A dielectric component with electrical connection is provided for a laminated heater mat (3) for an ice protection system for an aircraft (1). The dielectric component with electrical connection comprises at least one dielectric layer (50, 55) comprising thermoplastic material, and the dielectric layer (50) or a stack of the dielectric layers (50, 55) has first and second main surfaces and a hole (503) extending between the first and second main surfaces. A first sprayed metal coating (501) comprises a first portion (503) deposited on the first main surface (502) adjacent to the hole (503) and a second portion (5014) which projects into the hole. A second sprayed metal coating (5013, 5513) comprises a third portion deposited on the second main surface (506, 552) adjacent to the hole (505) and a fourth portion (5015) which projects into the hole (505). The second portion (5014) overlaps the fourth portion (5015) to form a continuous conductive path between the first main surface and the second main surface. This provides a cheap, neat and thin connection through the dielectric layer or the stack of dielectric layers.
FIELD OF THE INVENTION

The present invention relates to a dielectric component with electrical connection, such as a component part of an electrothermal heater mat for an electrothermal ice protection system suitable for use in an aircraft or other aerodynamic structure such as a blade of a wind turbine to prevent ice from forming and/or to remove ice that has already formed. These two functions may be termed anti-icing and de-icing, respectively.

BACKGROUND OF THE INVENTION

For an aircraft, the in-flight formation of ice on the external surface of the aircraft is undesirable. The ice destroys the smooth flow of air over the aircraft surface, increases drag and decreases the ability of an aerofoil to perform its intended function.

Also, built-up ice may impede the movement of a movable control surface such as a wing slat or flap. Ice which has built up on an engine air inlet may be suddenly shed in large chunks which are ingested into the engine and cause damage.

It is therefore common for aircraft, and particularly commercial aircraft, to incorporate an ice protection system. A commercial aircraft may use a system which involves bleeding hot air off from the engines, and the hot air is then ducted to the airframe components such as the leading edges of the wing and the tail which are prone to ice formation. More recently, electrically powered systems have been proposed, such as in EP-A-1,757,519 (GKN Aerospace) which discloses a wing slat having a nose skin which incorporates an electrothermal heater blanket or mat. The heater mat is bonded to the rear surface of a metallic erosion shield which comprises the forwardly-facing external surface of the nose skin.

The heater mat is of the "Spraymat" (trade mark) type and is a laminated product comprising dielectric layers made of preimpregnated glass fibre cloth and a heater element formed by flame spraying a metal layer onto one of the dielectric layers. The "Spraymat" has a long
history from its original development in the 1950s by D. Napier & Sons Limited (see their GB-833,675 relating to electrical de-icing or anti-icing apparatus for an aircraft) through to its subsequent use by GKN Aerospace.

A recent "Spraymat" produced by GKN Aerospace for use in a wing slat is formed on a male tool and involves laying up a stack of plies comprising (i) about 10 layers of glass fibre fabric preimpregnated with epoxy cured in an autoclave, (ii) a conductive metal layer (the heater element) which has been flame sprayed onto the laminate using a mask to form the heater element pattern and (iii) a final 3 or so layers of the glass fibre fabric. Wiring is soldered to the heater element to permit connection to the aircraft's power system. The heater mat is then cured in an autoclave.

A heater mat often incorporates a metal connection that extends through several dielectric layers and several conductive layers such as the heater element and a terminal at the end of the wiring in order to connect the heater element to the wiring. The metal connection is a separate element which is thick and bulky. The heterogeneous nature of the metal connection relative to the surrounding components such as the dielectric layers induces thermal and mechanical stresses in the heater mat which can result in fatigue failure.

It would be desirable to provide an improved dielectric component with electrical connection, suitable for use in a heater mat or generally in any laminated product.

**SUMMARY OF THE INVENTION**

According to a first aspect of the present invention, there is provided a dielectric component with electrical connection, suitable for use in a laminate and comprising:

- at least one dielectric layer comprising thermoplastic material, wherein the dielectric layer or a stack of the dielectric layers has first and second main surfaces and a hole extending between the first and second main surfaces;

- a first sprayed metal coating comprising a first portion deposited on the first main surface adjacent to the hole and a second portion which projects into the hole; and

- a second sprayed metal coating comprising a third portion deposited on the second main surface adjacent to the hole and a fourth portion which projects into the hole;
wherein the second portion overlaps the fourth portion to form a continuous conductive path between the first main surface and the second main surface.

In our current embodiments, the dielectric component with electrical connection is incorporated in a heater mat. However, the present invention has broader application than just to heater mats. For example, a laminated composite incorporating a conductive ground plane for dissipating a lightning strike on an aircraft could make use of the present invention to provide the electrical connection between the ground plane and the aircraft earth. For example, the first portion of the first sprayed metal coating could be extended to provide the complete ground plane. The present invention could also find application in the automotive industry in a laminated thermoplastic product.

The present invention enables a cheap, neat and thin connection to be provided through the dielectric layer or the stack of dielectric layers. Thus, for example, a heater element may be connected by the first sprayed metal coating through the hole to the second sprayed metal coating and then to a connector that leads to a heater control unit. The sprayed "through connection" comprising the overlapping first and second coatings may be arranged so that it does not add to the overall thickness when, for example, the first metal coating is provided as part of a sprayed heater element and the second metal coating is provided as a sprayed terminal for connection to the connector leading to the heater control unit.

In relation to spraying the first and second metal coatings, our current embodiments use flame spraying as being a cheap and neat way to form the coatings.

In our current embodiments, the spraying produces first and second metal coatings which are porous. This is advantageous when the dielectric component with electrical connection is incorporated in a laminated product by being sandwiched between thermoplastic layers because the thermoplastic material of those layers is able to migrate into the porous first and second metal coatings, thereby reducing the risk of subsequent de-lamination.

In one of our current embodiments, said at least one dielectric layer comprises a single dielectric layer.
In another of our current embodiments, said at least one dielectric layer comprises first and second dielectric layers and an electrical element is positioned between the first and second dielectric layers. The electrical element may be a conductive ground plane. Preferably the conductive ground plane is a sprayed ground plane. For example, the ground plane may be flame sprayed and when the first and second dielectric layers are laminated together the thermoplastic materials of the first and second dielectric layers are laminated together through the pores of the ground plane.

The length of the overlap of the second and fourth portions may be at least 20% of the length of the hole, more preferably at least 30%, 40%, 50%, 60%, 70%, 80% or 90%.

In some embodiments, the length of the overlap is substantially 100% or greater than 100%.

The second portion may have a distal end which extends substantially to the second main surface or round onto part of the second main surface adjacent to the hole.

The fourth portion may have a distal end which extends substantially to the first main surface or round onto part of the first main surface adjacent to the hole.

In our current embodiments, we use high-temperature engineering thermoplastic. Our preferred material comprises PEEK, PEKK, PPS, PEI or PES or a mixture thereof. These materials are able to withstand flame spraying without significant damage. We particularly prefer PEEK and PEKK.

In our current embodiments, a heater element comprises a sprayed metal track deposited on the first main surface and at least part of the heater element is provided by the first portion of the first sprayed metal coating. For example, the first portion of the first sprayed metal coating comprises a terminal of the heater element. Preferably, the first sprayed metal coating provides the full length of the track of the heater element. Thus, the second portion in the hole may be laid down at the same time as the spraying operation that lays down the heater element.
In our current embodiments, the thickness of the or each dielectric layer is 0.05 to 2mm. The hole has a diameter of 1 to 6mm. These dimensions appear to work well to produce the sprayed "through connection".

In our current embodiments relating to heater mats, the or each dielectric layer is a generally rectangular sheet with a width of 0.25 to 1m and a length of 1 to 4m.

The metal of the first sprayed metal coating may be the same as the metal of the second sprayed metal coating (for example, copper or copper alloy, which are particularly suited to being flame sprayed).

In our current embodiments, the second portion is cylindrical and the fourth portion is cylindrical, with the fourth portion being nested inside the second portion. Preferably, the fourth portion is hollow such that a bore extends through the fourth portion from the first main surface to the second main surface.

In our current embodiments, the dielectric layer or the stack of dielectric layers has a plurality of said holes with each hole having a respective said first sprayed metal coating and a respective said second sprayed metal coating. For example, the heater element may have a respective one of said holes at each end of the track of the heater element.

Each of our current embodiments comprises a laminated heater mat which incorporates the dielectric component with electrical connection as one or several of the dielectric layers of the heater mat.

The heater mat may form part of an electrothermal heater which also includes at least one connector having a first end which is electrically connected to the heater element via the continuous conductive path(s) through the hole(s) of the dielectric component with electrical connection and a second end which extends away from the heater mat for connection to a heater control unit.

In an electrothermal ice protection system, the second end of the or each connector is connected to the heater control unit.
According to a second aspect of the present invention, there is provided a method of manufacturing a dielectric component with electrical connection, comprising the steps of:

- providing at least one dielectric layer comprising thermoplastic material;
- forming a hole through the dielectric layer or a stack of the dielectric layers to extend from a first to a second main surface of the dielectric layer or stack of dielectric layers;
- flame spraying a first metal coating onto the first main surface to form a first portion adjacent to the hole and a second portion which extends into the hole; and
- flame spraying a second metal coating onto the second main surface to form a third portion adjacent to the hole and a fourth portion which extends into the hole;

wherein the flame spraying of the first and second metal coatings is such that the second portion overlaps the fourth portion to form a continuous conductive path between the first main surface and the second main surface.

In some embodiments, the first metal coating is sprayed into the hole from the first main surface such that the second portion extends substantially to the second main surface. Alternatively, the first metal coating is sprayed into the hole from the first main surface such that the second portion extends round onto part of the second main surface adjacent the hole.

In some embodiments, the second metal coating is sprayed into the hole from the second main surface such that the fourth portion extends substantially to the first main surface. Alternatively, the second metal coating is sprayed into the hole from the second main surface such that the fourth portion extends round onto part of the first main surface adjacent the hole.

**BRIEF DESCRIPTION OF THE DRAWINGS**

Specific embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:-

Fig. 1 is a diagrammatic plan view of an aircraft having slats in the leading edge of a wing.

Fig. 2 is a diagrammatic perspective view of a nose skin of a wing slat of Fig. 1.
Fig. 3 is a diagrammatic perspective view of a dielectric layer at a first stage of an assembly process for producing a heater mat in accordance with a first embodiment of the present invention.

Fig. 4 is a diagrammatic perspective view of the dielectric layer of Fig. 3 at a second stage of the assembly process.

Fig. 5 is a diagrammatic perspective view of the dielectric layer of Fig. 4 at a third stage of the assembly process.

Fig. 6 is a diagrammatic cross-sectional view taken on the section line in Fig. 5.

Fig. 7 is a diagrammatic enlargement of the circled area of Fig. 6.

Fig. 8 is a diagrammatic perspective view of two connectors for use in the assembly process.

Fig. 9 is a diagrammatic perspective view of the dielectric layer of Fig. 5 at a fourth stage of the assembly process when being assembled with connectors of the type shown in Fig. 8.

Fig. 10 is a diagrammatic perspective view of the partially-assembled heater mat of Fig. 9 at a fifth stage of the assembly process after being assembled with a further dielectric layer.

Fig. 11 is a diagrammatic perspective view of the partially-assembled heater mat of Fig. 10 at a sixth stage of the assembly process after being flame sprayed with a copper ground plane.

Fig. 12 is a diagrammatic cross-sectional enlargement of the circled area of Fig. 11 and shows the interface between the ground plane and the dielectric layer on which the ground plane has been sprayed.

Fig. 13 is a diagrammatic perspective view of the partially-assembled heater mat of Fig. 11 at a seventh stage of the assembly process after a connector of the type shown in Fig. 8 has been connected to the ground plane.
Fig. 14 is a diagrammatic perspective view of the partially-assembled heater mat of Fig. 13 at an eighth stage of the assembly process after a further dielectric layer has been added.

Fig. 15 is a diagrammatic perspective view of the partially-assembled heater mat of Fig. 14 at a ninth stage of the assembly process after a further dielectric layer has been added.

Fig. 16 is a diagrammatic perspective view of the partially-assembled heater mat of Fig. 15 at a tenth stage of the assembly process after the flame spraying of a second ground plane.

Fig. 17 is a diagrammatic perspective view of the partially-assembled heater mat of Fig. 16 at an eleventh stage of the assembly process after a further dielectric layer and a connector of the type shown in Fig. 8 have been added.

Fig. 18 is a diagrammatic perspective view of the heater mat of Fig. 17 at a twelfth stage of the assembly process after the assembled components of the heater mat have been laminated together.

Fig. 19 is a diagrammatic perspective view showing the heater mat of Fig. 18 being bonded to an erosion shield.

Fig. 20 is a diagrammatic perspective view of an intermediate stage of an alternative assembly process for producing a heater mat in accordance with a second embodiment of the present invention.

Fig. 21 is a diagrammatic perspective view of the partially-assembled heater mat of Fig. 20 at a subsequent stage of the alternative assembly process.

Fig. 22 is a diagrammatic perspective view of the partially-assembled heater mat of Fig. 21 at a subsequent stage of the alternative assembly process.

Fig. 23 is a diagrammatic perspective view of the partially-assembled heater mat of Fig. 22 at a subsequent stage of the alternative assembly process.
Fig. 24 is a diagrammatic perspective view of the partially-assembled heater mat of Fig. 23 at a subsequent stage of the alternative assembly process.

Fig. 25 is a diagrammatic perspective view of the partially-assembled heater mat of Fig. 24 at a subsequent stage of the alternative assembly process.

Fig. 26 is a diagrammatic perspective view of the partially-assembled heater mat of Fig. 25 at a subsequent stage of the alternative assembly process.

Fig. 27 is a diagrammatic perspective view of the heater mat of Fig. 26 after the components thereof have been laminated together.

Fig. 28 is a diagrammatic perspective view showing the heater mat of Fig. 27 of the second embodiment of the present invention when being assembled to an erosion shield.

Fig. 29 is a diagrammatic perspective view of an alternative area temperature sensor.

Fig. 30 is a diagrammatic perspective view of the area temperature sensor of Fig. 29 after being assembled onto the dielectric layer of Fig. 3.

Fig. 31 is a diagrammatic perspective view of an alternative connector.

Fig. 32 is a diagrammatic perspective view of a further alternative connector.

Fig. 33 is a schematic view showing the connections between a heater mat in accordance with the present invention and a power supply and control electronics unit of an aircraft.

While the invention is susceptible to various modifications and alternative forms, specific embodiments are shown by way of example in the drawings and are herein described in detail. It should be understood, however, that the drawings and detailed description of the specific embodiments are not intended to limit the invention to the particular forms disclosed. On the contrary, the invention is cover all modifications, equivalents and alternatives falling within the spirit and the scope of the present invention as defined by the appended claims.
DESCRIPTION OF SPECIFIC EMBODIMENTS

Fig. 1 is a plan view of an aircraft 1 having a wing 11 along the leading (forward) edge of which are positioned five wing slats 12. Each wing slat 12 incorporates an electrothermal ice protection system.

Fig. 2 is a diagrammatic perspective view of a demountable nose skin 13 of one of the wing slats 12 of Fig. 1. The configuration of the nose skin 13 may be generally the same as in EP-A-1,757,519 (GKN Aerospace) which discloses a wing slat having a demountable forward section comprising a nose skin.

The nose skin 13 comprises an erosion shield 14 and an electrically-powered heater 2.

The heater 2 comprises a heater blanket or mat 3 and a bundle of connectors 4 which connect the heater mat 3 to the power supply and control electronics of the aircraft 1.

The erosion shield 14 is generally rectangular and has a front surface 141 which is convexly curved and a rear surface 142 which is concavely curved. An apex 141 of the front surface 141 provides the leading edge of the aircraft wing 11.

The heater mat 3 is generally rectangular and has a front surface 31 which is convexly curved and a rear surface 32 which is concavely curved. The convex front surface 31 conforms to the shape of and is bonded to the rear surface 142 of the erosion shield 14. In this way, thermal energy generated as the heater mat 3 is operated passes, by conduction, into the erosion shield 14 in order to provide an ice protection function. The erosion shield 14 is metallic and may be made of aluminium (which is the usual material) or titanium (which is expensive but may offer some functional and processing benefits). An important function of the erosion shield 14 is to protect the aircraft against lightning strikes by absorbing and dissipating the lightning current.

The demountable nose skin 13 is convenient because just the nose skin may be removed from the main or rear section of the wing slat 12 to enable the nose skin to be repaired or replaced if it has been damaged, or to enable maintenance to be performed on the heater 2.
If the heater 2 has developed a fault, the nose skin 13 may be demounted from the main or rear section of the wing slat 12 by, for example, undoing or releasing releasable securing means such as screws. The heater 2 may then be inspected and tested. If possible, the heater 2 is repaired in situ. If this is not possible, the heater mat 3 is removed from the erosion shield 14 of the nose skin 13 and a heater mat of a new heater is secured to (e.g. bonded or glued onto) the erosion shield 14. The nose skin 13 is then ready to be returned to service. Whilst the old nose skin is being repaired, a new nose skin taken from stock may be fitted to the wing slat 12 to keep the aircraft in flying condition.

An assembly process for producing a heater mat in accordance with the first embodiment of the present invention will now be described with reference to Figs. 3-19 which depict, in a very diagrammatic manner, the components of the heater mat and how they are assembled together to produce the heater mat and how the heater mat is then bonded to an erosion shield.

The components shown in Figs. 3-19 are very diagrammatic. For example, in relation to the dielectric layer 50 shown in Fig. 3, the thickness has been exaggerated for the sake of clarity. Also, the width and length of the layer have been reduced for the sake of clarity. In a practical embodiment, the dielectric layer would be generally rectangular and would be a sheet having a width ranging typically from 0.25m to 1m and a length ranging from typically 1m to 4m. In use, the width of the sheet will usually wrap around the chord at the leading edge of the wing, and the length of the sheet will usually extend along the span of the wing. The dielectric sheet (the dielectric layer) would also typically have a thickness of 0.05mm to 2mm.

The dielectric layer 50 is made from a high-temperature engineering thermoplastic or from a reinforcement material (such as glass fibres) which is impregnated with the high-temperature engineering thermoplastic.

From the class of high-temperature engineering thermoplastics, we currently use: PEEK (polyether ether ketone), PEKK (polyetherketoneketone), PPS (polyphenylene sulphide), PEI (polyetherimide) or PES (polyethersulphone) or mixtures thereof. These materials have been selected based on the requirement for a suitable glass transition temperature and suitable thermal fatigue performance. PEEK and PEKK are particularly preferred because PEEK has
the necessary mechanical performance and is particularly receptive to a flame sprayed metal coating, and PEKK has similar properties but is easier to bond to the metal material.

The other components of the heater mat (to be described later) are each selected to be made from a material the same as or compatible with the material of the dielectric layer 50 so that, when the components are laminated together at the end of the assembly process, the components can merge or fuse together so that the heater mat is monolithic. This means that the laminated components of the heater mat will not delaminate from one another. Because of the absence of discontinuities between discrete layers, it is not possible for cracks to initiate at the (former) boundaries between adjacent substrate layers, and this improves the fatigue resistance of the heater mat.

Fig. 3 shows that the track of a heater element 501 has been laid down on the upper main surface 502 of the dielectric substrate layer 50. The heater element 501 extends from a first terminal 503 to a second terminal 504. The heater element 501 is shown in Fig. 3 as having a simple "C" shape. In practice, it will have a more complicated shape such as a shape that repeatedly zigzags from the first terminal 503 to the second terminal 504. The heater element 501 is shown in Fig. 3 as having a simple shape for the sake of clarity of the diagrammatic depiction.

The dielectric layer 50 has four through holes 505 which extend from the upper main surface 502 through to a lower main surface 506 (see Fig. 5). A mask is used to flame spray the track of the heater element 501 onto the upper main surface 502 of the dielectric layer 50 so that the track runs from the first terminal 503 to the second terminal 504. The heater element 501 is made of a resistive metal such as copper or metal alloy such as a copper-manganese alloy. Flame or hot metal spraying is a well-established technique dating back many years, for example back to GB-833,675 (D. Napier & Sons Limited) which relates to hot metal spraying various metal layers of an electrical de-icing or anti-icing apparatus for an aircraft, and the reader is referred to GB-833,675 which is incorporated herein by reference. The spraying is performed so that the heater element 501 is porous, with the degree of porosity depending on the number of passes of the spraying gun and the thickness of the metal coating that forms the heater element 501. A suitable spraying gun is the Mark 66E-Man produced by Metallisation Limited of Dudley, West Midlands, United Kingdom in combination with its associated control equipment.
The through holes 505 are formed before the flame spraying of the heater element 501. Each hole has a typical diameter of 3.5mm, but may range from 1 to 6mm in diameter, more preferably 2 to 5mm in diameter, or 3 to 4mm in diameter. During the flame spraying, some of the material of the heater element 501 is sprayed down into the two holes 505 at the first and second terminals 503, 504.

The next stage of the assembly process is shown in Fig. 4. A mask is used to flame spray an area temperature sensor 507 onto the upper main surface 502. Thus, the temperature sensor 507 is present on the same substrate layer as the heater element 501. The track of the temperature sensor 507 extends from a first terminal 508 to a second terminal 509. Each of the terminals 508, 509 is located at a respective through hole 505. During the flame spraying, some of the material of the temperature sensor 507 is sprayed down into the two holes 505 at the terminals 508, 509.

The area temperature sensor 507 is used as part of a control loop to provide temperature control and thermal-damage-prevention information to a control unit for the heater 2. The temperature sensor 507 is a resistance temperature device (RTD) sensor. The flame spraying lays down a conductive metal track having a suitable temperature coefficient of resistance. Suitable metals include nickel and nickel-based alloys, although any metal with a high temperature coefficient of resistance could be used as long as it is suited to being applied by a flame spraying process. The conductive metal coating may be used to form the entirety of the temperature sensor 507 from the first terminal 508 to the second terminal 509. Alternatively, as shown in Fig. 4, the conductive metal coating with the suitable temperature coefficient of resistance may be flamed sprayed to form a sensor head 5010 located between two intermediate boundaries 5011 on the track of the sensor 507. Leads 5012 may be flamed sprayed from the boundaries 5011 to the terminals 508, 509 so as to connect the sensor head 5010 to the terminals 508, 509. The leads 5012 may be a conductive metal such as copper.

The next stage of the assembly process is shown in Fig. 5. It involves turning over the dielectric layer 50 so that the lower main surface 506 is facing upwards. Then, a mask is used to spray conductive metal (e.g. copper) or alloy to form terminals or contact pads 5013 around the through holes 505. During this flame spraying, some of the material of the terminal 5013 coats the bore of each through hole 505. This is more clearly shown in Fig. 6 which is a
cross-sectional view taken on the section line in Fig. 5. The heater element 501 is shown in Fig. 6 as having a generally cylindrical projection 5014 which extends into the through hole 505 from the main surface 502 and forms a radially outer coating inside the through hole 505.

The terminal 5013 is shown as having a generally cylindrical projection 5015 which extends into the hole 505 from the main surface 506 and forms a radially inner coating of the through hole 505.

In Fig. 6, the cylindrical projection 5015 of coating material is shown as leaving the hole 505 as having a through bore 5016. If the coating thickness of the terminal 5013 and its projection 5015 is sufficiently thick, and/or if the diameter of the through hole 505 is sufficiently small, it is possible that the projection 5015 will occlude or block the radially inner part of the through hole 505 so as to form a central plug. Under these circumstances, there would be no through bore 5016 after the two coatings 501, 5013 have been applied.

As shown in Fig. 6, the free end 5017 of the coating projection 5014 extends beyond the free end 5018 of the coating projection 5015. Thus, the projection 5014 overlaps the projection 5015 within the hole 505. The free end 5017 is shown as stopping short of the main surface 506, but it could extend substantially to the main surface 506 and even sometimes extend slightly onto the main surface 506. This might occur, for example, if the sheet of dielectric material forming the layer 50 is positioned on the table of a metal spraying machine and the sheet vibrates during the flame spraying. This vibration would facilitate a "through plating" effect where the sprayed metal passes all the way through the hole 505 and carries on slightly to coat the far surface 506 around the hole 505.

Similarly, the coating projection 5015 of the terminal 5013 is shown as having its free end 5018 stopping short of the main surface 502. The flame spraying or other application process could be arranged to ensure that the free end 5018 extends substantially to the main surface 502 or, perhaps, even extends round onto part of the main surface 502 adjacent to the through hole 505. Of course, under these circumstances, the heater element 501 would be interposed between the free end 5018 and the main surface 502.

Because of the overlap between the free end 5017 and the free end 5018, there is a continuous conductive path between the main surface 502 and the main surface 506. This is true of each
of the through holes 505 which is subjected to the "spray plating" from both ends to form a continuous through connection.

In order to achieve a satisfactory through connection, it is beneficial for the dielectric layer to have a thickness in the range of 0.05mm to 2mm.

Fig. 7 is a diagrammatic enlargement of the circled area in Fig. 6 and shows the overlap between the two coatings forming the projections 5014, 5015. The flame spraying produces a coating having particles with a mean diameter typically between 30-150μm. Also, each coating 5014, 5015 forms a microporous conductor. The particles of the coatings at the interface between the projection 5014 and the projection 5015 are in intimate contact in order to form a good electrical connection between the heater element 501 and the terminal 5013.

Fig. 8 shows two connectors 41, 42 which comprise part of the bundle of connectors 4 shown in Fig. 2 and which are used to electrically connect the heater mat 3 to the power supply and control electronics unit 6 (see Fig. 33) of the aircraft 1.

Each of the connectors 41, 42 comprises a dielectric substrate layer 411, 421 which is a strip having the desired length for the connector to perform its connection function.

Each substrate layer 411, 421 is made of high-temperature engineering thermoplastic which is the same as or compatible with the materials of the other component dielectric layers and connectors of the heater 2 so that, when at the end of the assembly process the components of the heater are laminated together, the substrate layers 411, 421 will satisfactorily disperse into the adjacent dielectric layer(s) and/or connector(s) so that the components of the heater form a satisfactory monolithic unit without having to use glue to connect the dielectric substrate layers and connectors together.

Thus, the currently preferred materials for the dielectric substrate layer 411 or 421 are PPS, PEI, PEKK, PEEK and PES. Of these materials, we currently particularly prefer PEKK or PEEK. These materials are particularly good at ensuring that the components of the heater 2 will fuse or bond together to become monolithic and will not delaminate.
Preferably, each substrate layer 411, 421 is made of the same thermoplastic material as the other components as this helps to ensure that the stack of assembled components will disperse or merge into one another to form the monolithic unit when the thermoplastic material is heated to above its melt point and pressure is applied to the stack.

If the material of each substrate layer 411, 421 is not the same as that of the other components and is merely compatible with the material of the other components, then the compatibility can be achieved by selecting the thermoplastic of the substrate layers 411, 421 such that it is not necessary to use adhesive to bond it to the thermoplastic of the other components in the stack during the lamination. The dissimilar but compatible materials will bond to one another at each interface by one thermoplastic material (e.g. PEEK) fusing to but not dispersing into the other thermoplastic material (e.g. PEKK) when the stack of assembled components is heated to above the melt point of one of the abutting materials.

After a sheet of dielectric material has been cut to form the ribbon-like substrate layers 411, 421 a mask is then used to flame spray a conductive metal (e.g. copper) or metal alloy onto a main surface 412, 422 so as to lay down power or signal tracks. In the case of the connector 41, a power track 413 is laid down in the longitudinal direction of the dielectric strip 411 and terminates in a terminal 414 at an end 415 of the connector 41.

In the case of the connector 42, flame spraying is used to lay down the two generally-parallel signal tracks 423 each of which terminates at a terminal 424 at an end 425 of the connector 42.

The other end of each of the tracks 413, 423 may be terminated in any suitable manner for connection to the power supply and control electronics unit 6.

Fig. 9 shows the next stage of the assembly process. In this stage, the dielectric layer 50 of Fig. 5 is assembled with two connectors 41 and a single connector 42. The three connectors 41, 42 are positioned, as shown in Fig. 9, with their terminals 414, 424 facing downwards towards the terminals 5013 of the dielectric layer 50. The terminals 414, 424 are then welded or soldered to the terminals 5013.
In this way, the two connectors 41 are connected to the ends of the heater element 501 so that the heater element 501 can be powered by the power supply and control electronics unit 6 via the connectors 41. The ends of the temperature sensor 507 are connected via the connector 42 to the power supply and control electronics unit 6.

Fig. 10 shows the next stage of the assembly process. The partially-assembled heater mat of Fig. 9 has a further dielectric layer 51 positioned on the main surface 506 of the dielectric layer 50. The dielectric layers 50, 51 are made of the same material, such as PEEK or PEKK. In Fig. 10, the dielectric layer 51 does not cover the ends 415, 425 of the connectors 41, 42 but it could be arranged to cover the ends so that the dielectric layer 51 is generally the same size and shape as the dielectric layer 50. During lamination at the end of the assembly process, the increased thickness of dielectric material at the ends 415, 425 will be, at least partially, dispersed or spread out as a result of the heat and pressure applied during lamination. Furthermore, in the finished heater mat 3, it does not matter if, to some extent, the end product (the laminated product) is locally slightly thicker in places as a result of an increased thickness of dielectric material being present.

The next stage of the assembly process is shown in Fig. 11. In this stage, a ground plane 71 is flame sprayed onto the upper main surface 511 of the dielectric layer 51 of the partially-assembled heater mat of Fig. 10. The ground plane comprises flame sprayed copper or copper alloy and is typically 0.05mm thick, but may range from 0.01mm to 0.5mm in thickness, or from 0.03mm to 0.2mm in thickness. The exact thickness can be chosen depending on the conductivity that is required.

The purpose of the ground plane 71 is to detect a fault current caused by a heater fault in the heater element 501. For example, the fault could be damage such as heater burn-out. The ground plane 71 is connected to the aircraft earth 143 (see Fig. 19) as well as to the power supply and control electronics unit 6, so that when a fault occurs the unit 6 detects a change in current.

Fig. 12 is a diagrammatic cross-sectional enlargement of the circled area of Fig. 11 and shows the interface between the ground plane 71 and the dielectric layer 51 onto which the ground plane has been sprayed. The particles of the ground plane 71 are micro-porous so that, during the heating and pressing of the lamination process, the thermoplastic of the adjacent dielectric
layers will pass or migrate through the ground plane 71 as part of giving a monolithic structure to the heater mat 3. This migration is indicated by the arrows 711 which show migration paths between the particles 712 of the ground plane 71. Note that, in Fig. 12, only some of the particles 712 are labelled for clarity. The particles 712 are randomly positioned as a result of the spraying and have a random range of sizes with the mean diameter typically ranging from 30-150µm.

The next stage of the assembly process is shown in Fig. 13.

In this stage, a connector 43, which is the same as connector 41, is electrically connected to the ground plane 71 of the partially-assembled heater mat of Fig. 11. The connector 43 has a track 433 on its bottom surface which terminates at a terminal, and that terminal is welded or soldered to the ground plane 71. In this way, the ground plane 71 is electrically connected via the connector 43 to the power supply and control electronics unit 6.

The next stage of the assembly process is shown in Fig. 14. A dielectric layer 52 is laid on top of the ground plane 71 of the partially-assembled heater mat of Fig. 13. The dielectric layer 52 is made of the same material as the dielectric layers 50, 51. It is shown as having a cutout in the region of the connector 43. However, the dielectric layer 52 could be the same size and shape as the dielectric layer 50 such that it would cover the end 435 of the connector 43.

The next stage of the assembly process is shown in Fig. 15. The partially-assembled heater mat of Fig. 14 is turned upside down and a further dielectric layer 53 is positioned on the main surface 502 of the dielectric layer 50. The dielectric layer 53 is the same size and shape as the dielectric layer 50 and it is made of the same material as the other dielectric layers 50, 51 and 52. In Fig. 15, it is possible to see the tracks 413 of the connectors 41, the tracks 423 of the connector 42, and the track 433 of the connector 43.

The next stage of the assembly process is shown in Fig. 16. In this stage, the partially-assembled heater mat of Fig. 15 has a second ground plane 72 flame sprayed onto the exposed main surface 531 of the dielectric layer 53. The characteristics of the second ground plane 72 are the same as those of the first ground plane 71. In particular, it is preferable that the ground planes 71, 72 should be flame sprayed copper.
The next stage of the assembly process is shown in Fig. 17. In this stage, a further dielectric layer 54 is positioned on top of the ground plane 72 of the partially-assembled heater mat of Fig. 16. The dielectric layer 54 is made of the same material as the other dielectric layers 50, 51, 52, 53. A connector 44 is generally the same as the connector 41 and has, on its undersurface in Fig. 17, a track leading to a terminal at the end 445 of the connector 44. This terminal of the connector 44 is electrically connected to the second ground plane 72 by welding or soldering so as to establish an electrical connection between the ground plane 72 and the power supply and control electronics unit 6.

Collectively, the connectors 41, 42, 43, 44 comprise the bundle of connectors 4 which is diagrammatically shown in Fig. 2.

In Fig. 17, the dielectric layer 54 is shown as having a cutout around the end 445 of the connector 44. An alternative would be for the layer 54 to omit the cutout, such that the layer 54 has the same rectangular shape and size as the underlying dielectric layer 53. This would mean that the dielectric layer 54 would cover the end 445 of the connector 44. This might result, after lamination, in a slight local increase in thickness of the heater mat in the vicinity of the end 445.

During the laying up of the dielectric layers, reinforcement material may be included in the stack of components of the heater mat. The reinforcement material would be fibrous and examples of the reinforcement material include glass fibres, e.g. either as a uni-directional tape or as a woven fabric, which would be porous to the adjacent thermoplastic dielectric layers during the lamination process. Any reinforcement would need to be non-conductive in order to preserve the insulation provided by the dielectric layers. Also, the reinforcement material should be selected to be as thin as possible.

In Fig. 17, all of the components of the heater mat 3 are in position ready to be laminated together. The lamination process is diagrammatically illustrated in Fig. 18. Heat and pressure are applied to the stack of components so as to consolidate the laminate into a monolithic structure. The result is that the dielectric layers and the embedded ends of the connectors, all being made of the same or compatible engineering thermoplastics, disperse into one another, and the dielectric layers and the ends of the connectors merge or fuse together to become
monolithic. Consequently, the layers and the ends of the connectors will not delaminate as a result of the presence of a discontinuity at an interface caused by thermoplastic material which is incompatible and has not merged with the adjacent thermoplastic material. During the lamination, the embedded ends of the connectors effectively become part of the heater mat.

Lamination may be performed using a conventional autoclave, heated press or large laminating machine. Such machinery can be used to heat the stack of components to above the melt point of the thermoplastic material whilst applying pressure, in order to consolidate the laminate.

If reinforcement material is present in the stack of components, the pressure of the lamination process presses the reinforcement material into the thermoplastic of the adjacent layers to form a reinforced thermoplastic laminate. If the reinforcement material is a woven fabric, care should be taken to ensure that the treatments applied to it during the weaving and finishing processes are compatible with lamination temperatures in the order of 400°C.

The intention of the lamination process is to minimise or eliminate discontinuities in the resulting laminate. The end product in the form of the heater mat 3 with the embedded ends of the bundle of connectors 4 has a monolithic structure which can undergo generally uniform expansion as it is heated up. This reduces the thermomechanical stresses on the heater mat 3. This is an important consideration in view of the fact that the thermomechanical stresses are greater than the aerodynamic stresses that the heater mat 3 experiences when installed in the aircraft 1.

In conventional laminated products, glue is used and glue is a weak point at the interfaces between adjacent layers of the laminate. In a conventional heater where the dielectric layers are glued together in the laminate, the glued interfaces are where delamination can occur under fatigue loadings.

An advantage of the heater mat of the first embodiment of the present invention as shown in Fig. 18 is that it is glue free. Specifically, glue is not used to laminate together the dielectric layers and the embedded ends of the connectors.
Fig. 19 shows how the heater mat 3 is offered up to the rear surface 142 of the erosion shield 14. A suitable adhesive is used to glue or bond the front surface 31 of the heater mat 3 to the rear surface 142 of the erosion shield 14. For ease of illustration, in Fig. 19 the heater mat 3 and the erosion shield 14 are shown as being planar. In an actual representative installation such as shown in Fig. 2, the front surface 31 is convexly curved and the rear surface 142 is correspondingly concavely curved. The heater mat 3 resembles a large sheet which is comparatively long and wide relative to its thickness, and thus the heater mat 3 is flexible and may be easily bent to conform to the shape of the rear surface 142 of the erosion shield 14.

When the heater mat 3 has been installed behind the erosion shield 14, and when the nose skin 13 is being fitted onto the aircraft 1, the connectors 41, 42, 43 and 44 (which collectively form the bundle of connectors 4) may be connected to the power supply and control electronics unit 6 of the aircraft 1. Thus, the heater 2 is now ready for use.

In the first embodiment of the heater mat as discussed above with reference to Figs. 3-19, it is the case that the heater mat incorporates two ground planes (ground plane 71 and ground plane 72). When the aircraft 1 is struck by lightning on the erosion shield 14, a very large direct current (e.g. 200,000 amps) of a very short duration is dissipated to an aircraft earth 143 by the erosion shield 14. The very large current flowing in the erosion shield during the lightning strike will induce a current in any underlying parallel conductor as a result of electromagnetic coupling. Such parallel conductors include the heater element 501 and the temperature sensor 507. If the heater element 501 and the temperature sensor 507 are not adequately shielded from the electromagnetic coupling, the current that is induced in them may be of the order of 1,000 amps and this current might pass along the bundle of connectors 4 to the power supply and control electronics unit 6. The result could be a current surge in the power supply and control electronics unit 6, which is only designed to cope with currents in the order of 10 amps. A current surge is undesirable as it might damage the electronics inside the unit 6.

In relation to a conventional heater mat with a single ground plane, some current will be induced in the ground plane and will pass to the aircraft earth.

In the heater mat 3 of the first embodiment of the present invention, as disclosed with referenced to Figs. 3-19, it is the case that the heater mat 3 incorporates two ground planes 71,
72. These ground planes 71, 72 are positioned above and below the heater element 501 and the temperature sensor 507 so that the heater element 501 and temperature sensor 507 are "electromagnetically shielded" by the two ground planes 71, 72. This shielding is rather similar to the concept of coaxial shielding in a cable.

The ground planes generally have a low resistance. Because the two ground planes sandwich the vulnerable heater element 501, the temperature sensor 507 and the embedded ends of the connection bundle 4 which are connected to the heater element 501 and the temperature sensor 507, they shield those components and the induced current during a lightning strike is preferentially induced in the two ground planes 71, 72 and passes to the aircraft earth 143. Much-reduced currents are induced in the heater element 501, the temperature sensor 507 and the embedded ends of the connection bundle which lead away from the heater element 501 and the temperature sensor 507, thereby reducing the risk of damage to the electronics in the power supply and control electronics unit 6.

There will now be described an alternative build process. Specifically, Figs. 20-28 illustrate the relevant aspects of an alternative assembly process for producing a heater mat in accordance with the second embodiment of the present invention. Figs. 20-28 illustrate only those aspects of the build process that differ from what is shown in Figs. 3-19 in relation to the first embodiment of the present invention.

Thus, in Fig. 20, the second embodiment takes the dielectric layer 50 of Fig. 4 of the first embodiment and turns it upside down, and then a ground plane 73 is flamed sprayed onto the main surface 506 of the dielectric layer 50 such that the ground plane 73 has the same characteristics as the ground plane 71.

Then, in the next stage of this alternative assembly process of the second embodiment, a dielectric layer 55 is positioned on top of the ground plane 73 (see Fig. 21). The dielectric layer 55 is made of the same material as the dielectric layer 50. A connector 45 (which corresponds to the connector 43 of the first embodiment) is electrically connected to the ground plane 73. The dielectric layer 55 has a cutout around the end 455 of the connector 45, but this cutout may be omitted and the dielectric layer 55 may have the same size and shape as the dielectric layer 50 such that the dielectric layer 55 covers the end 455.
The next stage of the assembly process of the second embodiment is shown in Fig. 22. The through holes 505 of the dielectric layer 50 are extended through the ground plane 73 and the dielectric layer 55. Terminals or contact pads 5513 are then flame sprayed onto the upper main surface 552 of the dielectric layer 55, with the terminals 5513 of the second embodiment having the same characteristics as the terminals 5013 of the first embodiment.

The next stage of the assembly process is shown in Fig. 23. In this stage, the partially-assembled heater mat of Fig. 22 has a further dielectric layer 56 positioned on top of the dielectric layer 55. Two connectors 46 (which corresponds to the two connectors 41 of the first embodiment) and a connector 47 (which corresponds to connector 42 of the first embodiment) have their ends 465, 475 brought into electrical contact with the terminals 5513. A second ground plane 74 is flame sprayed onto the dielectric layer 56 and has characteristics corresponding to the second ground plane 72 of the first embodiment. In Fig. 23, the dielectric layer 56 does not cover the ends 465, 475 of the connectors 46, 47. It could, alternatively, be arranged to cover the ends 465, 475 and this would, in the end product (the laminated heater mat of the second embodiment), result in slight localised increased thickness of the heater mat.

The next stage of the assembly process of the second embodiment is shown in Fig. 24. A dielectric layer 57 is positioned on top of the second ground plane 74. A connector 48 (which corresponds to the connector 44 of the first embodiment) has an end 485 electrically connected to the second ground plane 74. The dielectric layer 57 is shown as having a cutout around the end 485. This cutout could be omitted, and the dielectric layer 57 could extend over the end 485.

The next stage of the assembly process is shown in Fig. 25. A further dielectric layer 58 is brought into contact with the main surface 502 of the dielectric layer 50 so as to cover the heater element 501 and the area temperature sensor 507. The result is shown in Fig. 26. In Fig. 26, all of the components of the heater mat 3 and the embedded ends 455, 465, 475, 485 of the connectors 45, 46, 47, 48 are in position and ready to be laminated together.

Heat and pressure are applied to the stack of components of Fig. 26 to produce the monolithic laminate of the heater mat 3 shown in Fig. 27. All of the dielectric layers 50, 55, 56, 57, 58 are made of the same or compatible high-temperature engineering thermoplastic (as per the
first embodiment) and thus fuse together during the lamination process. Where necessary, the thermoplastic material flows through the porous ground planes 73, 74 and through the porous heater element 501 and through the porous temperature sensor 507. Because the thermoplastic material merges or fuses together at the interfaces between the stacked components of Fig. 26, the interfaces substantially disappear and thus interface discontinuities are, in effect, not present in the end product (the heater mat 3 of the second embodiment). Discontinuities are undesirable because they can function as crack initiation sites which are sites of potential structural or fatigue weakness. Substantially removing discontinuities from the end product (the laminated heater mat 3) produces a more durable heater mat.

The heater mat 3 of the second embodiment (Fig. 27) then has its front surface 31 adhesively bonded to the rear surface 142 of the erosion shield 14, as shown in Fig. 28.

The connectors 45, 46, 47, 48 collectively form the bundle of connectors 4 which serve to electrically connect the heater mat 3 to the power supply and control electronics unit 6.

In the second embodiment, the two ground planes (ground planes 73, 74) have different positions relative to the heater element 501 and the temperature sensor 507 as compared with the two ground planes (ground planes 71, 72) of the first embodiment.

In the second embodiment, the heater element 501 and the temperature sensor 507 are not sandwiched between the two ground planes 73, 74. Instead, the two ground planes 73, 74 are positioned on the side of the heater element 501 and temperature sensor 507 remote from the erosion shield 14. In other words, the heater element 501 and the temperature sensor 507 are sandwiched between (i) the erosion shield 14 and (ii) the two ground planes 73, 74. Compared with a heater mat having only a single ground plane, the two ground planes 73, 74 of the second embodiment provide improved protection against a lightning strike inducing excessive currents in the heater element 501, the temperature sensor 507 and the embedded ends of the connection bundle 4 which lead away from the heater element 501 and the temperature sensor 507. However, the protection is less effective than the protection provided by the configuration of the two ground planes of the first embodiment, because in the first embodiment the two ground planes 71, 72 sandwich the heater element 501 and temperature sensor 507 and thus provide a type of "coaxial shielding" to the heater element 501 and temperature sensor 507.
Figs. 29 and 30 show an alternative area temperature sensor. In Fig. 29, the area temperature sensor 507 is positioned on a carrier 5019 which is separate from the dielectric layer 50. The carrier 5019 is of smaller width and length than the dielectric layer 50 but is preferably made of the same high-temperature engineering thermoplastic as the dielectric layer 50. Alternatively but less desirably, the carrier 5019 is made of a high-temperature engineering thermoplastic which is compatible with the dielectric layer 50 and the other components of the heater mat 3 with which it will be fused during the lamination process. Our currently preferred materials for the carrier 5019 include PPS, PE1, PEKK, PEEK and PES. Of these materials, PEKK and PEEK are particularly preferred.

Fig. 29 also shows how the temperature sensor 507 may, optionally, be partially encapsulated within an encapsulation layer 5020 which is made of the same material as the carrier 5019. The encapsulation layer 5020 is shown in chain-dotted line in Fig. 29. When the encapsulation layer 5020 is positioned on the carrier 5019, the encapsulation layer 5020 covers all of the sensor head 5010 and the adjacent first parts of the leads 5012.

The area temperature sensor 507 is flame sprayed onto the upper main surface 50191 of the carrier 5019. The flame spraying of the temperature sensor 507 results in the first and second terminals 508, 509 of the temperature sensor being positioned around through holes 5021 of the carrier layer 5019.

Then, as shown in Fig. 30, the carrier 5019 is positioned on the dielectric layer 50 of Fig. 3. The positioning is such that the through holes 5021 of the carrier 5019 align with the relevant through holes 505 of the dielectric layer 50.

Other aspects of the manufacturing process for producing a heater mat are the same as for the first embodiment described with reference to Figs. 3-19 or the second embodiment described with reference to Figs. 20-28.

Fig. 31 shows a connector 49 which is a variant of the connector 41 of Fig. 8.

In relation to the connector 49, it uses the same dielectric substrate layer 411, main surface 412, power track 413, terminal 414 and end 415 as for the connector 41 of Fig. 8.
difference is that the connector 49 of Fig. 31 additionally includes an encapsulation layer 491 which is made of a high-temperature engineering thermoplastic the same as or compatible with the dielectric substrate layer 411. The encapsulation layer 491 stops at a position 492 of the main surface 412 which leaves exposed the terminal 414 and an adjacent short length of the power track 413. The connector 49 may be used to replace the connectors 41, 43 and 44 of the first embodiment or the connectors 45, 46 and 48 of the second embodiment. The position 492 of the connector 49 is chosen so that the end 493 of the encapsulation layer 491 butts up to, and does not enter into, the laminated components of the heater mat 3.

When the connector 49 is being produced, heat and pressure are applied to the layers 411, 491 so that they merge or fuse together to form a laminated structure.

However, because the encapsulation layer 491 does not penetrate into the laminated components of the heater mat 3, it would be possible to change the material of the encapsulation layer 491 to, for example, a protective film that is sprayed on. The nature of the material of the sprayed film will not particularly matter in the context of laminating together the components of the heater mat 3, because the material of the encapsulation layer 491 will not penetrate into the stack of components forming the heater mat 3.

Fig. 32 shows a further alternative connector 41A which is generally the same as the connector 41 of Fig. 8, except that a metallic (e.g. copper) plug 416 is attached (e.g. by welding or soldering) to the terminal 414 of Fig. 8, thereby to produce the connector 41A as a variant of the connector 41 of Fig. 8. The plug 416 is shown in Fig. 32 as having a circular base portion 4161 and a circular upper portion 4162 which is of smaller diameter than the base portion 4161. The diameter of the upper portion 4162 is preferably set to be the same as that of the holes 505 of Fig. 3. Thus, in a variant of Fig. 9, when the connector 41A replaces the connector 41, the upper portion 4162 of the plug 416 will project into and nest neatly inside the corresponding through hole 505 of the dielectric layer 50.

Fig. 33 is a schematic depiction of the connections between the heater mat 3 and the power supply and control electronics unit 6.

The heater mat of the present invention may be incorporated in any (e.g. forwardly-facing) surface of an aircraft that may be prone to ice formation in flight. For example, alternatives to
incorporating the heater mat in the leading edge of a wing include incorporating it in the leading edge of a fin or tailplane, or at the air intake of an engine, or in a trailing-edge flap to stop ice formation on the flap when it is deployed, or in an aileron.

In the above first and second embodiments, the heater mat 3 has been independently assembled and then laminated, before being attached to the erosion shield 14. An alternative would be to start with the erosion shield 14 and then stack in sequence, on the erosion shield, the components of the heater mat and the connectors. The first component could be bonded to the erosion shield. Then, when the full stack of components has been assembled onto the first component, heat and pressure could be applied to the components and the erosion shield so as to laminate together the components of the heater mat and the connectors in situ on the erosion shield.

There have been described first and second embodiments of a laminated heater mat 3 which incorporate a dielectric component with electrical connection, comprising: at least one dielectric layer 50, 55 comprising thermoplastic material, wherein the dielectric layer 50 or a stack of the dielectric layers 50, 55 has first and second main surfaces 502, 506, 552 and a hole 505 extending between the first and second main surfaces; a first sprayed metal coating 501 comprising a first portion 503 deposited on the first main surface 502 adjacent to the hole 505 and a second portion 5014 which projects into the hole 505; and a second sprayed metal coating 5013, 5513 comprising a third portion deposited on the second main surface 506, 552 adjacent to the hole 505 and a fourth portion 5015 which projects into the hole 505; wherein the second portion 5014 overlaps the fourth portion 5015 to form a continuous conductive path between the first main surface and the second main surface.

There have also been described methods of manufacturing first and second embodiments of a laminated heater mat 3 which incorporate a method of manufacturing a dielectric component with electrical connection, comprising the steps of: providing at least one dielectric layer 50, 55 comprising thermoplastic material; forming a hole 505 through the dielectric layer 50 or a stack of the dielectric layers 50, 55 to extend from a first to a second main surface of the dielectric layer or stack of dielectric layers; flame spraying a first metal coating 501 onto the first main surface 502 to form a first portion 503 adjacent to the hole 505 and a second portion 5014 which extends into the hole 505; and flame spraying a second metal coating 5013, 5513 onto the second main surface 506, 552 to form a third portion adjacent to the hole 505 and a
fourth portion 5015 which extends into the hole 505; wherein the flame spraying of the first and second metal coatings 501, 5013, 5513 is such that the second portion 5014 overlaps the fourth portion 5015 to form a continuous conductive path between the first main surface and the second main surface.
CLAIMS

1. A dielectric component with electrical connection, comprising:
   at least one dielectric layer comprising thermoplastic material, wherein the dielectric layer or a stack of the dielectric layers has first and second main surfaces and a hole extending between the first and second main surfaces;
   a first sprayed metal coating comprising a first portion deposited on the first main surface adjacent to the hole and a second portion which projects into the hole; and
   a second sprayed metal coating comprising a third portion deposited on the second main surface adjacent to the hole and a fourth portion which projects into the hole;
   wherein the second portion overlaps the fourth portion to form a continuous conductive path between the first main surface and the second main surface.

2. A dielectric component with electrical connection according to Claim 1, wherein said at least one dielectric layer comprises a single dielectric layer.

3. A dielectric component with electrical connection according to Claim 1, wherein said at least one dielectric layer comprises first and second dielectric layers and an electrical element is positioned between the first and second dielectric layers.

4. A dielectric component with electrical connection according to Claim 3, wherein the electrical element is a conductive ground plane.

5. A dielectric component with electrical connection according to any preceding claim, wherein the second portion has a distal end which extends substantially to the second main surface.

6. A dielectric component with electrical connection according to Claim 5, wherein the distal end of the second portion extends round onto part of the second main surface adjacent to the hole.
7. A dielectric component with electrical connection according to any preceding claim, wherein the fourth portion has a distal end which extends substantially to the first main surface.

8. A dielectric component with electrical connection according to Claim 7, wherein the distal end of the fourth portion extends round onto part of the first main surface adjacent to the hole.

9. A dielectric component with electrical connection according to any preceding claim, wherein the or each thermoplastic material comprises PEEK, PEKK, PPS, PEI or PES or a mixture thereof.

10. A dielectric component with electrical connection according to any one of Claims 1 to 8, wherein the or each thermoplastic material comprises PEEK, PEKK or a mixture thereof.

11. A dielectric component with electrical connection according to any preceding claim, wherein a heater element comprises a sprayed metal track deposited on the first main surface and at least part of the heater element is provided by the first portion of the first sprayed metal coating.

12. A dielectric component with electrical connection according to Claim 11, wherein the first portion of the first sprayed metal coating comprises a terminal of the heater element.

13. A dielectric component with electrical connection according to Claim 11 or 12, wherein the first sprayed metal coating provides the full length of the track of the heater element.

14. A dielectric component with electrical connection according to any preceding claim, wherein the thickness of the or each dielectric layer is 0.05 to 2mm.

15. A dielectric component with electrical connection according to any preceding claim, wherein the hole has a diameter of 1 to 6mm.
16. A dielectric component with electrical connection according to any preceding claim, wherein the or each dielectric layer is a generally rectangular sheet with a width of 0.25 to 1m and a length of 1 to 4m.

17. A dielectric component with electrical connection according to any preceding claim, wherein the metal of the first sprayed metal coating is the same as the metal of the second sprayed metal coating.

18. A dielectric component with electrical connection according to any preceding claim, wherein the second portion is cylindrical and the fourth portion is cylindrical, with the fourth portion being nested inside the second portion.

19. A dielectric component with electrical connection according to Claim 18, wherein the fourth portion is hollow such that a bore extends through the fourth portion from the first main surface to the second main surface.

20. A dielectric component with electrical connection according to any preceding claim, wherein the dielectric layer or the stack of dielectric layers has a plurality of said holes with each hole having a respective said first sprayed metal coating and a respective said second sprayed metal coating.

21. A dielectric component with electrical connection according to Claim 20 when dependent on at least Claim 11, wherein the heater element has a respective one of said holes at each end of the track of the heater element.

22. A laminated heater mat comprising dielectric layers which sandwich a dielectric component with electrical connection according to Claim 11 or any one of Claims 12 to 21 when dependent on at least Claim 11.

23. A laminated heater mat according to Claim 22, wherein each of the dielectric layers comprises the same thermoplastic material.

24. An electrothermal heater comprising a laminated heater mat according to Claim 22 or 23 and at least one connector having a first end which is electrically connected to the heater
element via the continuous conductive path(s) through the hole(s) of the dielectric component with electrical connection and a second end which extends away from the heater mat for connection to a heater control unit.

25. An electrothermal ice protection system comprising an electrothermal heater according to Claim 24 and a heater control unit to which the second end of the or each connector is connected.

26. Ice protected apparatus comprising an external skin and an electrothermal heater according to Claim 24, wherein the heater mat is in thermal contact with a rear surface of the external skin.

27. A nose skin comprising an erosion shield and an electrothermal heater according to Claim 24, wherein the heater mat is bonded to a rear surface of the erosion shield.

28. A wing slat comprising a rear section and a forward section comprising a nose skin according to Claim 27.

29. A wing slat according to Claim 28, wherein the nose skin is demountable from the rear section.

30. A method of manufacturing a dielectric component with electrical connection, comprising the steps of:

   providing at least one dielectric layer comprising thermoplastic material;

   forming a hole through the dielectric layer or a stack of the dielectric layers to extend from a first to a second main surface of the dielectric layer or stack of dielectric layers;

   flame spraying a first metal coating onto the first main surface to form a first portion adjacent to the hole and a second portion which extends into the hole; and

   flame spraying a second metal coating onto the second main surface to form a third portion adjacent to the hole and a fourth portion which extends into the hole;

   wherein the flame spraying of the first and second metal coatings is such that the second portion overlaps the fourth portion to form a continuous conductive path between the first main surface and the second main surface.
31. A method according to Claim 30, wherein the first metal coating is sprayed into the hole from the first main surface such that the second portion extends substantially to the second main surface.

32. A method according to Claim 30, wherein the first metal coating is sprayed into the hole from the first main surface such that the second portion extends round onto part of the second main surface adjacent to the hole.

33. A method according to any one of Claims 30 to 32, wherein the second metal coating is sprayed into the hole from the second main surface such that the fourth portion extends substantially to the first main surface.

34. A method according to any one of Claims 30 to 32, wherein the second metal coating is sprayed into the hole from the second main surface such that the fourth portion extends round onto part of the first main surface adjacent to the hole.

35. A method according to any one of Claims 30 to 34, wherein the or each thermoplastic material comprises PEEK, PEKK, PPS, PEI or PES or a mixture thereof.

36. A method according to any one of Claims 30 to 34, wherein the or each thermoplastic material comprises PEEK, PEKK or a mixture thereof.

37. A method according to any one of Claims 30 to 36, wherein said at least one dielectric layer comprises a plurality of dielectric layers and each of the dielectric layers comprises the same thermoplastic material.

38. A dielectric component with electrical connection substantially as herein described with reference to, or with reference to and as illustrated in, the accompanying drawings.

39. A method of manufacturing a dielectric component with electrical connection substantially as herein described with reference to the accompanying drawings.