techniques or by evaporating the material onto a masked surface to achieve the desired pattern. Both techniques are well known in the art.

FIG. 2 shows a schematic sectional view of metallic segments 30 formed on a substrate 34 and including a susceptor film 36 having a metallized layer 37 and a polymer layer 39 to form a microwave packaging material 38 according to the present invention.

In a second embodiment shown in FIG. 3, a first set of bent metallic segments 40 define a first perimeter 42 having a length equal to one-half an operating wavelength of a microwave. Like the first embodiment, the first perimeter 42 preferably defines a multi-lobed shape in order to evenly distribute microwave energy. The smaller perimeter pattern shown in FIG. 3 has a higher reflection effect under light or no loading than the larger perimeter pattern shown in FIG. 1, at the expense of a proportionate amount of microwave energy absorption and heating power. A second set of metallic segments 44 encloses the first set of metallic segments 40 and defines a second perimeter 46 approximately equal to one-half the operating frequency of a microwave. Preferably, the second set of metallic segments 44 are arranged in a nested configuration and define a hexagonal second perimeter.

A third embodiment of a pattern of metallic segments, in accordance with the present invention, is shown in FIG. 4. The third embodiment includes a third set of metallic segments 60 in addition to first and second sets of metallic segments 62, 64 defining first and second perimeters 63, 65 similar to those in the first embodiment. The third set of segments 60 encloses the second set of metallic segments 64 and define a third perimeter 68. Preferably the third set of segments 60 define a hexagonal third perimeter 68. In the third embodiment, additional metallic segments 70a, b, c are preferably included within each lobe 72 (70a) between each lobe 72 (70b) and at a center 74 (70c) of the five-lobed flower shape defined by the first set of metallic segments 62. The additional metallic segments 70a and b which are arranged between and within the lobes 72 preferably are triangular shaped with a vertex pointing in the direction of the center 74 of the flower shape. The additional segments 70a, b, c further enhance the even distribution of microwave energy, in particular from the edges of the perimeter to the center of the perimeter.

An example of a sheet of microwave packaging material according to the present invention is shown in FIG. 5. A pattern according to the third embodiment shown in FIG. 4 is repeated on a substrate 76 which may be microwave transparent (e.g., paperboard), or include a susceptor film. Preferably, the third set of metallic segments 60 is repeated with the first and second 62, 64 sets of metallic segments in a nested array 78 best seen in FIG. 5. A nested array 78 is an arrangement wherein each of the metallic segments in an outer set of metallic segments is shared by adjacent sets of metallic segments (i.e., one strip of metallic segments divides one first or second set of segments from another first or second set). The nested array 78 contributes to the continuity of the overall pattern and therefore to the quasi-shielding effect of the present invention. Furthermore, outer sets of metallic segments are preferably arranged to define a hexagonal shape to better facilitate a nested array 78 of sets of metallic segments.

Preferably, in the pattern according to the third embodiment shown in FIGS. 4 and 5, the second set of metallic segments 64 defines the second perimeter approximately equal to a multiple of one-half the effective wavelength of microwaves and the third perimeter 68 defined by the third set of metallic segments 60 with a similar, but deliberately altered perimeter length.

Note, the effective wavelength, λeff, of a microwaves in a dielectric material (e.g., food products) is calculated by the formula $\lambda eff = \frac{\lambda o}{\sqrt{\varepsilon}}$. Where λo is the wavelength of microwaves in air and ε is the dielectric constant of the material. According to the present invention, the perimeter of each set of metallic segments is a predetermined ratio of the operating or effective wavelength of a domestic microwave oven. The predetermined ratio is selected based on the properties of the food to be cooked, including the dielectric constant of the food and the amount of bulk heating desired for the intended food. For example, a perimeter of a set of segments can be selected to be about equal to an effective wavelength for a particular food product, or a ratio thereof. Furthermore, a large perimeter or large ratio of the microwave wavelength is used when the material is to be used to cook a food requiring a large amount of bulk heating and a small perimeter or small ratio is used when the material is used to cook food requiring less bulk heating, but more surface heating. Therefore, the benefit of concentric but slightly dissimilar perimeters is to provide good performance across a greater range of food properties (e.g., from frozen to thawed food product).

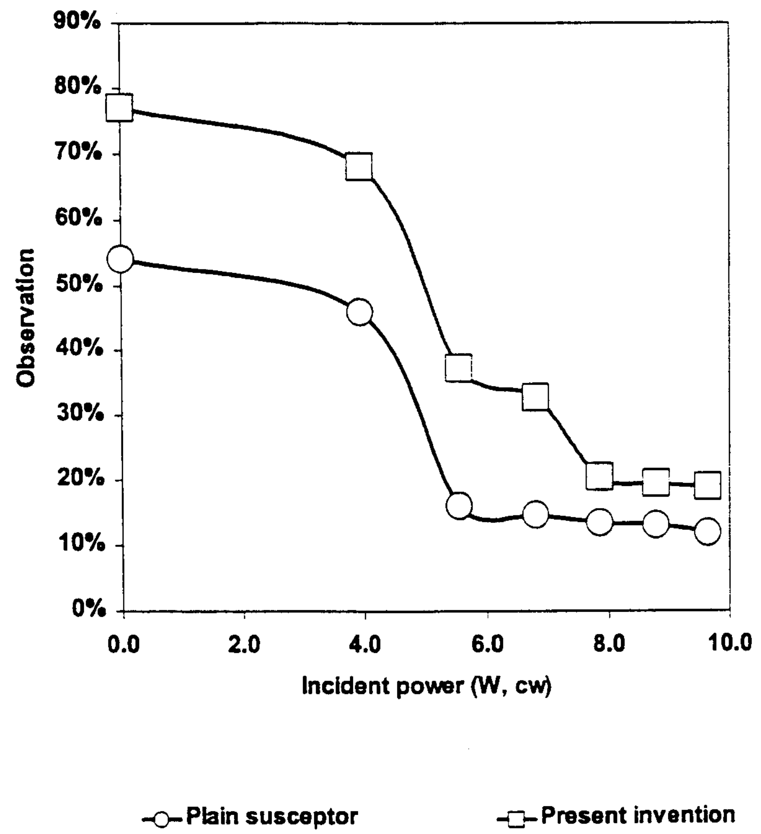
Further advantages and features of the present invention are discussed in the context of the following examples.

graphs show that a susceptor including a segmented foil pattern shown in FIG. 3 performed a higher power reflection than the plain susceptor at E-field strength of 6 kV/m under an open load. The power reflection for plain susceptor reaches 54% at low E-field strength radiation and 16% at high E-field strength radiation. While power reflection of a susceptor laminated to arrays of metallic segments according to the present invention susceptor gives 77% at low E-field radiation and 34% at high E-field radiation. The graphs demonstrate that a material including a repeated pattern of metallic segments according to the present invention has much improved shielding characteristics compared to plain susceptor material.

Example 1

Applied Electric Field (kV/m)	Plain Susceptor Transmission	Reflection	Absorption	Present Invention Transmission	Reflection	Absorption
0.0	6%	54%	40%	1%	77%	21%
3.9	14%	46%	40%	4%	68%	28%
5.6	50%	16%	34%	40%	37%	26%
6.8	57%	15%	29%	45%	33%	21%
7.9	66%	14%	21%	69%	21%	11%
8.8	65%	13%	22%	67%	20%	14%
9.6	66%	12%	22%	67%	19%	14%

Reflection characteristics

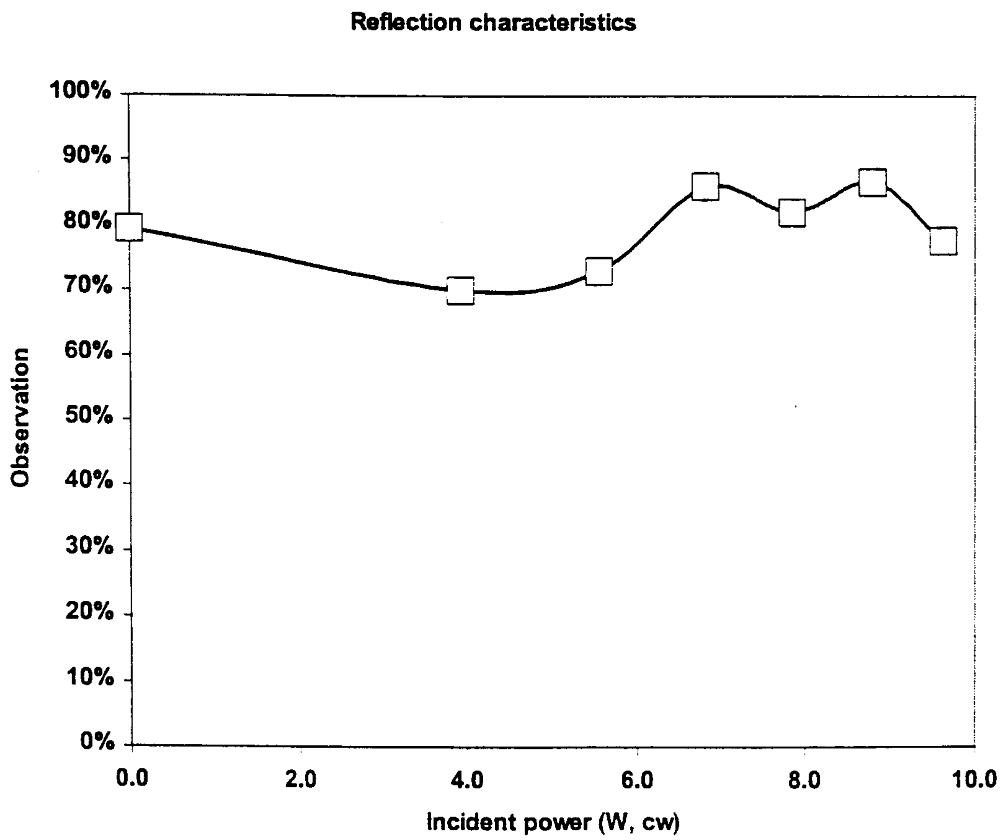


EXAMPLE 2

Example 2 shows RAT performance of the third embodiment of the present invention (FIG. 4) laminated on a susceptor. The measurements were taken with a layer of pastry in contact with the packaging material according to the present invention. The quasi-resonance and power reflection effect occurs when the food is in contact with the metallic segments so as to complete the segmented pattern. The test showed that the power reflection of the present invention 73% to 79% (plain bulk metallic foil has a power reflection of 100%). This test demonstrates that the present invention can be used as a quasi-shielding material in microwave food packaging. The benefit of the present invention is that, unlike bulk metallic foil, it is abuse-tolerant and safe for microwave oven cooking yet still has much of the shielding effect of bulk metallic foil when loaded with food (even under the very high stress conditions of this test).

Example 2

Applied Electric Field (kV/m)	Present Invention Transmission	Reflection	Absorption
0.0	1%	79%	20%
3.9	4%	70%	26%
5.6	4%	73%	23%
6.8	4%	86%	10%
7.9	4%	82%	15%
8.8	12%	87%	1%
9.6	21%	78%	1%



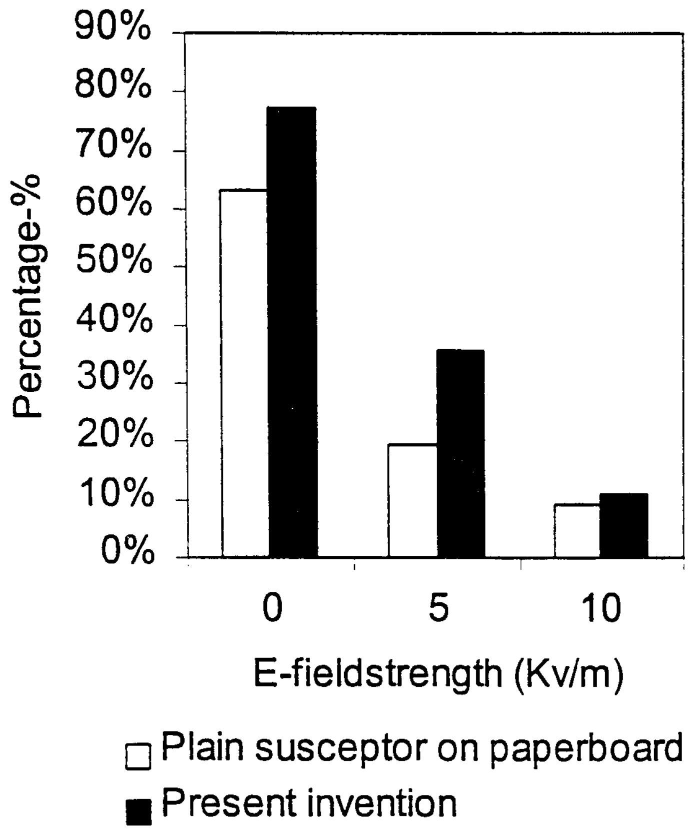
EXAMPLE 3

Example 3 shows the stability of the power reflection performance of both a plain susceptor and the microwave packaging material according to the third embodiment (FIGS. 4 and 5) the present invention laminated to a susceptor under increasing E-field strengths in open load operation. RAT characteristic data of each material was measured after two minutes of continuous radiation in each level of E-field strength. The test showed that the metallic strip susceptor material is also more durable than the plain susceptor. While not wishing to be bound by one particular theory, the inventors presently believe that the increased durability of the present invention results from the metallic segments imparting mechanical stability to the polymer layer commonly included in susceptor films.

Example 3

E-Field Strength (Kv/m)		Reflection	Transmission	Absorption	Film Appearance
Plain Susceptor on Paperboard	0	63%	4%	33%	no crack
	5	19%	52%	28%	visible crack
	10	9%	80%	11%	crack
Present Invention	0	77%	9%	14%	no crack
	5	36%	50%	14%	no crack
	10	11%	75%	14%	slight cracked lines

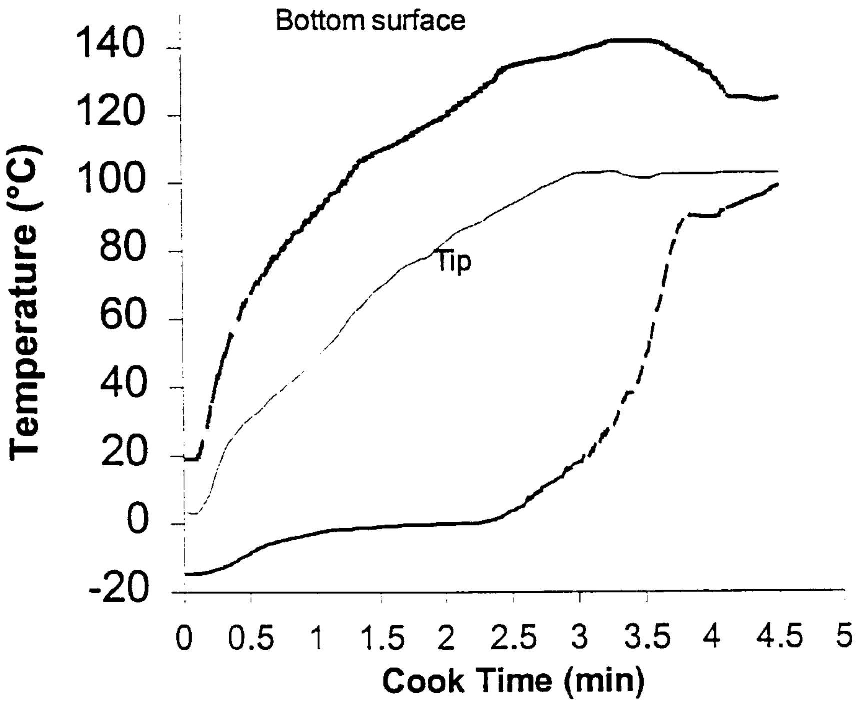
Deterioration in power reflection



EXAMPLE 4

Temperature profiles of frozen chicken under heating with metallic patterned susceptor sleeves according to the present invention are shown in Example 4. Three fiber-optic temperature probes were placed at the different portion of frozen chicken to monitoring the cooking temperature. The test results indicated that the patterned metallic segments included with a susceptor sleeve delivered a high surface temperature which causes good surface crisping of the chicken. Note that the center of the chicken heated after the surface and tip of the chicken were heated. This is close to the heating characteristics which would be observed in a conventional oven. The chicken cooked using microwave packaging according to the present invention achieved comparable results to a chicken cooked in a conventional oven. The chicken had a browned, crisped surface and the meat retained its juices.

Frozen chicken thigh (177 g) in breadcrumbs



EXAMPLE 5

A metallic patterned susceptor lid according to the present invention as seen in FIG. 5 was used for microwave baking of a 28 oz. frozen fruit pie. It takes approximately 15 minutes in a 900 watt output power oven to bake such a pie. As seen in FIG. 5, the lid of this cooking package used the metallic patterned susceptor sheet with periodical array of the basic structure shown in FIG. 4. Both the lid and tray are abuse-tolerant and safe for operation in a microwave oven. Testing showed this lid generated an even baking over the top surface. The lid can be exposed to an E-field strength as high as 15 kV/m unloaded by food without any risk of charring, arcing, or fire in the packaging or paper substrate tray.

EXAMPLE 6

In another experiment, the baking results for raw pizza dough using two kinds of reflective walls were compared. One wall is made with an aluminum foil sheet and the other was made from a packaging material according to the present invention. The quasi-shielding wall according to the present invention is shown in FIG. 6. A 7 μm thick aluminum foil was used in both wall structures (i.e., the metallic segments of the packaging material according to the present invention are 7 μm thick). Fairly similar baking performance was achieved in both pizzas. Thus the packaging material according to the present invention achieved the same good results as the less safe bulk foil.

The present invention can be used in several formats such as baking lids, trays and disks, with or without a laminated layer of susceptor film. In general, a susceptor laminated with the present invention is able to generate higher reflection of radiation power than a plain susceptor at the same level of input microwave power. The present invention can be treated as an effective quasi-shielding material for various microwave food packaging applications.

The present invention has been described with reference to a preferred embodiment. However, it will be readily apparent to those skilled in the art that it is possible to embody the invention in specific forms other than as described above without departing from the spirit of the invention. The preferred embodiment is illustrative and should not be considered restrictive in any way. The scope of the invention is given by the appended claims, rather than the preceding description, and all variations and equivalents which fall within the range of the claims are intended to be embraced therein.

WHAT IS CLAIMED IS:

1. An abuse-tolerant microwave packaging material comprising:

a continuously repeated first set of metallic foil segments on a substrate, each first set of metallic segments defining a first perimeter having a length approximately equal to a predetermined ratio of an operating wavelength of a microwave oven, and each segment in each first set being spaced from adjacent segments.

2. The abuse-tolerant microwave packaging material of claim 1, wherein the length of the first perimeter is approximately equal to a multiple of one-half of the operating wavelength of a microwave oven.

3. The abuse-tolerant microwave packaging material of claim 1, wherein the length of the first perimeter is approximately equal to one-half the operating wavelength of a microwave oven.

4. The abuse-tolerant microwave packaging material of claim 1, wherein the length of the first perimeter is approximately equal to the operating wavelength of a microwave oven.

5. The abuse-tolerant microwave packaging material of claim 1 comprising:

a continuously repeated second set of metallic foil segments, each second set defining a second perimeter enclosing one of the continuously repeated first sets of metallic segments, the second perimeter having a length being approximately equal to predetermined ratio of an operating microwave wavelength, and each metallic segment of each second set being spaced from adjacent segments.

6. The abuse-tolerant microwave packaging material of claim 5, wherein the length of the second perimeter is approximately equal to a multiple of one-half of an operating microwave wavelength.

7. The abuse-tolerant microwave packaging material of claim 5, wherein the length of the second perimeter is approximately equal to one-half of an effective microwave wavelength for frozen food products.

8. The abuse-tolerant microwave packaging material of claim 5, wherein the length of the second perimeter is approximately equal to an effective microwave wavelength for thawed food products.

9. The abuse-tolerant microwave packaging material of claim 5, wherein the second set of metallic segments define a hexagonal shape.

10. The abuse-tolerant microwave packaging material of claim 5, wherein each of the second sets of metallic segments is nested with adjacent second sets of metallic segments.

11. The abuse-tolerant microwave packaging material of claim 5 comprising:

a repeated third set of metallic foil segments, each third set defining a third perimeter enclosing one of the repeated second sets of microwave-interactive elements, the third perimeter having a length being approximately equal to a predetermined ratio of an effective microwave wavelength and the segments in each of the third sets being spaced from adjacent segments.

12. The abuse-tolerant microwave packaging material of claim 11, wherein the length of the third perimeter is approximately equal to a multiple of one-half of an operating microwave wavelength.

13. The abuse-tolerant microwave packaging material of claim 11, wherein the length of the third perimeter is approximately equal to one-half of an effective microwave wavelength for frozen food products.

14. The abuse-tolerant microwave packaging material of claim 11, wherein the length of the third perimeter is approximately equal to an effective microwave wavelength for thawed food products.

15. The abuse-tolerant microwave packaging material of claim 11, wherein the third set of metallic segments define a hexagonal shape.

16. The abuse-tolerant microwave packaging material of claim 11, wherein each of the third sets of metallic segments is nested with adjacent third sets of metallic segments.

17. The abuse-tolerant microwave packaging material of claim 1, wherein each of the repeated first sets of metallic segments define multi-lobe shape.

18. The abuse-tolerant microwave packaging material of claim 17, wherein the multi-lobe flower shape is a five-lobe flower shape.

19. The abuse-tolerant microwave packaging material of claim 1, wherein each metallic segment has an area less than 5. mm^2.

20. The abuse-tolerant microwave packaging material of claim 1, wherein the substrate includes a susceptor film.

21. The abuse-tolerant microwave packaging material of claim 1, wherein the substrate is microwave transparent.

22. The abuse-tolerant microwave packaging material of claim 21, wherein the substrate is a paper based material.

23. The abuse-tolerant microwave packaging material of claim 1, wherein metallic segments are formed of aluminum.

24. An abuse-tolerant microwave packaging material comprising:

a continuously repeated first set of segments formed of a high optical density evaporated material, the first set of segments located on a substrate, each first set of segments defining a first perimeter having a length approximately equal to a predetermined ratio of an operating effective wavelength of a microwave oven, and each segment in each first set being spaced from adjacent segments.

25. The abuse-tolerant microwave packaging material of claim 24, wherein the length of the first perimeter is approximately equal to a multiple of one-half of an operating wavelength of a microwave oven.

26. The abuse-tolerant microwave packaging material of claim 24, wherein the length of the first perimeter is approximately equal to one-half an operating microwave wavelength.

27. The abuse-tolerant microwave packaging material of claim 24, wherein the length of the first perimeter is approximately equal to an operating microwave wavelength.

28. The abuse-tolerant microwave packaging material of claim 24 comprising:

a continuously repeated second set of segments formed of a high optical density evaporated material, each second set defining a second perimeter enclosing one of the continuously repeated first sets of segments, the second perimeter having a length being approximately equal to predetermined ratio of an effective microwave wavelength, and each metallic segment of each second set being spaced from adjacent segments.

29. The abuse-tolerant microwave packaging material of claim 28, wherein the length of the second perimeter is approximately equal, to a multiple of one-half of an operating microwave wavelength.

30. The abuse-tolerant microwave packaging material of claim 28, wherein the length of the second perimeter is approximately equal to one-half of an effective microwave wavelength for frozen food products.

31. The abuse-tolerant microwave packaging material of claim 28, wherein the length of the second perimeter is approximately equal to an effective microwave wavelength for thawed food products.

32. The abuse-tolerant miprowave packaging material of claim 28, wherein the second set of segments define a hexagonal shape.

33. The abuse-tolerant microwave packaging material of claim 28, wherein each of the second set of segments is nested with adjacent second sets of segments.

34. The abuse-tolerant microwave packaging material of claim 28 comprising:

a repeated third set of segments formed of a high optical density evaporated material, each third set defining a third perimeter enclosing one of the repeated second sets of microwave-interactive elements, the third perimeter having a length being approximately equal to a predetermined ratio of an operating microwave wavelength and the segments in each of the third sets being spaced from adjacent segments.

35. The abuse-tolerant microwave packaging material of claim 34, wherein the length of the third perimeter is approximately equal to a multiple of one-half of the operating microwave wavelength.

36. The abuse-tolerant microwave packaging material of claim 34, wherein the length of the third perimeter is approximately equal to one-half of an effective microwave wavelength for frozen food products.

37. The abuse-tolerant microwave packaging material of claim 34, wherein the length of the third perimeter is approximately equal to an effective microwave wavelength for thawed food products.

38. The abuse-tolerant microwave packaging material of claim 34, wherein the third set of segments define a hexagonal shape.

39. The abuse-tolerant microwave packaging material of claim 34, wherein each of the third sets of segments is nested with adjacent third sets of segments.

40. The abuse-tolerant microwave packaging material of claim 24, wherein each of the repeated first sets of segments define multi-lobe shape.

41. The abuse-tolerant microwave packaging material of claim 40, wherein the multi-lobe flower shape is a five-lobe flower shape.

42. The abuse-tolerant microwave packaging material of claim 24, wherein each metallic segment has an area less than 5 mm^2.

43. The abuse-tolerant microwave packaging material of claim 24, wherein the substrate includes a susceptor film.

44. The abuse-tolerant microwave packaging material of claim 24, wherein the substrate is microwave transparent.

45. The abuse-tolerant microwave packaging material of claim 44, wherein the substrate is a paper based material.

46. The abuse-tolerant microwave packaging material of claim 24, wherein segments of high optical density evaporated material are formed of aluminum.

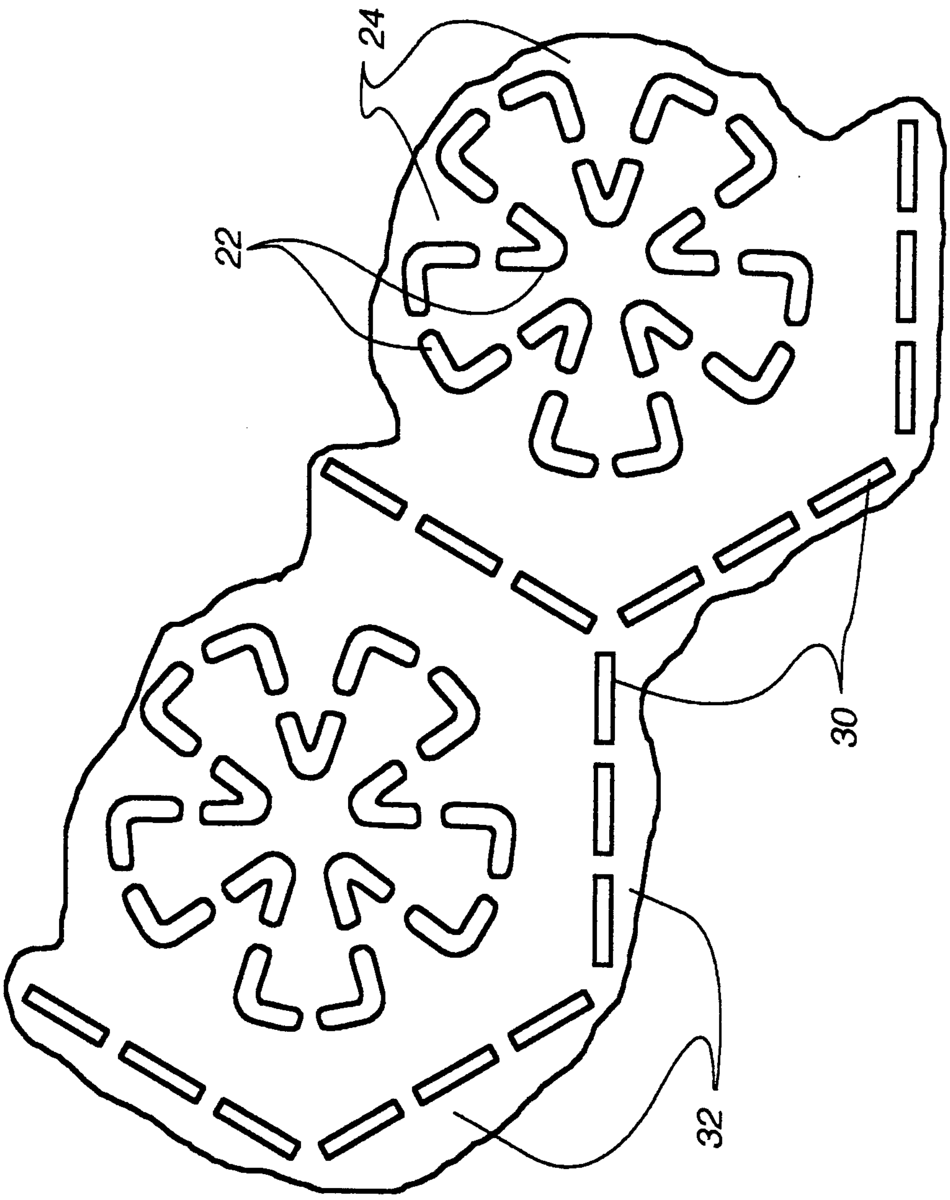


Fig. 1

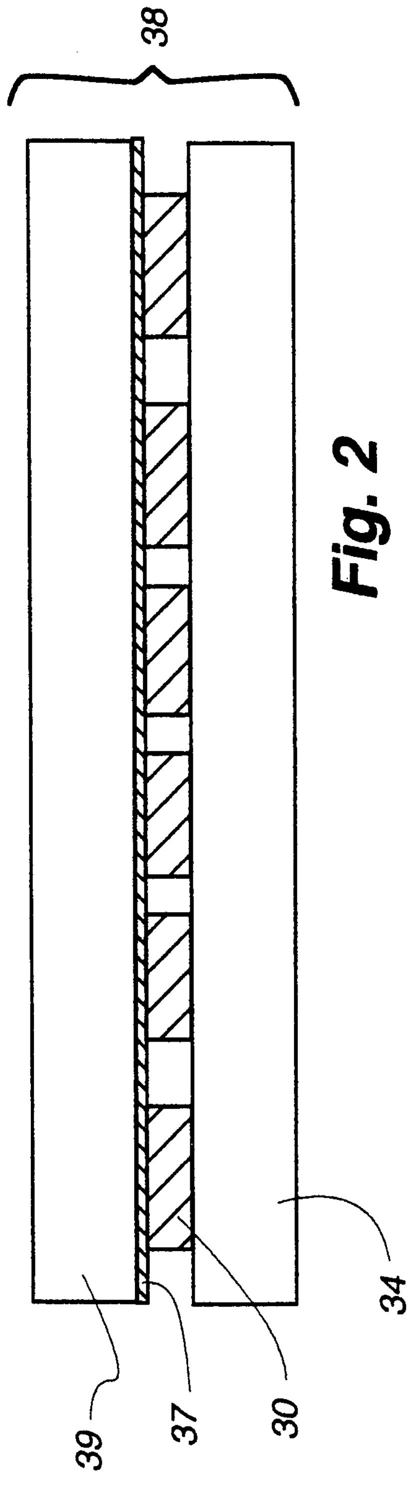


Fig. 2

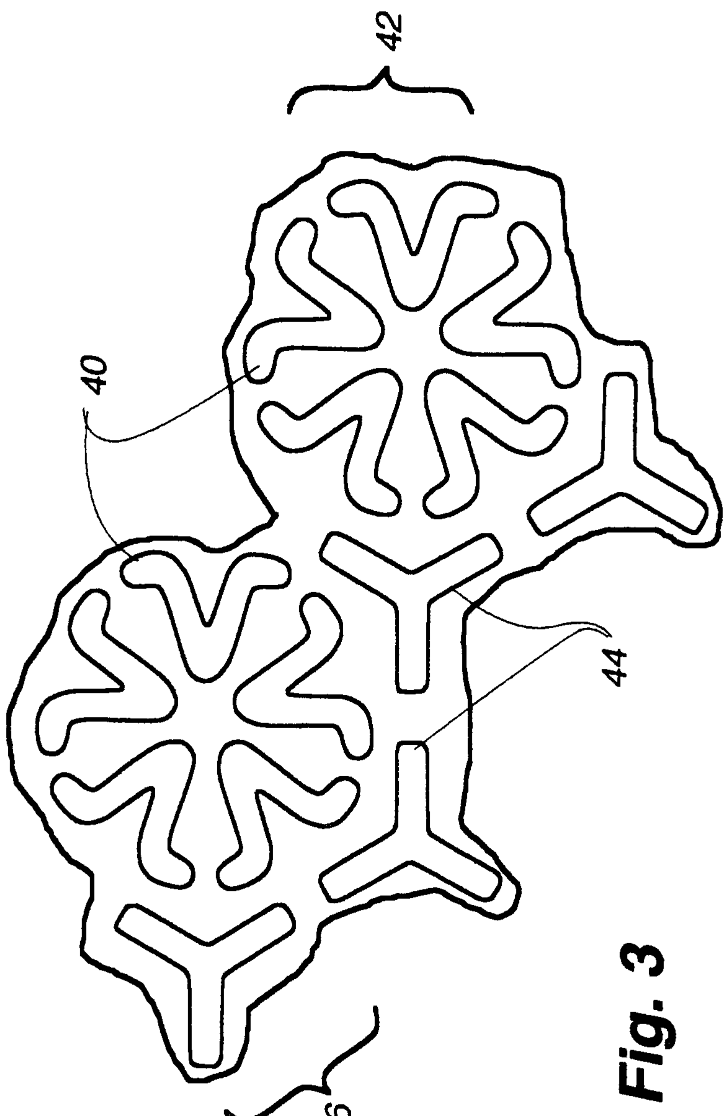


Fig. 3

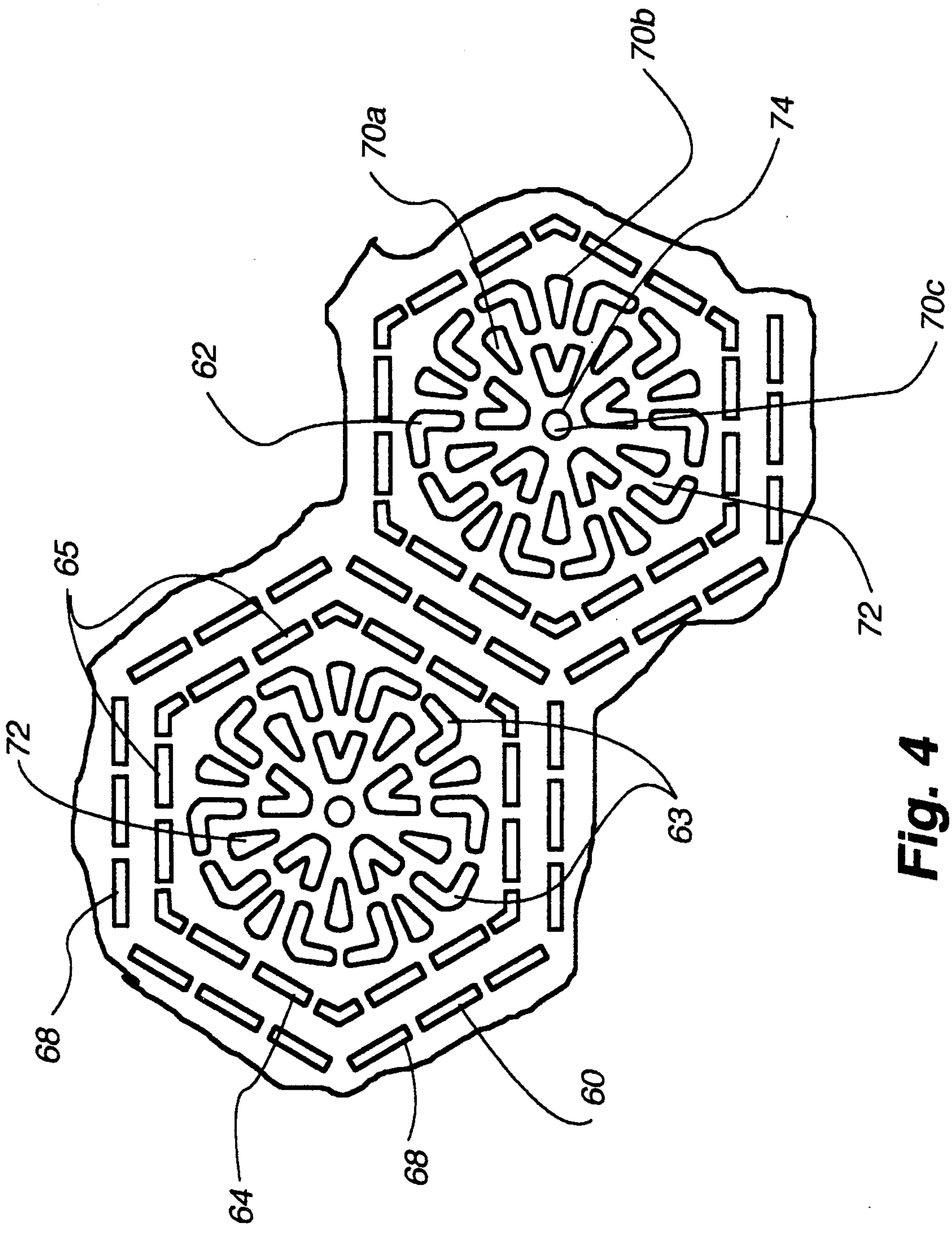


Fig. 4

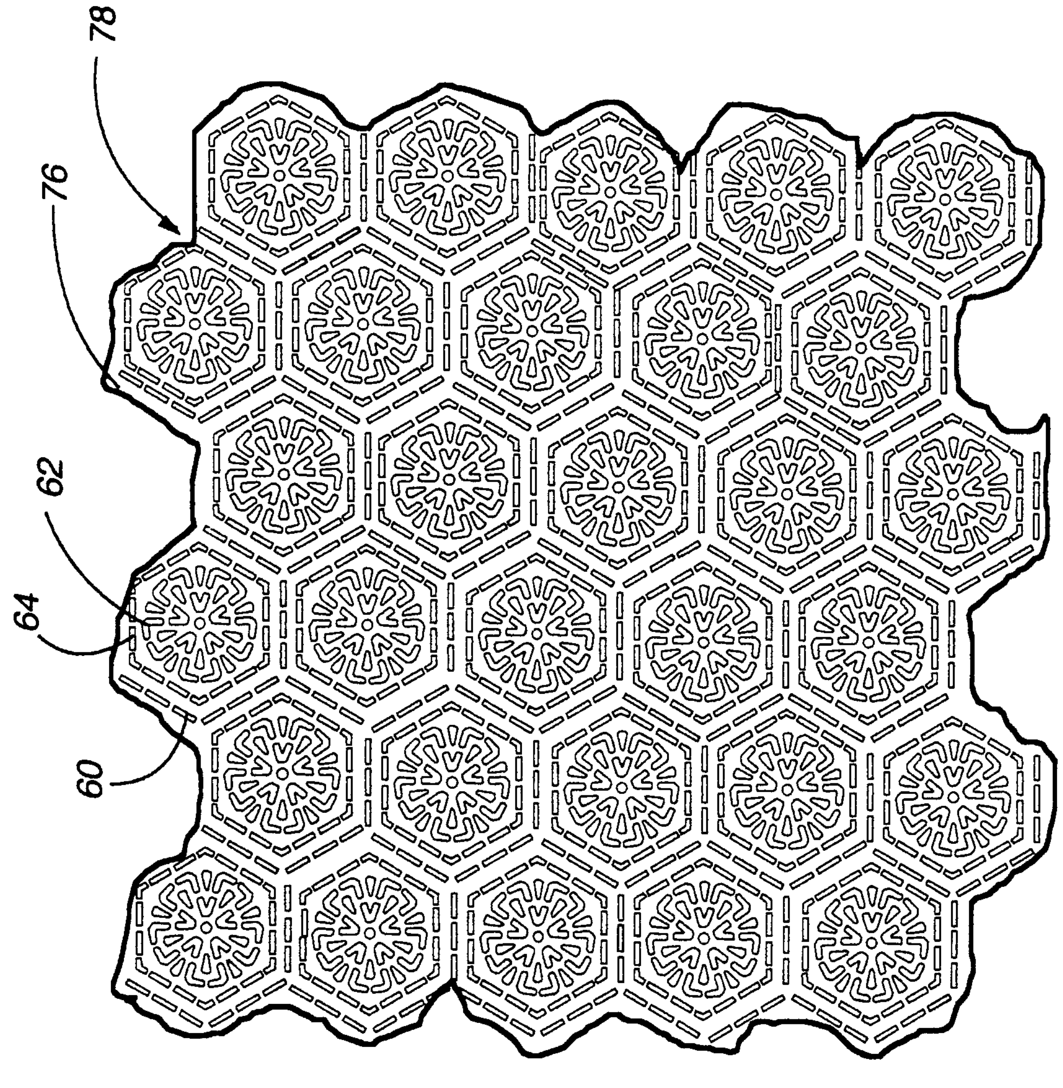


Fig. 5

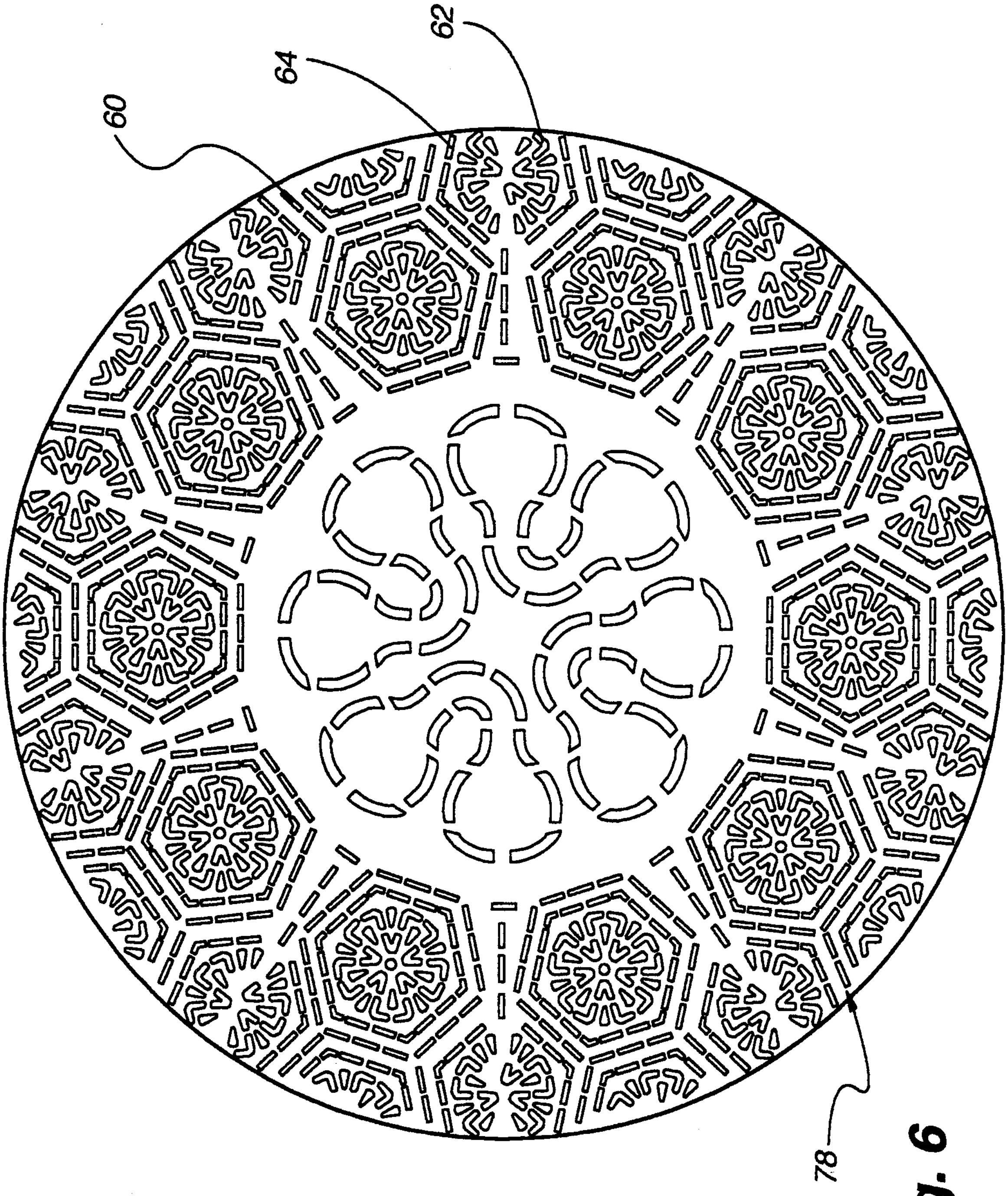


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/40930

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :H05B 6/30
US CL :219/727-730
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 219/727-730

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,698,127 A (LAI et al) 16 December 1997, see entire document.	1, 24
A	US 5,446,270 A (CHAMBERLAIN et al) 29 August 1995, Abstract, claims 1-9	1-46

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 DECEMBER 2000	16 JAN 2001
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer JEFFREY PWU Telephone No. (703) 308-7835