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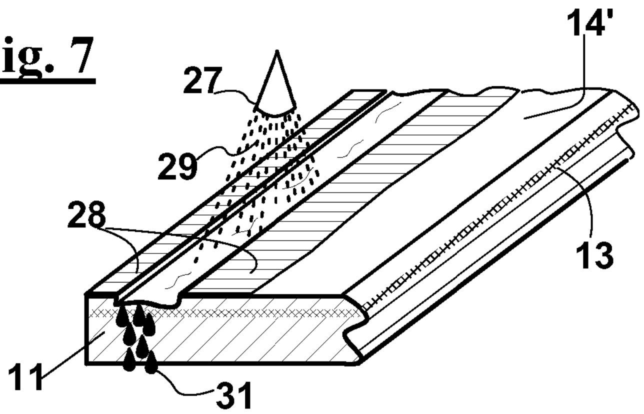
(54) **Title**: A METHOD FOR MAKING ELECTRICALLY CONDUCTIVE STIFF COMPOSITE ARTICLES AND FOR CREATING A CONNECTION OF SAID ARTICLES

Fig. 7



(57) **Abstract**: A method for manufacturing an electrically conductive stiff composite layer article (10) that has an outer surface layer made of an insulating polymeric material, comprising the steps of prearranging an electrically conductive layer (13) incorporated within an electrically insulating matrix (11) made of the polymeric material; prearranging an amount of a metal connection material (29) in a loose form; choice of an electric connection zone (21) on a surface (14') of the stiff composite layer article (10); removal of a surface portion of the polymeric material of the electrically insulating matrix (11), deposit of said loose metal connection material (29) at said connection zone (21) and union of said loose metal connection material (29) with said electrically conductive layer (13), forming an uncovered electric terminal layer (25). In an advantageous exemplary embodiment, the metal connection material in loose form (29) is deposited at a temperature higher than a transition temperature of the polymeric material, in such a way that the polymeric material turns from a coherent solid state into a molten state, in order to cause the removal of the polymeric material at the connection zone (21), and so that the metal connection material is connected at least in part to the electrically conductive layer (13), by forming an uncovered electric terminal layer (25) at the connection zone (21).

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TITLE

A METHOD FOR MANUFACTURING ELECTRICALLY CONDUCTIVE STIFF COMPOSITE ARTICLES AND FOR CREATING A CONNECTION OF SAID ARTICLES

DESCRIPTION

Field of the invention

The present invention relates to a method for manufacturing electrically conductive stiff articles made of a composite material that has a layer structure, in a polymeric matrix.

In particular, the invention relates to boards comprising a polymeric matrix and a layer of an electrically conductive material incorporated within the polymeric matrix.

Furthermore, the invention relates to a method for joining such articles or boards to each other or to metal elements, for manufacturing a Faraday shield container.

The container comprising connections made according to the invention can be used to protect appliances comprising electronic devices that can be affected by electromagnetic waves.

A container that comprises connections made according to the invention can be used in naval or aeronautical installations or, more in general, in vehicle structures.

Technical problem and brief description of the prior art

Faraday shield containers are widely used to electromagnetically shield electronic devices that can be affected by electromagnetic waves, in order to prevent faulty operation of these devices. In particular, they are necessary in the case of small spaces such as boats, airplanes, and vehicles in general, where devices are provided for controlling the vehicle or on-board installations, as well as any equipment adapted to emit high intensity electromagnetic waves, such as satellite antennas.

The problem is particularly in case high-frequency waves are to be shielded, i.e. waves of frequency of about one gigahertz. These frequencies are typically used by radar devices.

The structure of shield containers generally comprises an electrically insulating matrix, which is also mechanically resistant, and a layer of a continuous electrically conductive material incorporated within the matrix.

Another well-known problem is to make connections between container elements, e.g. panels that have the above described structure, in order to ensure the shielding capacity of the container. To this purpose, an electrical continuity must be provided between the electrically conductive layers of each element of the container, even if the boards are manufactured in such a way that the whole surface of the electrically conductive layers is coated by the electrically insulating matrix. Apart from the boards, the containers may comprise movable elements of access or inspection door, openings for the passage of cables, metal plates, shells, and the like.

A method to provide electrical continuity comprises making a container comprising in which joint elements are present between wall members, and the container receives a metallization treatment or a conductive painting. However, at the junctions, in particular at the edges of the container, the metallization or conductive painting layer has a poor resistance to mechanical stresses and atmospheric agents, therefore it is not reliable with time.

Another method comprises making in which portions of the electrically conductive layer of the wall members of the container protrudes out of the matrix, at the connection zone, and also comprises connecting, e.g. welding, these conductive protruding portions with one another. This requires much labour, both for manufacturing and for joining the wall members to one another. Moreover, this method is well-suited only if the conductive layer is a relatively large-mesh network, typically with a pitch larger than 1 to 3 mm, for which a reasonably limited number of connections is enough. With such a pitch, the electrically conductive layer cannot shield high-frequency waves, i.e. waves whose frequency is higher than one gigahertz. In order to shield such frequencies, the conductors must have a far higher surface density. Furthermore, this technique obliges to define the connection zone only when the wall members are designed or manufactured, which limits its possibility of use. Furthermore, a leakage of water or of any different substance may take place into the structure or the container.

US4880679 describes an article that consists of two portions that are joined to each other along a fusion line and that comprises a plastic electrically insulating matrix and an electrically conductive fibre reinforcement incorporated within the matrix, wherein an electrically conductive insert is incorporated within the surface of the article along a fusion line insofar as insofar to form a low resistance electric path between the two portions of the article. Moreover, a process is described to make such an article, in which the two portions, each comprising a plastic electrically insulating matrix and an electrically conductive fibre reinforcement, are brought into contact along a contact line, and a conductive insert is arranged to cross the contact line and is incorporated by moulding into the matrix insofar to form an electrically conductive path between the two portions, for instance, in case of a thermoplastic matrix. In an exemplary embodiment, the insert comprises a network of conductive fibres.

US4880679 also describes an article that comprises a plastic electrically insulating matrix and the electrically conductive fibres incorporated within the matrix, and that comprises an insert partially incorporated within the article, forming a surface portion thereof, and embedded in the article insofar to cross the matrix ant to come into contact with the fibres, in order to form this way an electrically conductive path between the fibres and the surface of the article. A process is also described for creating an electric connection between the fibres incorporated within a plastic electrically insulating matrix of an article and the surface of the article itself, wherein a part of the article is heated until it softens, and the electrically conductive insert is pressed within the softened matrix insofar to come into contact with the fibres.

EP0609942 describes plastic articles in which an infill electrically conductive material is incorporated to make shield containers that comprise removable portions or inserts, in order to uncover the conductive filling material.

US5578790 describes a gasket that has an elongated shape to form a tight and electrically conductive connection between two electrically conductive boards, and that comprises a resiliently compliant core that is wrapped by an electrically conductive shell, and that is equipped with a longitudinal adhesive layer for positioning on one of the two boards. The seal has an element that extends along the adhesive layer and that protrudes therefrom, in order to ensure a compression contact with the board since the starting since the gasket sticks to the sheet.

US2002/0180108 describes an injection moulding process to form a Faraday shielding container.

EP1096077 describes a coating material to protect buildings from moisture and from electromagnetic waves, comprising a matrix of bituminous material where a layer of an electrically conductive material is incorporated. The coating material comprises bituminous matrix removable hook-loop portions for uncovering the layer of the electrically conductive material, in order to connect a coating sheet with an electric supply, or to earth, or to another coating sheet.

Summary of the invention

It is therefore a feature of the present invention to provide a method for manufacturing conductive composite articles such as boards that comprise a polymeric electrically insulating matrix and a layer of an electrically conductive material incorporated within the polymeric matrix, in particular an electrically conductive material completely incorporated within the polymeric matrix.

It is also a feature of the invention to provide a method for joining such composite elements to one another, in particular composite elements used as wall members of a container, in order to ensure the electrical continuity of the electrically conductive layers of the composite elements and, accordingly, ensure the shielding capacity of the container at the junctions.

It is a particular feature of the invention to provide such a method for manufacturing a container that can shield high-frequency waves, in particular waves whose frequency is higher than 1 GHz.

It is another particular feature of the invention to provide such a method for defining a connection zone at substantially any position of the wall member.

It is a further particular feature of the invention to provide such a method that provides such a junction between wall members and movable elements of the container, such as access and inspection doors.

These and other objects are achieved by a method for manufacturing an electrically conductive stiff composite layer article that has an outer surface layer made of an insulating polymeric material, the method comprising the steps of:

- prearranging a stiff composite layer article comprising an electrically insulating matrix made of this polymeric material and an electrically conductive layer incorporated within the electrically insulating matrix, in particular an electrically conductive layer completely incorporated within the electrically insulating matrix;
- prearranging an amount of a loose metal connection material;
- selecting an electric connection zone on a surface of the composite stiff layer article;
- removing a surface layer portion of the polymeric material of the electrically insulating matrix at the connection zone;
- depositing at least one part of the loose metal connection material at the connection zone, and welding at least one part of the loose metal connection material with the electrically conductive layer, forming an uncovered electric terminal layer at the connection zone.

In other words, an uncovered layer terminal is formed at the selected connection zone, which is well suited for an electric connection. In particular, two terminals may be provided at distinct connection zones, in order to use the article as an electrically conductive element, or as an element for transferring a voltage between two elements each of which is connected at a respective terminal of the two terminals. The junction between these articled, or their incorporation in containers comprising an electrically conductive wrapper layer, makes them suitable for manufacturing wrapper structures that provides an insulation towards electric and electromagnetic fields. Such containers can be advantageously used to protect appliances that are affected by electric and electromagnetic fields.

By "layer composite stiff article " an article is meant that extends along at least one flat or curved surface. Both the electrically conductive layer and the electrically insulating matrix extend along this surface. The article comprises at least two layers of an electrically insulating material in which the electrically conductive layer is sandwiched. In particular, the electrically conductive layer may be located next to a face of the article, in other words the two layers of the electrically insulating matrix, which contain the electrically conductive layer, may have different thicknesses. In particular, the thickness of one of the two layers may be shorter than one mm, more in particular, it may be about 100 μm.

The electrically insulating matrix normally plays a protective role for the electrically conductive layer, i.e. it plays an insulation role against any external mechanical action, and/or against the weather. The electrically insulating matrix itself may be rigid, in particular it may have a prefixed mechanical resistance. In alternative, or in addition, the article may comprise a further stiff and mechanically resistant layer, which is distinct from the electrically insulating matrix and is stuck to the electrically insulating matrix. If the electrically insulating matrix comprises layers of different thicknesses, the mechanically resistant layer may be arranged along the outer face of the thickest layer of the electrically insulating matrix. The article may also comprise further layers for heat insulation, or for other functions. These further layers extend along a face of the electrically insulating matrix or of the mechanically resistant layer, by the side of the thickest layer of the electrically insulating matrix, if any.

The article may be a flat article, such as a sheet, or a curved article, such as a shell that may extend along a portion of a cylinder or of a sphere, or it may be an angled article comprising two wings that extend along respective planes at a solid angle with respect to each other.

The electrically conductive material may comprise a metal network or fabric structure. In alternative, or in addition, the electrically conductive material may comprise a non-metallic material such as carbon fibre. In alternative, or in addition, the electrically conductive material may comprise metalized that behaviour like a metal, or an intrinsically insulating material that, on the other hand, is made conductive or semi-conductive by addition of conductive chemical substances.

The material of the electrically insulating matrix may be any thermoplastic or thermosetting polymer material. The material of the electrically insulating matrix may contain various strengthening agents or fillers, like fibre strengthening agents, as well known in the art. In a particular exemplary embodiment, the electrically insulating matrix is made of fibreglass, i.e. in a plastic material, like a thermosetting polyester resin, that is reinforced by incorporating glass fibres, to form a stiff structure.

In particular, the electrically insulating polymeric matrix may be rigid, in which case the matrix itself makes the articled stiff.

In particular, the step of removing the surface layer portion of the polymeric material may occur during the step of deposition.

For instance, the step of depositing the loose metal connection material is carried out on the outer surface layer of the stiff composite layer article by maintaining the loose metal connection material at a deposition temperature higher than a transition temperature of the polymeric material, at which the polymeric material turns from a coherent solid state into an incoherent state if it is brought to a temperature higher than the transition temperature, in order to cause the step of removing a surface layer portion of the polymeric material of the electrically insulating matrix during the step of deposition.

The transition temperature, above which the loose metal connection material is maintained, may be a melting temperature, in particular if the polymeric material is a thermoplastic material. In alternative, the transition temperature may be a temperature of sublimating the polymeric material. If the transition temperature is exceeded, the polymeric material turns from a substantially solid state to a liquid or gaseous incoherent state, so that it leaves the matrix of the article. In alternative, the transition temperature is a temperature above which a decomposition of the polymeric material takes place, in particular in the case of a thermosetting polymeric material, thus creating typically low-molecular weight and/or gaseous decomposition products, which can leave the matrix of the article.

This way, it is possible to remove the polymeric material of the matrix and to provide a coherent uncovered electric terminal layer at the selected connection zone, in a same treatment step.

The step of depositing the loose metal connection material and of forming the uncovered electric terminal layer may be carried out after the step of removing a surface layer portion of the polymeric material, the step of removing creating a portion not covered by the electrically insulating matrix of the electrically conductive layer. In this case, the step of depositing the loose metal connection material and of forming the uncovered electric terminal layer may also comprise a step of keeping the connection metal at a predetermined temperature.

The step of hot depositing may be carried out according to a thermal spraying step, where the steps are provided of:

- melting the connection metal;
- reducing the connection metal into liquid particles of a predetermined size, typically into particles in the order of magnitude of one micron or of ten microns;
- projecting the liquid particles of the connection metal against the connection zone. For instance, the *thermal spraying* technique may be a plasma spraying step, a detonation thermal spraying step, a wire arc thermal spraying step, a flame thermal spraying step, or a different technique.

In alternative, the step of hot depositing may comprise a technique of flame deposition, i.e. of thermal spraying metallization, where the steps are provided of:

- heating a portion of the connection metal up to a temperature close to the melting temperature of the connection metal, wherein said metal is in an advanced plastic state. In particular, the connection metal may be obtained from a wire;
- projecting the loose metal connection material from the heated body onto the connection zone, in particular by means of a carrier fluid.

In particular, the projection is carried out using compressed air as the carrier fluid. The thermal energy for increasing the temperature of the metal can be obtained by burning a gas fuel, from a plasma, or by burning a liquid fuel. The flame deposition is particularly advantageous for removing the polymeric material of the electrically insulating matrix and for depositing the connection metal on the electrically conductive layer in a single step, since this technique does not damage the electrically conductive layer, even if this layer is made of a carbon fabric.

In alternative, the step of hot depositing may comprise a step of physical vapour deposition, wherein the steps are provided of:

- evaporating the metal connection material, obtaining a vapour of the connection metal;
- projecting the vapour of the metal connection material onto the stiff composite layer article at the connection zone.

The step of physical vapour deposition may be carried out by resorting to well-known techniques, such as evaporative deposition, sputter deposition, electron beam physical vapour deposition, cathodic arc deposition and pulsed laser deposition.

In alternative, the loose metal connection material is prearranged in the form of a solid particles of a predetermined grain size, and the step of depositing comprises a step of projecting the solid particles onto the connection zone at a predetermined projection rate, such that a plastic impact occurs between the particles and the electrically conductive layer and the particles remain stuck on the electrically conductive layer and on the connection metal already deposited thus forming the uncovered layer terminal.

The step of depositing subsequent to the step of removing the surface layer of polymeric material may comprise a cold depositing technique or of *cold spraying*, in other words the particles of the connection metal may be projected at substantially at room temperature, i.e. without any temperature change due to the deposition process.

The conductive connection material may also be different from the material of the conductive layer of the wall member and/or of the container, in particular it may be a material that is galvanically compatible with the material of the conductive layer of the wall member and/or of the container. Preferably, the conductive connection material is Nickel, or an alloy thereof, in order to provide a high chemical stability impart to the uncovered electric terminal layer. This way, the article is well suited for applications in a corrosive environment such as a marine environment.

In alternative, the step of prearranging a stiff composite layer article comprises a step of forming a peelable zone of the matrix at the connection zone, and the step of removing a surface layer portion of the polymeric material comprises a step of removing the peelable zone. In particular, this step of making a removable zone can comprise a step of arranging a detachable fabric strip on said electrically conductive layer, preferably provided with a tear means, such as a peel-ply type strip.

The step of removing a surface layer portion of the polymeric material may comprise a sandblasting step, i.e. a step of projecting a particulate solid material against a surface of the electrically insulating matrix, at the connection zone and at a prefixed speed that is suitable for locally removing the electrically insulating matrix and for forming the uncovered portion of the electrically conductive layer. Preferably, the sandblasting step is carried out, in such a way to provide a surface of predetermined roughness on the region of the electrically conductive layer that is not covered by the electrically insulating matrix. This assists the metal connection material to stick on the uncovered region of the electrically conductive layer. In particular, the sandblasting step may be carried out using a material of a predetermined grain size, in particular set between 10 µm and 150 µm, more in particular, of grain size set between 60 µm and 80 µm. Preferably, the sandblasting step is carried out by sand.

In alternative, or in addition, the step of removing may comprise a step of contacting the article with an amount of a substance adapted to erode the electrically insulating matrix, at the connection zone. For example, this substance may comprise methylene chloride.

In alternative, or in addition, the step of removing a surface layer portion of the polymeric material of the matrix may comprise a step of projecting a laser beam of a predetermined power onto said connection zone.

According to an aspect of the invention, the step of depositing is carried out by bridging the above-described article, and a contiguous articled selected among an article of a conductive material and a further electrically conductive stiff composite layer article that has an outer surface layer made of an insulating polymeric material, and that is subjected to the steps of selecting a further connection zone and to the step of removal, such that the uncovered electric terminal layer connects the article and the contiguous article. In particular, the article and the contiguous article are a first wall member and a second wall member of a Faraday shield container.

This way, a structurally strong conductive connection can be formed between the wall members of the container, suitable for withstanding mechanical stresses and the inclemency of the weather.

For instance, by the technique according to the invention, containers are obtained in which the connections between the wall members have a shielding capacity of at least 30 dB towards electromagnetic waves of frequency set between 20 kHz and 40 GHz.

Moreover, the method according to the invention can provide connections between the wall members that are provided with a narrowly meshed conductive layer, or with a carbon fibre fabric, and that have a shielding capacity against high frequency electromagnetic waves, for example against electromagnetic waves of frequency of about one GHz, which are typically used for radar transmissions.

The step of creating an electrical continuity may comprise a step of contacting the connection zones of the wall members.

Said step of creating an electrical continuity may comprise a step of arranging an resiliently or plastically compliant electrically conductive element in contact with the connection zone and with the further connection zone. For example, the element conductor may comprise a seal against moisture and/or against the inclemency of the weather.

In particular, the step of arranging the first wall member and the second wall member can be made in such a way that at least one degree of freedom is left to the first wall member with respect to the second wall member. In particular, the first wall member is integral to the shield container, and the connection zone and the further connection zone are linearly extending connection zones, and the degree of freedom is a rotational degree of freedom of the second wall member with respect to the first wall member, and so with respect to the shield container, about an axis located between the linearly extending connection zones. This way, it is possible to provide movable walls, access doors, inspection doors, handholes and the like, providing an access into the container.

In particular, the other wall member is a metal wall member.

In particular, this metal member comprises a metal plate configured for serving as a ground element of an electric device mounted on the shield container, in particular of an antenna, while the shield container has an own ground connection element.

The method according to the invention can be advantageously used to provide a ground plane for a device such as an antenna mounted on a surface of the shield container, in particular on top of the container, wherein the other wall member provides a ground plane for the device. In this case, the ground connection of the antenna or of a different device is provided by the electrically conductive layer of the shield container, which is suitably earthed as established by the regulations and suggestate by the good construction practices.

Brief description of the drawings

The invention will be now shown with the description of exemplary embodiments of the method according to the invention, exemplifying but not limitative, with reference to the attached drawings, in which like reference characters designate the same or similar parts, throughout the figures of which:

— Fig. 1 is a diagrammatical cross sectional view of a stiff composite layer article made of a composite material comprising an electrically insulating matrix, and an electrically conductive layer incorporated therein;

— Fig. 2 is a perspective diagrammatical view of the stiff composite layer article of Fig. 1;

— Figs. 3 and 4 diagrammatically show partial sectional views of the article of Fig. 1 and 2 that are taken to show the electrically conductive layer;

— Fig. 5 is a partial diagrammatical cross sectional view of the article of Fig. 2, in which it a connection zone is shown;

— Fig. 6 is a partial perspective view of the article of Fig. 2 arranged for removing a polymeric layer of the matrix and for preparing an uncovered portion of the electrically conductive layer;

— Fig. 7 diagrammatically shows a step in which a conductive deposit, i.e. an uncovered electric terminal layer of the connection zone, is formed while removing a polymeric layer of the matrix at the connection zone;

— Fig. 8 shows the article obtained by the step of Fig. 7;

— Fig. 9 diagrammatically shows a step of removing a polymeric layer carried out by sandblasting;

— Fig. 10 shows the article obtained by the step of Fig. 9;

— Fig. 11 shows an article like in Fig. 2, which also comprises a releasable detachable fabric strip made above the electrically conductive layer at a selected connection zone;

— Fig. 12 shows a step of removing the detachable fabric strip of Fig. 11;

— Fig. 13 shows a step of depositing a connection metal at a connection zone, with a deposition techniquefrom metal in vapour phase or in liquid phase;

— Fig. 14 shows the article obtained by the step of Fig. 13;

— Fig. 15 shows a step of depositing a connection metal at a connection zone, by flame deposition from a metal wire that is in the advanced plastic state;

— Fig. 16 shows a butt connection between two articled, e.g. boards, in which respective connection zones are provided according to the invention;

— Fig. 17 shows an angle connection between an article, e.g. a sheet in which a connection zone is provided according to the invention or, in alternative, a further sheet;

— Fig. 18 shows a T-shaped article;

— Fig. 19 shows another butt connection between two articled, e.g. boards, in which a connection zone is provided according to the invention;

— Fig. 20 shows a connection between two boards that are movable with respect to each other and in which respective connection zones are provided according to the invention;

— Fig. 21 shows a shield container structure comprising a ground plane for an antenna.

<u>Description of preferred exemplary embodiments</u>

Figs. 1 and 2 diagrammatically show, in a cross sectional view, the structure of a stiff composite layer article 10 made of a composite material comprising an electrically insulating matrix 11 made of a polymeric material, and an electrically conductive layer 13 incorporated within electrically insulating matrix 11. In particular, electrically conductive layer 13 may be completely incorporated within electrically insulating matrix 11, i.e. it may be completely covered with the polymeric material of insulating matrix 11.

Stiff composite layer article 10 extends along at least one surface, which may be a flat surface 15, as shown in Figs. 1 and 2, or a curved surface, not shown, according to which both electrically conductive layer 13 and matrix 11 extend. Matrix 11 comprises two layers 12', 12" between which electrically conductive layer 13 is sandwiched, and that are formed by joining together matrix 11 and electrically conductive layer 13, where electrically conductive layer 13 is substantially plunged into a liquid layer of the polymeric material of matrix 11. In the exemplary embodiment of Fig. 1, two layers 12',12" of matrix 11 may have different thicknesses s',s", in particular electrically conductive layer 13 is located proximate to a face 14' of the article. Typically, thickness s' of the thinnest layer may be about 100 μm.

In the articles diagrammatically shown in Figs. 1 and 2, electrically insulating matrix 11 may be intrinsically rigid, in this case it may form stiff composite layer article 10 together with electrically conductive layer 13.

Electrically insulating matrix 11 may be made of a material based on any polymer, preferably on a thermosetting polymer such as an epoxy resin, or a phenolic resin, or a polyester resin or another known resin, but it may be also made of a material based on a thermoplastic polymer. In matrix 11, reinforcing agents are normally provided, for example matrix 11 may be of a plastic reinforced by incorporated fibreglass.

The article may comprise a further stiff layer 19 that may serve as a mechanically resistant layer and that is stuck to matrix 11. This layer is optional, and is shown in dotted line in Fig. 1. In particular, mechanically resistant layer 19 is arranged on an outer face 14" of layer 12" of matrix 11, i.e. opposite to electrically conductive layer 13. Further layers, not shown, may be provided on the same side of face 14" of matrix 11 for thermal insulation, or for different purposes.

The article may also extend along to a plurality of surfaces, in particular it may be an angled article 50 like in Fig. 17, which has two wings 55, 56 at an angle α with respect to each other, in this case 90°. The article may also be a T-shaped article 30 as diagrammatically shown in Fig. 18, which has three wings 57, 58, 59 at an angle β with respect to one another, in this case 90°, wherein a connection zone of T middle wing is shown.

As diagrammatically shown in Figs. 3 and 4, electrically conductive layer 13 may have a network or fabric structure, respectively. Electrically conductive layer 13 may be made of a metal material or of a non-metal material such as carbon fibre, or of a mixed material. Electrically conductive layer 13 may be also made of an intrinsically non-metal fabric that is subsequently metalized and made electrically conductive accordingly. For instance, this fabric may be a nickeled prepreg polyester fabric that is incorporated in the layer articledtructure.

Fig. 1 also shows two connection zones 21 where electrically conductive layer 13 is uncovered, as described hereinafter. Therefore, connection zone 21 may serve for electrically connecting article 10 with other conductive articled, in particular with other articles that comprise an electrically insulating matrix and an electrically conductive layer incorporated within the matrix. As also described hereinafter, connection zone 21 may serve as a mechanical connection zone that provides electrical continuity between article 10 and the articles or the structures connected thereto.

In Fig. 2, connection zone 21 has a linear arrangement and is parallel to edges 23 of sheet 10. However, they it may have any arrangement along the surface of sheet or article 10. The connection zone may even be made in a middle board portion or article 10. The shape and the position of the connection zone is advantageously selected responsive to the connection to be provided.

In order to uncover electrically conductive layer 13 at connection zone 21, a step of removing a surface layer portion of the polymeric material of matrix 11 is carried out at connection zone 21. This is diagrammatically shown in Fig. 5, where thickness s' of layer 12' of matrix 11 (Fig. 1) has been augmented for the sake of clearness. In fact, thickness s' that can be obtained by a common incorporation method of conductive fabric or network 13 into polymeric matrix 11 allows obtaining a thickness s' of layer 12' of about 100-200 µm, versus an overall thickness s of matrix 11 of several mm. Fig. 5 also shows a layer 25 of a connection metal which may be deposited along connection zone 21 to form an uncovered electric terminal layer strong enough to provide a reliable conductive connection between article 10 and a conductive member, for instance another article that comprises an electrically insulating matrix and an electrically conductive layer incorporated therein.

As diagrammatically shown in Figs. 6-8, in order to remove a surface portion of the polymeric material an amount of a connection metal 29 is heated up to a prefixed deposition temperature that is remarkably higher than a melting or softening/fusion or decomposition temperature of the polymeric material of matrix 11. At this temperature, metal 29 may be into a molten or liquid state, or in a vapour state. The metal is projected against face 14' of matrix 11 by a projection device 27. Connection zone 21 may be defined by preferably removable strips of a protective material 28, so that connection metal 29 reaches prefixed connection zone 21 only. Only at connection zone 21, the polymeric material is evaporated or molten/softened or decomposed and leaves article 10, thus uncovering electrically conductive layer 13. Fig. 7 shows the case of melting/softening the polymeric material of matrix 11 leaves connection zone 21, in particular as a liquid 31. In the same treatment step, deposited connection metal 29 is merged with electrically conductive layer 13 at connection zone 21, to create a coherent uncovered electric terminal layer 25.

In alternative, as diagrammatically shown in Fig. 9, the removal of the surface portion of polymeric material comprises sandblasting a particulate solid material 33, which may be a sand of known type to a skilled person. Particulate solid material 33 is projected against face 14a of matrix 11. Also in this step, connection zone 21 may be defined by preferably removable strips of protective material 28 so that projected particulate solid material 33 reaches predetermined connection zone 21 only. This way, as shown in Fig. 10, polymeric material 34 is locally withdrawn from matrix 11 at connection zone 21 only, where conductive layer 13 is no longer covered by matrix 11. In particular, particulate solid material or sand 33 has a grain size set between 10 and 150 µm, more in particular it has a grain size set between 60 µm and 80 µm.

In alternative, as shown in Fig. 11, article 10 may be made by providing a strip 35 of peelable detachment fabric, which may be of a known type, such as a peel-ply fabric, which is arranged, when manufacturing the article, on electrically conductive layer 13, along connection zone 21. Strip 35 has a gripp means 36, for example in the form of a tang protruding from matrix 11, as shown in Fig. 12. In order to remove the surface portion of polymeric material 37 at connection zone 21, peelable strip 35 is withdrawn from article 10, by pulling tang 36. Once removable fabric strip 35 has been removed, electrically conductive layer 13 is no longer covered by matrix 10 at connection zone 21, as shown in Fig. 10.

The condition of Fig. 10 may be obtained, according to an exemplary embodiment of the method, not shown, by a chemical reaction with a substance adapted to erode the polymeric material of matrix 11 on connection zone 21. For example, this substance may be methylene chloride.

As shown in Fig. 13, after the step of removing the surface portion of polymeric material 37, a deposit of a connection metal 39 can be carried out on the portion of electrically conductive layer 13 that is no longer covered by electrically insulating matrix 11, for instance, by a projection device 27, in order to form a coherent uncovered electric terminal layer 25, as shown in Fig. 14.

The deposit of material 39 of Fig. 14 may be carried out by a hot deposition technique of known type, for example by a thermal spraying technique, in which metal connection material 39 is brought to a loose form and comprises particles of molten metal of a predetermined size. In particular, the thermal spraying technique may be a plasma thermal spraying technique, a detonation thermal spraying technique, a wire arc thermal spraying technique or a flame thermal spraying technique.

As shown in Fig. 15, another possible hot deposition technique of the metal connection material may be a technique of flame deposition. In particular, may be used a technique of wire flame deposition. According to this technique, a wire 42 comprising the connection metal is heated up to a temperature close to the melting temperature of the connection metal, at which the connection metal is in an advanced plastic state. Subsequently, the molten connection metal of the wire is projected as loose material 49 from the wire 42 onto electrically conductive layer 13, at connection zone 21, by a flow of a carrier fluid 43 that may be compressed air. Even in this step, connection zone 21 may be defined by preferably removable strips of protective material 28 so that the projected particulate solid material 33 reaches predetermined connection zone 21 only.

Another possible hot deposition technique of the metal connection material may be a physical vapour deposition technique. According to this technique, the metal connection material is vaporized before being projected on article 10 at connection zone 21. In this case, evaporation and projection means 32 of Fig. 13 may be configured, as known to a skilled person, for carrying out techniques of thermal deposition such as evaporative deposition, electron beam physical vapour deposition, sputter deposition, cathodic arc deposition and pulsed laser deposition.

The above indicated deposition techniques of connection metal 29, 39 may be used also for carrying out the step of removing the surface portion of polymeric material of matrix 10 at connection zone 21, as shown in Fig. 7, and as previously described.

Fig. 13 may be considered representative also of a deposition technique, in which connection metal 39 is deposited as a solid material, by a process similar to sandblast. In other words, the connection metal is reduce to solid particles 39 that are projected onto connection zone 21, in particular onto an uncovered portion of electrically conductive layer 13. Connection metal 39 and the deposition conditions, in particular the speed of the connection metal, are selected in such a way that a plastic impact occurs between connection metal 39 and electrically conductive layer 13. This way, connection metal 39 projected against article 10 remains stuck on electrically conductive layer 13 and on already deposited connection metal 39. In particular, this deposition technique may be a cold depositing technique or a cold spraying technique, in which where connection metal 39 is projected onto the connection zone of article 10 at substantially at room temperature.

Figs. 16 to 20 diagrammatically show connections between structural elements 11,11', 51, at least one of which is a stiff composite layer article comprising an electrically insulating matrix 11,11' made of a polymeric material, and an electrically conductive layer 13,13' incorporated within electrically insulating matrix 11,11' that has a connection zone 21, i.e. a coherent uncovered electric terminal layer 25, obtained according to one of the above mentioned or described techniques. The connections are obtained by bringing two structural elements with respective connection zones 21 arranged next to each other, in particular with the linearly extending connection zones 21 adjacent to each other, and creating this way an electrical continuity between connection zones 21.

For example, Fig. 16 shows a butt connection between two flat articles or boards 10, 10' having connection zones 21, 21' proximate to respective edges 23, 23'. Boards 10,10' are arranged with edges 23, 23' parallel to each other. The electrical continuity between connection zones 21, 21' and, therefore, between conductive layers 13,13', may be provided by placing conductive material 47 to form a bridge between connection zones 21, 21' at edges 13,13', to make a contact, i.e. a stable electric connection, between connection zones 21 and 21'. Conductive element 47 may be a deposit obtained by a deposition technique selected, for example, among the previously described techniques for depositing the connection metal at connection zones 21, 21', or may be a conductive strip 47 fixed to boards 10,10' by conventional fixing means such as bolts, not shown. The mechanical cohesion between boards 10,10' may be ensured by conventional fixing means, for example by a support 46 mounted opposite to connection zone 21, 21', or it may be ensured by gluing.

In an advantageous exemplary embodiment, conductive strip 47 may be obtained by depositing a plurality of prepreg webs or fabrics, overlapped to one another, which contain a metal such as nickel. These fabrics may be made of a polyester, for instance. In particular, these fabrics comprise strips of decreasing width, from the first deposited tape to last deposited tape. In particular, said fabrics have a width set between 5 and 20 cm across a connection line between boards 11 and 11'.

For example, Fig. 17 shows an angle connection between an article 50 comprising a polymeric electrically insulating matrix 11, and an electrically conductive layer 13 incorporated within matrix 11, and a metal support 51. More in detail, article 50 is an angled article comprising a board portion 56 and a fastening wing 55 orthogonal to board portion 56. Angled article 50 has a connection zone 21 made on fastening wing 55, by one of the above mentioned or described techniques. The connesction shown in Fig. 17 may be used for earthing a composite structure comprising board portion 56. To provide this connection, article 50 is arranged proximate to metal support 51 with fastening wing 55 parallel to metal support 51. The electrical continuity of metal support 51 with connection zone 21, and then with electrically conductive layer 13 is provided through a preferably resiliently or plastically compliant electrically conductive element 54, for example through a conductive seal element 54 or through a conductive deposit 54 of such a material as conductive silicone rubber arranged along connection zone 21. The connection between metal support 51 and board 50 is completed and secured by conventional fixing means comprising a compression means of conductive seal element 54, such as bolts 53. Seal 54 may also serve to provide tightness against moisture and/or against the inclemency of the weather.

Angled article 50 may also be used to form an angle connection with a board, not shown, whose structure comprises an electrically insulating matrix that incorporates an electrically conductive layer, and that is arranged like metal support 51, and has a connection zone corresponding to connection zone 21 of board 50.

As shown in Fig. 19, angled article 50 may also be used to form a butt connection with another angled article 50', by arranging articles 50, 50' with the respective fastening wings 55, 55' facing each other, and with respective connection zones 21, 21' facing each other. The electrical continuity between articles 50 and 50', i.e. between respective electrically conductive layers 13,13', is provided through a preferably resiliently or plastically compliant electrically conductive element 54, for example through a conductive seal element 54 or through a conductive deposit 54 of such a material as a conductive silicone rubber arranged along connection zones 21, 21' facing each other. The connection between articles 50, 50' is completed and secured by a fixing means 53 of the same type as indicated when describing Fig. 17.

Fig. 20 diagrammatically shows a connection between two articles 40 and 40' that have the shape of boards or have respective board portions, each comprising a polymeric electrically insulating matrix 11,11' that incorporates an electrically conductive layer 13,13'. Sheet 40' has a rotational degree of freedom with respect to sheet 40, in particular it is movable between a closed position A, in which it has an edge 23' at the side of an edge 23 of article 40, and an open position B in which edge 23' is arranged at a predetermined distance from side 23, For instance, article 40 may be an element of a shield container, and article 40' is a wing of a door or a small access or inspection door, and the like, of the container. The rotatable constraint between container elements 40, 40' is provided in a conventional way, not shown, and the electric contact between connection zones 21, 21', which are typically linear and parallel to the rotation axis of container element 40' with respect to container element 40, is made by means of a resiliently or plastically compliant element, for example by means of a conductive seal element 57;

Fig. 21 shows a shield container 60, in which the container elements, in this case in the form of boards 10, 10", comprise a polymeric electrically insulating matrix and an electrically conductive layer incorporated therein. In particular, sheet 10" has a hole 17, in this case a rectangular central hole, and a connection zone 21 made proximate to the perimeter of hole 17, by one of the previously described methods. Shield container 60 also comprises a further metal wall member, in particular a metal support plate 16, that is configured for serving as a ground element of an electric device. For instance, plate 16 may be a ground plane of an antenna 62 that is equipped with a rod antenna element 63. An electric connection is made between support plate 16, in this case a rectangular support plate, and sheet 10", at hole 17. This way, an electrical continuity is provided between support plate 16 and conductive layer sheet 10" through connection zone 21 of sheet 10". A material compliant conductor, not shown, may be located between plate 16 and connection zone 21. The contact may be secured by a conventional mechanical connection means between plate 16 and sheet 10", not shown, which may comprise bolts, gluing lines and the like. Sheet 10" is in turn connected to boards 10 by angled connection means, like the previously described ones, to provide an electrical continuity between respective conductive layers 13. The electrically conductive structure of shield container 60, formed by the plurality of electrically conductive layers 13 of boards 10, 10", is earthed via an own ground connection element 64 and via a connection line 65 to ground 67.

The foregoing description exemplary embodiments of the invention will so fully reveal the invention according to the conceptual point of view, so that others, by applying current knowledge, will be able to modify and/or adapt in various applications the specific exemplary embodiments without further research and without parting from the invention, and, accordingly, it is meant that such adaptations and modifications will have to be considered as equivalent to the specific embodiments. The means and the materials to realise the different functions described herein could have a different nature without, for this reason, departing from the field of the invention. It is to be understood that the phraseology or terminology that is employed herein is for the purpose of description and not of limitation.

CLAIMS

1. A method for manufacturing an electrically conductive stiff composite layer article (10) that has an outer surface layer made of an insulating polymeric material, said method comprising the steps of:
   - prearranging a stiff composite layer article (10) comprising an electrically insulating matrix (11) made of said polymeric material and an electrically conductive layer (13) incorporated within said electrically insulating matrix (11);
   - prearranging an amount of a loose metal connection material (29, 39, 49);
   - selecting an electric connection zone (21) on a surface (14’) of said stiff composite layer article (10);
   - removing a surface layer portion of said polymeric material of said electrically insulating matrix (11) at said connection zone (21);
   - depositing at least one part of said loose metal connection material (29, 39, 49) at said connection zone (21) and welding at least one part of said loose metal connection material (29, 39, 49) with said electrically conductive layer (13), forming an uncovered electric terminal layer (25, 47) at said connection zone (21).

2. A method according to claim 1, wherein said step of depositing said loose metal connection material (29, 39, 49) is carried out on said outer surface layer of said stiff composite layer article (10) by maintaining said loose metal connection material (29, 39, 49) at a deposition temperature higher than a transition temperature of said polymeric material, at which said polymeric material turns from a coherent solid state into an incoherent state if it is brought to a temperature higher than said transition temperature, in order to cause said step of removing a surface layer portion of said polymeric material of said electrically insulating matrix (11) during to said step of deposition.

3. A method according to claim 1, wherein said step of depositing said loose metal connection material (29, 39, 49) and of making said uncovered electric terminal layer (25, 47) is carried out after said step of removing a surface layer portion (37) of polymeric material, said step of removing

creating a portion not covered by said electrically insulating matrix (11) of said electrically conductive layer (13).

4. A method according to claim 1, wherein said step of depositing said loose metal connection material comprises a thermal spraying step, wherein the steps are provided of:

- melting said connection metal;
- reducing said connection metal into liquid particles (29) of a predetermined size, in particular into liquid particles of a size set between 1 μm and 100 μm;
- projecting said liquid particles against the connection zone,

in particular, said thermal spraying step is selected from the group consisting of: a plasma spraying step, a detonation thermal spraying step, an wire arc thermal spraying step or a flame thermal spraying step.

5. A method according to claim 1, wherein said step of depositing loose metal connection material (49) comprises a step of flame deposition, wherein steps are provided of:

- heating a part (42) of said loose metal connection material up to a temperature close to the melting temperature of said loose metal connection material, wherein said loose metal connection material is in a plastic state;
- trasformation into a molten state of said loose metal connection material from said plastic state;
- projecting the loose metal connection material (49) from said heated portion (42) onto said connection zone by a carrier fluid (43),

in particular, said portion of said loose metal connection material is a wire (42);

in particular, said carrier fluid (43) is compressed air.

6. A method according to claim 1, wherein said step of depositing loose metal connection material comprises a step of physical vapour deposition, comprising the steps of:

- evaporating said loose metal connection material (39), obtaining a vapour (39) of said connection metal;

– projecting said vapour (39) of said loose metal connection material against said composite stiff layer article, at said connection zone (21),

in particular, said step of physical vapour deposition is selected from the group consisting of: an evaporative deposition step, an electron beam physical vapour deposition step, a sputter deposition step, a cathodic arc deposition step, a pulsed laser deposition step, a combination of the above steps.

7. A method according to claim 1, wherein said loose metal connection material is prearranged in the form of a solid particles (39) of a predetermined grain size, and said step of depositing comprises a step of projecting said solid particles (39) onto said connection zone (21) at a predetermined projection rate, such that a plastic impact occurs between said particles (39) and said electrically conductive layer (13) and said particles remain stuck on said electrically conductive layer (13) and on said connection metal already deposited thus forming said uncovered layer terminal (25, 47).

8. A method according to claim 3, wherein

– said step of prearranging a stiff composite layer article (10) comprises a step of forming a peelable zone (37) of said matrix at said connection zone (21), and
– said step of removing a surface layer portion of the polymeric material comprises a step of removing said peelable zone (37),

in particular, said step of making a removable zone comprises a step of arranging a detachable fabric strip (35) on said electrically conductive layer (13).

9. A method according to claim 3, wherein said step of removing a surface layer portion of the polymeric material is selected from the group consisting of:

– a sandblasting step, wherein a particulate solid material (33) is projected at a prefixed speed against a surface (14) of said electrically insulating matrix (13), at said connection zone (21), in order to locally remove said electrically insulating matrix (13) and to form said uncovered portion of said electrically conductive layer (13).

- a step of contacting said article (10), at said connection zone (21) with an amount of a corrosive substance adapted to erode said polymeric material, in particular said corrosive substance comprises methylene chloride.
- a step of projecting a laser beam of a predetermined power onto said connection zone (21).

10. A method according to claim 1, wherein said step of depositing is carried out by bridging said article (10,20,50) and a contiguous article (10',51,50',16) selected from the group consisting of:

- an article of a conductive material (16);
- a further electrically conductive stiff composite layer article (10',51,50') that has an outer surface layer made of an insulating polymeric material, and is subjected to said steps of selecting a further connection zone (21') and to said step of removal,

such that said uncovered electric terminal layer (47) connects said article (10,20,50) and said contiguous article (10',51,50',16), in particular said article and said contiguous article are a first wall member (10,20,50) and a second wall member (10',51,50') of a Faraday shield container (60).

11. A method according to claim 10, wherein before said step of depositing a step is provided of interposing an resiliently or plastically compliant electrically conductive element (54,57) in contact with said connection zone (21) and with said further connection zone (21'),
in particular, said electrically conductive element (54,57) comprises a seal against moisture and/or against the inclemency of the weather.

12. A method according to claim 10, wherein said step of prearranging said first wall member (10) and said second wall member (10') is made in such a way that at least one degree of freedom is left to said first wall member (10) with respect to said second wall member (10'),
In particular,

- said first wall member (10') is integral to said shield container (60), and
- said connection zone (21) and said further connection zone (21') are linearly extending connection zones, and

- said degree of freedom is a rotational degree of freedom of said second wall member (10') with respect to said first wall member, and therefore with respect to said shield container, about an axis located between said linearly extending connection zones (21, 21').

13. A method according to claim 10, wherein said shield container (60) has an own ground connection element (64, 65), and said second wall member (16) comprises a plate configured for serving as a ground element of an electric device (62) arranged on said shield container,
in particular, said metal plate (16) is a ground plane for a device as an antenna (62) arranged on a surface (10") of said shield container (60), wherein said second wall member (16) forms said ground plane of said device (62).

Fig. 1

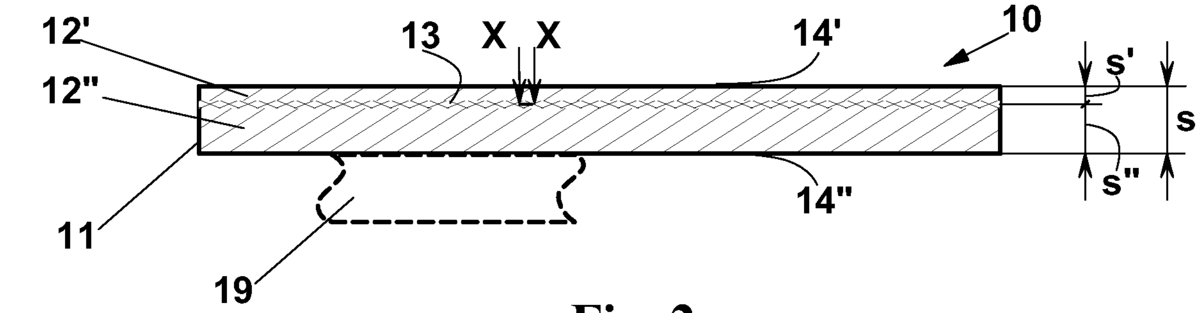

Fig. 2

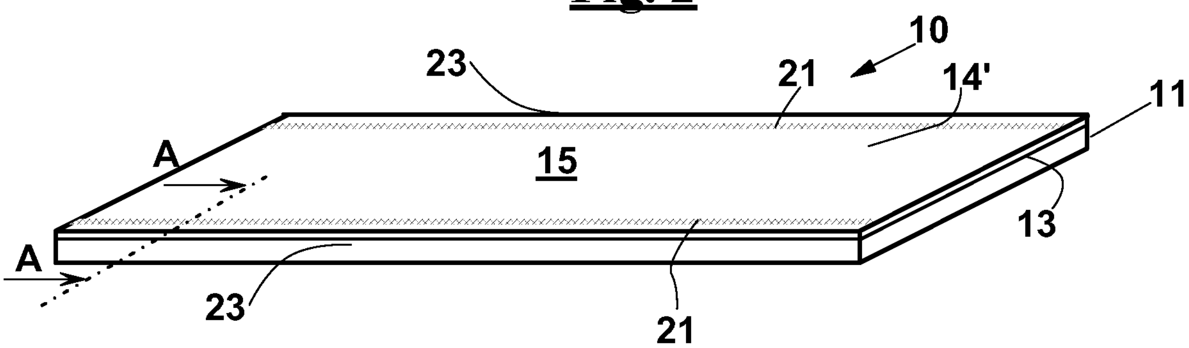

Fig. 3

X-X

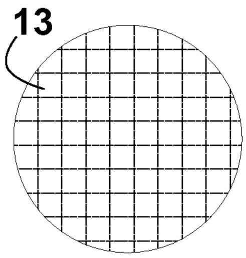

Fig. 4

X-X

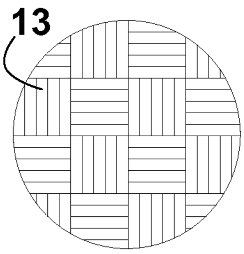

Fig. 5

A-A

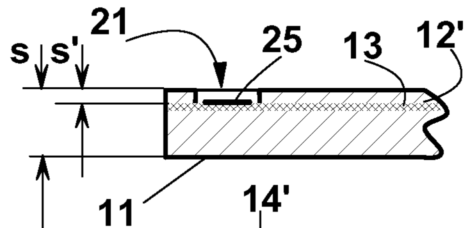

Fig. 7

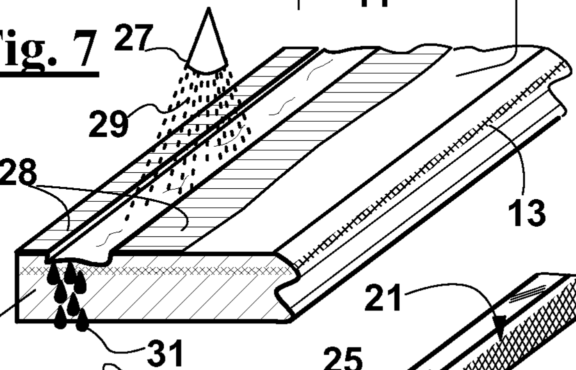

Fig. 8

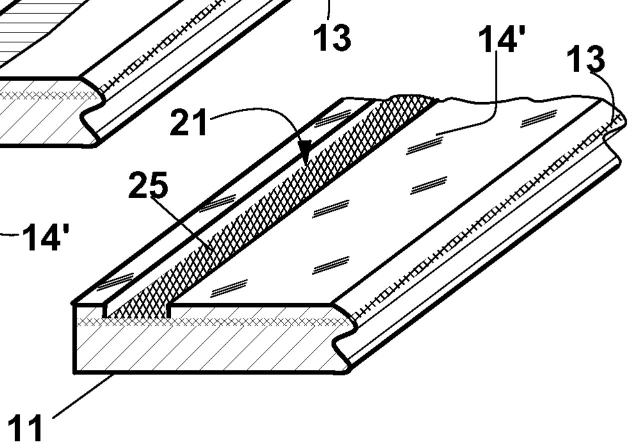

Fig. 6

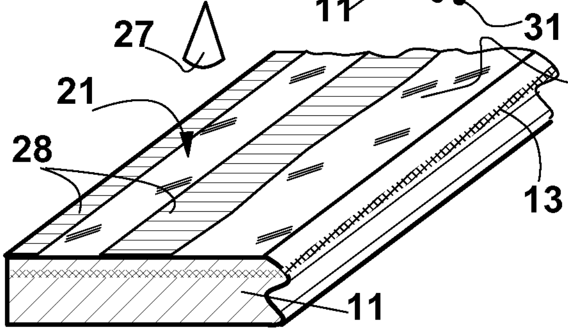

Fig. 9

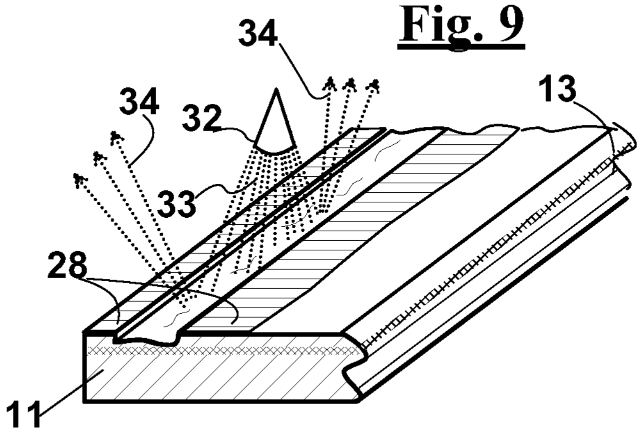

Fig. 10

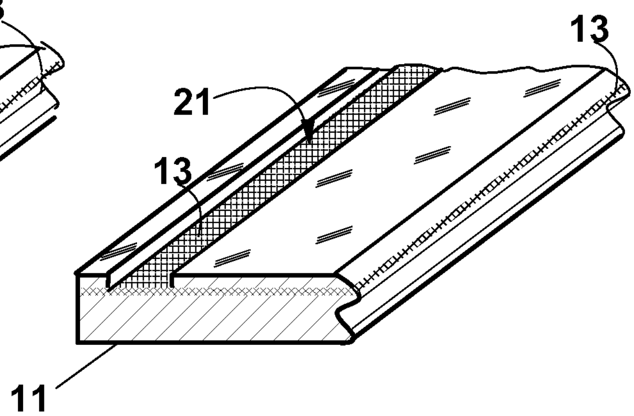

Fig. 11

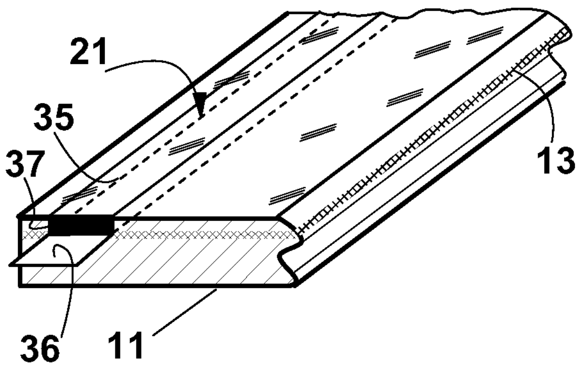

Fig. 12

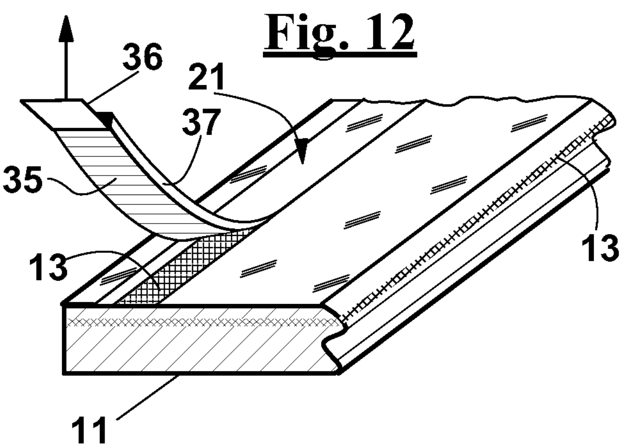

Fig. 13

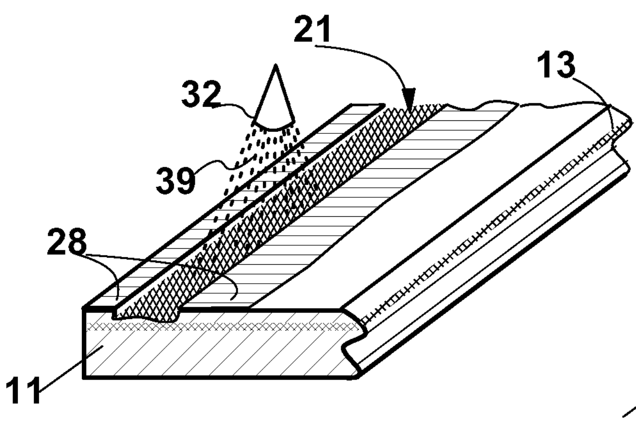

Fig. 14

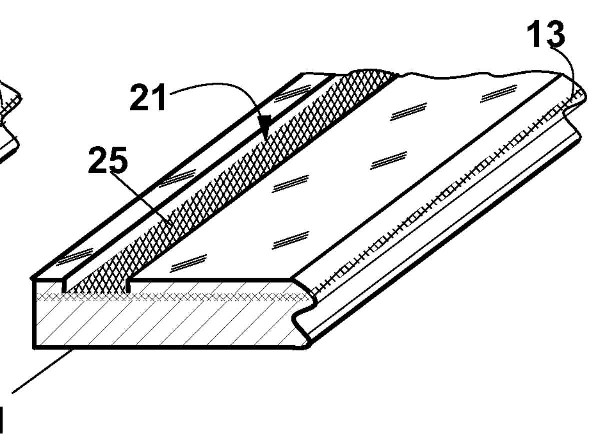

Fig. 15

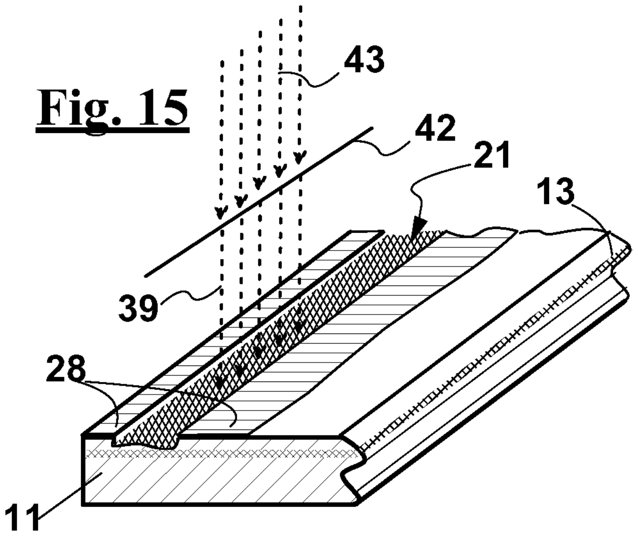

Fig. 16

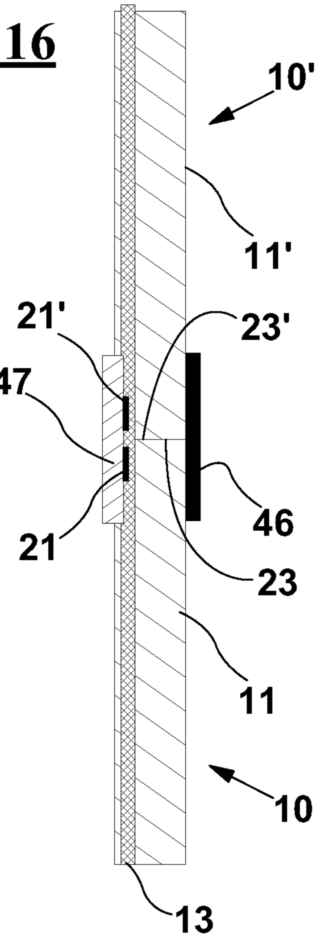

Fig. 17

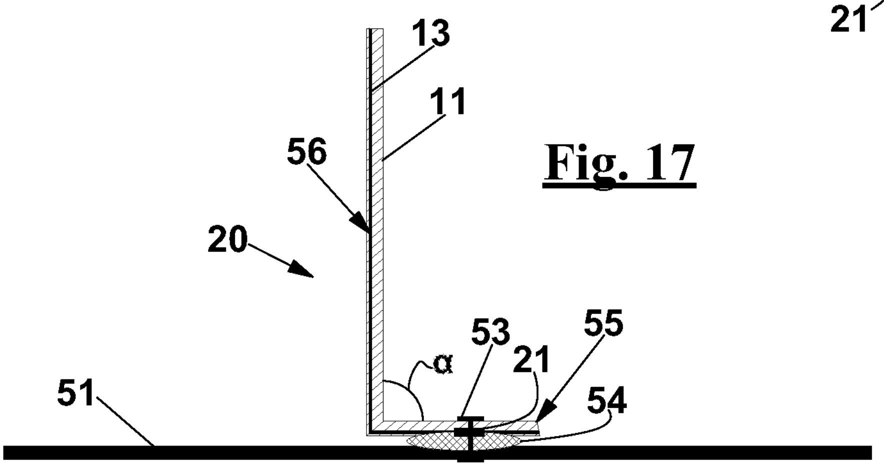

Fig. 18

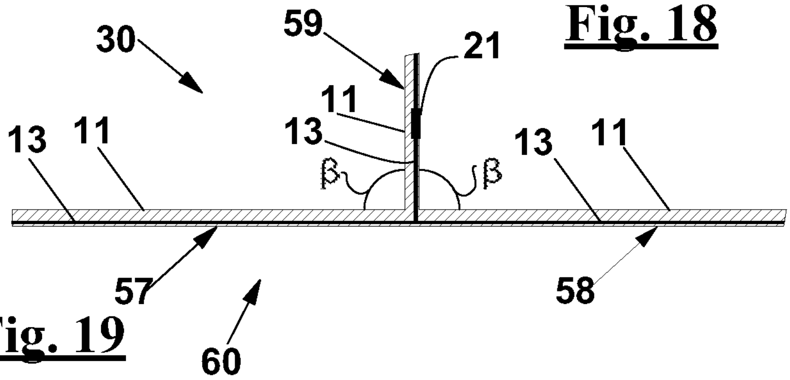

Fig. 19

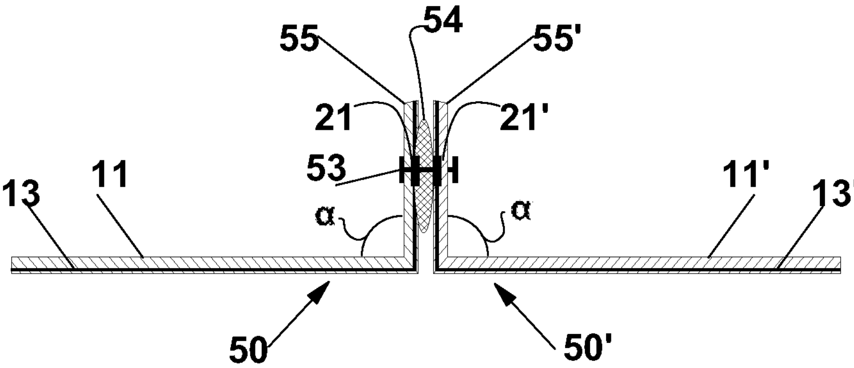

Fig. 20

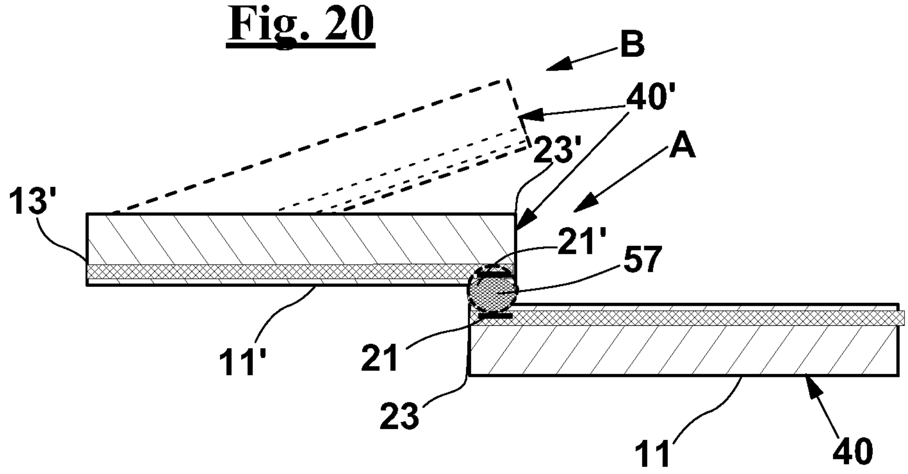

Fig. 21