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(54) **Non-moire shielded window.**

(57) An EMI/RFI shielded substrate, preferably a window or CRT screen is disclosed. The conductive pattern is formed of a series of randomly distributed vertices interconnected with linear and/or curvilinear elements. The pattern is formed by moving the vertices of a normal rectangular grid from their established x,y coordinates to new x',y' coordinates which are a small distance from the x,y coordinates at an angle, α , which is from 0° to 360°. Preferably, the vertices are displaced by an increment that is 50% or less of the distance between the vertices of the x,y coordinate pattern.

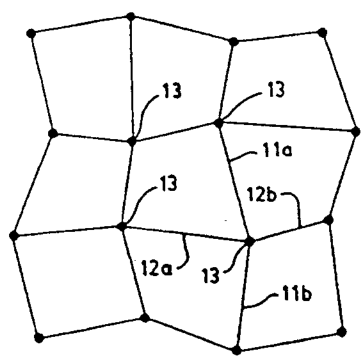

FIG. 2

EP 0 446 038 A2

NON-MOIRE SHIELDED WINDOW

This invention relates to a shielded window, more particularly, it relates to an EMI/RFI shielded window that prevents the generation of moire patterns.

A normal cathode ray tube (CRT) such as may be used in a computer terminal is composed of a transparent screen with a phosphor layer formed on its inner surface. The phosphor layer is stimulated by one or more electron beams so that the layer emits light energy. This light energy is the visual representation viewed by an observer of the screen.

The screen and tube are typically not shielded against the radiation of EMI/RFI energy generated within the CRT. The ingress and egress of EMI/RFI energy must be controlled for health and security reasons. For example, recent studies have suggested that the EMI/RFI energy emanating from CRT devices may affect the health of its users. Additionally, it is known that EMI/RFI emissions from CRT devices can affect the operation of adjacent unshielded devices and may also be detected and read by highly sensitive detectors.

One approach to eliminating the movement of EMI/RFI energy through the CRT screen has been to use a transparent shield which contains an electrically conductive mesh or grid. Mounting such mesh is difficult and time consuming as the mesh tends to distort or tear easily. The shielded structure suffers from reduced visual opacity in that the mesh interferes with one's viewing of the screen. More importantly, the use of the conductive mesh causes the formation of moire patterns which interfere with the viewing of the screen.

Moire patterns are caused by the overlaying of two patterns which are similar in spatial frequency and distribution. In CRT devices, they are caused by the overlaying of two similar grid patterns. The first grid is the wire mesh used in the EMI/RFI shielding device. The second grid is formed by the CRT scan lines and pixel delineation. The frequency and distribution of the second grid is variable as each CRT screen has different spatial distributions. The problem is more severe when using a high resolution screen, as the spatial definition of the pixels is closer to that of the wire screen, thus generating denser moire interference lines.

One method for avoiding the generation of moire' patterns is to eliminate the wire mesh, while maintaining the EMI/RFI shielding. Various coated shields or screens have been offered and while the shields do reduce or eliminate the moire' patterns, they also have major disadvantages. The main problem with such coatings is that the visual opacity of the CRT screen is significantly reduced (generally up to 50% less than on an unshielded screen). This requires the operator to increase the screen's luminescence to a higher level which reduces the useful life of the screen. Additionally, the coatings are generally less conductive than the wire mesh and therefore do not provide the same effective level of EMI/RFI shielding.

Another method for avoiding the generation of moire' patterns is the use of a randomly oriented, non linear conductive pattern such as one formed from a large number of interconnected circles or ovals which are distributed in such a manner so as to prevent the generation of moire' patterns. While providing excellent shielding and moire' prevention, the manufacture of such a pattern is difficult and costly to reproduce.

The present invention overcomes the difficulties encountered with the present devices. The shield of the present invention provides excellent EMI/RFI shielding and visual opacity without generating moire patterns.

The present invention is a randomly oriented conductive pattern useful as an EMI/RFI shield on CRT screens and similar devices. The random, pattern provides excellent EMI/RFI shielding capabilities without generating moire' patterns.

It is an object of the present invention to provide a transparent EMI/RFI shield with good visual opacity and which does not cause the generation of a moire pattern.

Another object of the present invention is to provide an EMI/RFI shield comprising a substrate which is transparent or translucent and a shielding means formed of a randomly oriented linear pattern.

A further object of the present invention is to provide a method of forming an EMI/RFI shield for CRT devices that does not generate moire patterns comprising the steps of generating a randomly oriented, linear pattern, creating a photomask of such pattern, imaging the pattern onto a resist formed on a transparent substrate, developing the resist, etching away a selected portion of the resist and/or substrate so as to form the pattern on the substrate, plating the resultant pattern to render it conductive and applying a conductive termination layer along the edges of the substrate so that the shield is electrically continuous with the CRT device.

Additionally, an object of the present invention is to form a conductive pattern by distorting a straight grid pattern such that all vertices are displaced by some small increment at a random angle, and applying the pattern to a surface to be rendered conductive.

These and other objects of the present invention will be made clear from the specifications, drawings and appended claims.

Figure 1 shows a planar view of a normal, grid-like pattern.

Figure 2 shows a planar view of a pattern according to the present invention.

Figure 3 shows a cross-sectional view of a preferred embodiment of the present invention.

Figure 4 shows a cross-sectional view of a further embodiment of the present invention.

The present invention relates to a highly conductive, randomly oriented, pattern formed on a transparent or translucent substrate for use in EMI/RFI shielding

In shielded windows that use a mesh or a conductive grid, such as is shown in Figure 1, the grid is formed of a series of vertical and horizontal elements of equal length which intersect at a series of vertices. A vertex (vertices) is herein defined as a point at which adjoining linear elements intersect and terminate. In the formation of Figure 1, the angle formed between intersecting and joining vertical elements (1a, 1b) and horizontal elements (2a, 2b) is 90° at the vertex 3. Likewise, the angle formed between adjoining intersecting vertical elements 1a and 1b is 180° as it is for adjoining, intersecting horizontal elements 2a and 2b.

Each vertex has a definitive position on the substrate. This portion is normally defined in reference to a horizontal (x) and a vertical (y) coordinate. Thus each vertex will have its own unique x,y coordinate.

Figure 2 shows a preferred embodiment of a conductive pattern formed according to the present invention. As can be seen, the vertical elements (11a,11b) as well as the horizontal elements, (12a,12b) and the vertices (13) are randomly distributed about the pattern and randomly oriented to each other. Further, as shown in Figure 2 the length of each element is not necessarily equal to that of the other elements, preferably adjoining elements are not of equal length.

The pattern of Figure 2 is formed by taking the arranged vertices of Figure 1 and moving each vertex from a normal x,y coordinate by some small increment at a random angle, α . Preferably, the increment is less than 50% the length of an element in the regular grid of Figure 1. More preferably, it is from 10 to 50% of the distance between the vertices of the regular pattern of Figure 1. Moreover, it is preferred that the increment be from 20 to about 40% of the distance between vertices in the regular grid of Figure 1. The angle, α , can be any angle from 0° to 360°.

As can be appreciated from Figure 2, the conductive pattern is formed of a series of vertical elements and horizontal elements interconnected by a series of vertices such that a substantial number of the adjoining vertical elements and horizontal elements meet at an angle that is less than or greater than but not equal to 90°. Correspondingly, the intersection of two adjoining vertical elements, or two adjoining horizontal elements, is less than or greater than but not equal to 180°. This array is generated throughout the entire conductive pattern.

Other similar patterns may also be generated using the same basic principles mentioned above, namely that the vertices are distorted by a small increment and a random angle, α , from that which it would normally occupy in a purely horizontally and vertically aligned grid pattern.

While the above patterns have been described with reference to a four sided (square or rectangular) grid reference, it is clear that other such patterns can be formed from triangular or other polygonal grid patterns to form randomly angled linear patterns that do not generate moire patterns.

Moreover, one can use curvilinear elements of various curvatures instead of linear elements. The curvilinear elements may all have the same curvature or preferably may be of different curvatures. One may also form the pattern from a combination of linear and curvilinear elements.

A device according to the preferred embodiment of the invention is shown in Figure 3 and comprises one or more layers of a transparent or translucent substrate 30. The substrate 30 may be formed from such materials as glass, and various rigid plastics, either thermoplastic or thermoset including but not limited to polyacrylates and polycarbonates. At least one surface of the substrate 30 contains a conductive pattern 31 formed of randomly oriented, interconnected electrically conductive elements 32. In this preferred example, the elements 32 are shown as being linear.

The elements 32 are shown as being in contact with each of their adjoining horizontal and vertical vertices so that electrical continuity is maintained throughout the pattern 31. While each element 32 is in contact with its neighboring elements, the elements are preferably arranged so that they do not present a linear component that is greater in length than the length of one element.

The size of the elements 32 depends in large part upon the shielding and visual opacity characteristics desired. The smaller the elements, the greater the shielding characteristics and the lesser the visual opacity and vice versa. Preferably the selected elements 32 should be of size such that they do not severely detract from either characteristic.

Two dimensions are relevant in discussing the size of the elements 32; the length of the elements and the annular width of the elements.

With linear elements, the length can be the same as that generally used to form a linear grid such as that of the mesh of the prior art such as from about .002 inches to about 0.10 inches. In general, the linear elements range from about four elements per inch to about one hundred elements per inch, preferably about 50 to 100 elements per inch.

The annular width is herein defined as the distance from one outer edge of the element to the corresponding outer edge of the element. If a variation in annular width occurs, either due to the manufacturing process or due to a desired purpose, the annular width shall be an average of the distances taken from various points across the diameter of the element. The annular width of an element should be fairly consistent throughout. The annular width of the elements ranges from about .0002 inches to about .005 inches, preferably about .001-.002 inches.

Preferably, the elements 32 of a pattern will vary over a range of lengths due to the distortion of the vertices. Moreover, the arrangement of elements in the pattern may be selective such that the length of elements in one portion of the substrate are different from those in another area. For example, if one wishes to have less visual opacity around the edge of the conductive substrate, one may use elements 32 along the edge of the substrate that have a smaller average length and/or greater width than the elements on the inner portion of the substrate. Also, one may use elements of different average lengths and/or widths to ensure that there is complete and adequate conductivity throughout the pattern.

Preferably, the conductive pattern 31 is terminated along its outside edges with a conductive strip, commonly called a bus bar 33.

The bus bar 33 may be a conductive layer formed on or in the surface of the substrate. The bus bar 33 can be formed in a manner identical to the formation of the pattern except preferably it is void free. However, if desired, one could use elements 32 that are smaller in diameter and/or thicker in annular width along the edges of the pattern 31 to form the bus bar 33.

Additionally, the bus bar 33 can be formed of a separate conductive layer sintered or bonded to the edge areas of the substrate 30. For example, the bus bar 33 can be a conductive ink or epoxy, a conductive metal plating, a metal strip, a conductive, sinterable frit such as silver coated glass, or more preferably, a conductive metal tape, such as CHO-FOIL®, available from Chomerics, Inc.

The bus bar 33 is designed in such a manner that it establishes and maintains electrical continuity between the substrate 30 and the frame, cabinet or closure to which it is attached. The bus bar 33 may do so directly, i.e. its surface meets and mates with a conductive surface of the frame, cabinet or closure to which the substrate is attached.

Preferably, the bus bar is connected to a conductive lead such as a grounding strap, a metal frame, or a conductive gasket that establishes contact with the surface to which the substrate is mounted. By using the intermediate connection between the bus bar of the substrate and surface, one avoids the problems of establishing a perfect fit between the surfaces as would be required by a direct connection between the surface and the substrate.

Figure 4 shows another preferred embodiment of the present invention.

The surface 41 of the substrate 40 containing the pattern 42 may also be covered by a protective coating 43, such as a conformal coating to prevent oxidation and damage to the conductive pattern during handling. Such coatings are well known and generally are formed of a sprayable plastic material, such as polyurethane. The coating can also be a film, such as MYLAR® films or KAPTON® films, which may be bonded to the substrate surface.

The surface 41 of the substrate 40 containing the pattern 42 may also be covered by a transparent conductive coating 43, such as indium tin oxide. This coating may be applied by vacuum deposition, sputtering, or spray pyrolysis. The addition of this conductive coating will increase the effective shielding of the assembled window.

If desired, the substrate can be joined with another substrate to form a laminate of two or more layers. In this embodiment, the surface of the substrate containing the conductive pattern faces the inner surface of the other substrate. Such laminations and processes for forming them are well known and generally consist of a bonding layer between the substrates to hold the two substrates together. Typically, a polyvinyl butyral material is used as the bonding agent, although other similar adhesive material such as polyurethanes can be used. Alternatively, the two substrates can be melt bonded together, although one must take care not to injure the conductive pattern in doing so.

A preferred method of forming the pattern on the conductive window of this invention is by a photolithography or an electroforming method.

In the preferred process, a desired pattern is first created. The pattern can be drawn by hand or preferably by a computer generated program. A preferred simple means for creating the randomly oriented pattern of the present invention is to use a computerized print program which will lay out a series of elements of the desired length and width in an arrangement so that the vertices of the elements are randomly oriented from their normal x and y coordinate by a small increment and angle, α. A photomask is made of the pattern and imaged onto a resist coated substrate. The resist coated substrate is exposed to actinic radiation and developed. The developed image is then plated to form a conductive pattern.

A suitable computer program used to generate the pattern follows the following logic: The x,y coordinates for a series of equally spaced vertices are generated and stored. Preferably, the x,y coordinates are equidistant from each other i.e. a square-like grid pattern. Each coordinate is then moved by a small increment in either the x or y or both the x and y coordinate and at a random angle, α, wherein α can be any angle between 0 to 360°. The small incremental distance may be uniform i.e. a percentage of the distance between the established adjoining x,y coordinates or it may be random, varying over a preselected range, i.e.

equal to or less than a certain percentage of the distance between the established adjoining x,y coordinates. A new series of x',y' coordinates are then plotted. Elements are then formed to interconnect the vertices, e.g. using the elements to interconnect the x' to x' and y' to y' coordinates of adjoining vertices. The output of the computer program is the x'/y' coordinates and element lengths which are used to drive a computer plotter or photomask generator. The generated photomask may be either a positive or a negative photomask.

One preferred embodiment is to use a resist coated metal layer substrate to form the desired pattern. The substrate has a metal layer bonded or plated onto its desired surface. The metal layer is coated with a resist layer. The resist is exposed to a negative photomask and developed and the unwanted portion of the metal layer is etched away to leave a conductive metal pattern on the surface of the substrate. As discussed above, in relation to the resist covered substrate, additional conductive layers may be placed upon the conductive pattern, preferably by a plating process. Suitable substrates include, but are not limited to glass and various transparent or translucent plastics. The metal layer may be formed of any conductive metal such as silver, gold, platinum, palladium, nickel, copper, tin, zinc, aluminum, etc. It is preferred that the metal layer be formed of copper due to its cost, availability and ease of etching and plating. The metal layer may be in the form of a metal foil or film which is embedded into or bonded onto the substrate surface. It may also be formed by vapor deposition, sputter coating or other deposition means which form a uniform metal layer on the substrate's surface. As stated above, the resultant pattern can be further plated or treated to render it more conductive.

In another preferred embodiment, one can form the pattern on a resist coated substrate which will form the conductive window. This substrate may be formed of any transparent or translucent material typically used for such conductive windows. Examples of such materials include, but are not limited to, glass and various plastics such as polycarbonates and polyacrylates. In this embodiment, the resist is formed on the desired surface of the substrate. The resist is then exposed to the pattern formed on a positive photomask and developed. The substrate is then etched, preferably with an acid, to create the desired pattern in the substrate surface. The etched pattern is then filled with a conductive material such as a conductive ink a conductive adhesive, preferably a conductive epoxy, a conductive frit, such as a conductive ceramic frit, or a conductive metal, such as copper, silver, nickel, gold, tin, zinc, aluminum or platinum. It is preferred to use a conductive adhesive, especially a silver filled epoxy. If desired, the conductive pattern may additionally be plated with conductive metals, such as, but not limited to silver, gold, platinum, nickel, tin, zinc, aluminum or copper to enhance its conductivity and reduce oxidation.

If one desires to form a free standing conductive material incorporating the desired pattern, one can form a resist on a suitable mandrel, generally having a metal surface, expose and wash the resist, and etch the desired pattern into the mandrel's surface. A plating is then formed on the mandrel's surface such as by an electrodeposition bath. The plated material is then removed from the mandrel and applied like any other conductive mesh known in prior art to the transparent substrate.

The shielding capability of the present invention is equal to that of shielded devices using a mesh like grid. For example, a conductive substrate formed according to this invention, having linear elements of an average length of 0.010 inches and an average annulus width of 0.0013 inches has a shielding capability comparable to that of a wire mesh shielding device having 100 openings per inch and a mesh diameter of 0.0015 inches (a shielding capability of 65 dBs at 100 megahertz).

If desired, the substrate containing the conductive pattern may be curved, either before or after formation of the conductive pattern. Typically the curvature is formed after the formation of the conductive pattern by placing the substrate in an oven and allowing the substrate to soften and flow or slump to the correct curvature. If necessary, a mold or means for applying pressure to the substrate surface may be used to ensure the formation of the correct curvature.

The present invention may be used in a computer terminal as an EMI/RFI shield. It also has applications in the area of EMI/RFI shielded windows, such as in high security buildings and vehicles. It may also be used in applications that require a conductive or heated window such as a rear window defogger in an automobile. It is believed that in this application the conductive pattern is less distractive to the operator than the grid like formation that is currently in use.

Additionally, when the conductive pattern is formed as a freestanding material, it can be a replacement for knitted or braided conductive mesh used in forming conductive gaskets.

While the present invention has been described with reference to its preferred embodiments, other embodiments can achieve the same result. Variations and modifications of the present invention will be obvious to those skilled in the art and it is intended to cover in the appended claims all such modifications and equivalents as fall within the true spirit and scope of this invention.

Claims

1. An EMI/RFI shielded article comprising a transparent or translucent substrate and a randomly

oriented, conductive pattern in or on the substrate, the pattern being formed of a series of interconnected elements which form a grid-like pattern wherein a substantial number of adjoining elements meet at an angle which is less than or greater than, but not equal to 90°.

2. An EMI/RFI shielded device comprising a transparent or translucent substrate and a randomly oriented, pattern formed on a surface of the substrate, wherein the pattern comprises interconnected elements wherein the junction between the elements are randomly located in both the vertical and horizontal coordinates relative to a normal rectilinear pattern having elements of equal length.

3. An EMI/RFI shield according to claim 1 or 2 wherein the electrically conductive pattern is formed from a conductive metal, conductively filled adhesive, ink or frit.

4. An EMI/RFI shield according to claim 1, 2 or 3 wherein the transparent substrate is formed from glass or a rigid transparent plastic, preferably polyvinyl butyral, polyurethane, polyacrylate or polycarbonate.

5. An EMI/RFI shield according to any one of the preceding claims further comprising a bus bar formed along at least one outer edge of the pattern, the bus bar being electrically conductive and in intimate electrical contact with at least one edge of the pattern.

6. An EMI/RFI shield according to any one of the preceding claim wherein the elements are rectilinear in shape, of a length of between 50.8µm and 2.54mm and diameter of between 5.08µm and 127µm.

7. A EMI/RFI shield according to any one of the preceding claim further comprising a second substrate bonded to a surface of the first substrate upon which the pattern is formed so as to form a laminate, the bonding layer preferably consisting of a polyvinyl butyral, polyurethane, epoxy or mixture thereof.

8. A method for forming a EMI/RFI shield comprising the steps of:

a) generating a negative photomask pattern having a series of randomly oriented, interconnected elements; said elements being interconnected in such a manner that a substantial portion of adjoining first and second sets of elements form an angle that is less than or greater than but not equal to 90°, and adjoining first elements and adjoining second elements form an angle that is less than or greater than but not equal to 180°;

b) coating a substrate, preferably a glass or plastic, with a conductive metal;

c) coating the metal with a photoresist;

d) exposing the photoresist to the negative photomask;

e) developing the exposed photoresist;

f) etching the exposed metal to the substrate;

g) removing the photoresist;

h) coating a conductive material, preferably a metal, conductive adhesive, conductive ink or conductive frit.

i) placing the plated substrate within a frame for mounting to an electronic device.

9. A method for forming a EMI/RFI shield comprising the steps of:

a) generating a positive photomask pattern having a series of randomly oriented, interconnected, elements; said elements being interconnected in such a manner that a substantial portion of adjoining first and second sets of elements form an angle that is less than or greater than but not equal to 90° adjoining said first elements and adjoining said second elements form an angle that is less than or greater than but not equal to 180°;

b) coating a substrate with a photoresist;

c) exposing the photoresist to the positive photomask;

d) developing the exposed photoresist;

e) etching the exposed substrate;

f) removing the photoresist;

g) filling the etched pattern in the substrate with an electrically conductive material; and

h) placing the plated substrate within a frame for mounting to an electronic device.

10. An EMI/RFI shield comprising a substrate having a surface upon which a conductive pattern is formed, the pattern is comprised a series of randomly oriented vertical and horizontal elements interconnected at a plurality of vertices, the vertices being displaced from regular rectilinearly distributed (x,y) positions by a random angle, of between 0° and 360°, and a small incremental distance of the distance between regularly rectilinearly distributed vertices more preferably between 20% and 40% of the distance between regularly rectilinearly distributed vertices so as to assume irregular (x',y') positions.

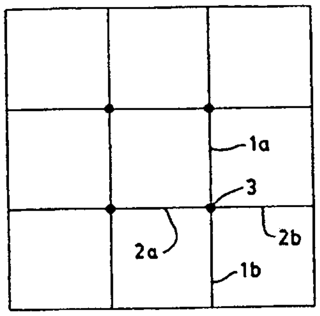

FIG. 1

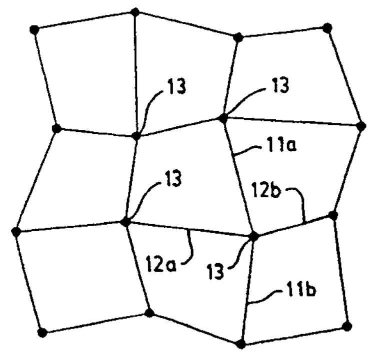

FIG. 2

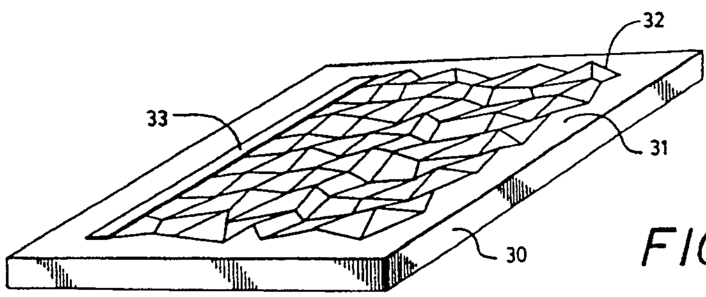

FIG. 3

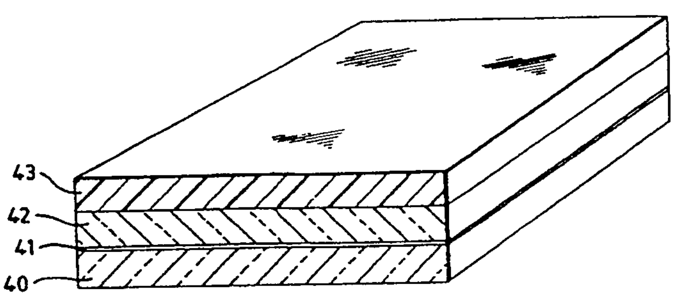

FIG. 4