Title: HEATING ELEMENT HAVING A CNT COATING

FIG. 2

Abstract: The present disclosure relates to a heating element, comprising: - a rigid, plate-like, electrically insulating carrier (1) having a low thermal expansion coefficient in a predetermined temperature range; - a CNT coating (11) on the carrier, comprising carbon nano tubes; and - an electrical connection (7) in contact with the CNT coating to apply a voltage over the CNT coating, wherein the electrical connection comprises at least one electrically conductive, elongate member in the form of a strip of copper paint, applied on and extending over the CNT coating. Preferably, the heating element is such that the carrier comprises at least one element from a group comprising: a printed circuit board; a slate plate; a stone plate, a plastic plate, a resin plate; and the like. Preferably the carrier is made of the same epoxy based material as a printed circuit board.

[Continued on next page]
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HEATING ELEMENT HAVING A CNT COATING

The present disclosure relates to a heating element having a CNT coating. When a voltage is applied over such a CNT coating, heat may be generated.

In the prior art, such CNT coatings are known to be applied to fibre mats. In woven embodiments of such prior art, electrically conductive wires may be inserted in a weave of the fibre mats, to provide for electrical power supply.

Irrespective of the high accuracy weaves that are possible nowadays, or smooth finish of non-woven materials, applying a CNT coating on a fibre mat is cumbersome, and prone to result in production fall-out and write-off. Especially in case of woven fibre mats, a sufficiently homogenous weave is difficult (if not impossible) to achieve and allow a CNT coating to be arranged thereon with effective heating all over the surface of the fibre mat based heating element. Also, even if the heating element based on the fibre mat is successfully produced, life expectancy of the resulting heating elements is short due to the combination of higher temperatures with the fibrous material of the mats and due to the bendable nature of the mats.

According to a prior art disclosure in US-2009/194525, a heating element may be provided, comprising: a rigid, plate-like, electrically insulating carrier having a low thermal expansion coefficient in a predetermined temperature range; a CNT coating on the carrier, comprising carbon nano tubes; and an electrical connection in contact with the CNT coating to apply a voltage over the CNT coating. In the prior art heating element, an electrical connection is provided in the form of a rigid, elongate and rectangular silver panel with a copper lead wire on the silver panel, wherein the copper lead wire is also plate-like and configured to supply power to the silver panel.

This prior art heating element has been found wanting in relation to efficiency in terms of a heat to power ratio and/or other respects. Moreover, in tests, the prior art heating element has been reported to be unstable and even generate sparks. The prior art heating element is complex and costly through the use of silver panel and copper lead wire.

The skilled person would obviously realise that the stack of silver panel and copper lead requires severe attaching using for example a conductive adhesive to provide the required connection for power supply. Although soldering is not mentioned in the prior art disclosure, this could affect the CNT layer detrimentally.

The objective of the present disclosure is to improve on the prior art heating element simultaneously in terms of efficiency, reliability, production costs, power supply, and more and other considerations. However, the skilled person has no incentive from other available prior art, such as DE-20 2009 000136 and DE-10 2005 049428 how to achieve this objective.
According to the present disclosure, the heating element is distinguished over the prior art in that the electrical connection comprises at least one electrically conductive, elongate member in the form of a strip of copper paint, applied on and extending over the CNT coating. Although improved conductive adhesive and/or using a singular silver panel also as an electrode to obviate the need for copper lead wire and/or soldering the copper lead wire to the silver panel in advance of applying the resulting assembly onto the CNT coating and the like could be considered obvious solutions, the present disclosure exceeds such measures as could be expected from the skilled person in that a simple and elegant configuration results, against strongly reduced costs, exhibiting a severely improved connection to the power supply, without detrimental effect on the CNT coating, and so on.

The present disclosure relates further to many preferred embodiments, some of which may be described in the below embodiment description and/or some of which may be defined in the appended dependent claims.

In a particular embodiment, the heating element of the present disclosure may exhibit the feature that the carrier comprises at least one element from a group comprising: a printed circuit board; a slate plate; a stone plate, a plastic plate, a resin plate; and the like.

In an additional or alternative embodiment, the heating element of the present disclosure may exhibit the feature that the carrier is an epoxy based printed circuit board.

In an additional or alternative embodiment, the heating element of the present disclosure may exhibit the feature that the CNT coating is arranged on the carrier in the form of a CNT dispersion.

In an additional or alternative embodiment, the heating element of the present disclosure may exhibit the feature that the CNT coating is configured to emit IR radiation, when the voltage is applied over the CNT coating. In such an embodiment, preferably the CNT coating is configured to emit IR-C radiation, when the voltage is applied over the CNT coating.

In an additional or alternative embodiment, the heating element of the present disclosure may exhibit the feature that a temperature of the CNT coating defining a radiating surface of the heating element, is in a range between 50°C and 110°C, preferably between 60°C and 100°C and more preferably between 75°C and 95°C.

In an additional or alternative embodiment, the heating element of the present disclosure may exhibit the feature that the carrier exhibits no or at least hardly any thermal compression or expansion in the temperature range at least between 0°C and 100°, preferably between 0° and 150°C, and most preferably between 0°C and at least 200°C.

In an additional or alternative embodiment, the heating element of the present disclosure may exhibit the feature of a front plate. In such an embodiment, preferably the front plate is arranged over the CNT coating. Also in said an embodiment, additionally or alternatively,
preferably the front plate is arranged on the CNT coating. Also in said embodiment, additionally or alternatively, preferably the front plate comprises any one or more than one material from a group comprising ceramic material, slate, epoxy, plastic, and the like. Also in said embodiment, additionally or alternatively, preferably the front plate is at least one of rigid; plate-like; electrically insulating; and having a low thermal expansion coefficient in a predetermined temperature range, preferably in a temperature range between at least 0°C and at least 100°C.

In an additional or alternative embodiment, the heating element of the present disclosure may exhibit the feature that the electrical connection comprises at least one electrically conductive, elongate member extending over the CNT coating. In such an embodiment, preferably the elongate member is arranged along a side of the carrier over the CNT coating. Then, preferably, the carrier comprises an opposing side opposite the side with the electrically conductive elongate member, and an additional electrically conductive elongate member is arranged on the CNT coating along the opposing side and a power source is connected with the member and the additional member to apply the voltage over the CNT coating. Also in said embodiment of the elongate member, additionally or alternatively, preferably at least one of the electrically conductive elongate member and the additional electrically conductive elongate member is formed by a strip of copper paint, applied on the CNT coating.

In an additional or alternative embodiment, the heating element of the present disclosure may exhibit the feature that at least one side of the carrier comprises a coupling configuration configured to couple the heating element and an adjacent heating element.

In an additional or alternative embodiment, the heating element of the present disclosure may exhibit the feature that the carrier comprises at least one of thermal insulation and reflection, for instance in a layer.

In an additional or alternative embodiment, the heating element of the present disclosure may exhibit the feature that a control is connected with the electrical connection, to selectively apply the voltage over the CNT coating.

Based on the above indications of features of a heating element, provided in terms of the appended claims, below an embodiment description of a heating element according to the present disclosure will be provided, as shown in the appended drawing, including (some) production steps thereof. However, it is noted here that the disclosure is by no means to be interpreted as limited to any merely preferred features, unless essential for proper functioning as defined in the single appended independent claim, where the scope of protection may even include obvious alternatives for specifically recited features in the appended independent claim. In the drawing:

Figure 1 shows application of a coating of a dispersion of CNT on a carrier;
Figure 2 shows application of a conductive member;
Figure 3 shows application of conductors;
Figure 4 shows a side view along arrow IV in figure 3; and
Figure 5 shows a side view along arrow V in figure 3.

In figure 1 it is shown that carriers 1 are progressed along a path in the direction of arrow A, where a wide nozzle 3 is arranged over the path of arrow A to apply a dispersion 2 of carbon nano tubes (herein after also referred to as CNT) onto a surface of the carriers 1. Other forms of application than in a dispersion are also conceivable. Thereby a CNT coating 11 is formed.

The dispersion originates from a vessel 5 and is supplied to the nozzle 3 via a conduit 4, which may contain a schematically represented valve 5 to control a flow of dispersion 2 to nozzle 3.

The carriers 1 are rigid, plate-like, electrically insulating elements having a low thermal expansion coefficient in a predetermined temperature range. This is to say that carriers will not compress or expand (or hardly so) when a voltage from a source 14 in figure 4 is applied over the CNT coating. Carriers may suitably be formed by printed circuit boards (PCB’s); slate plates; stone plates; plastic plates; resin plates, and the like. Preferably, the carriers are epoxy based printed circuit boards, precisely because of easy production thereof. The circuit boards may or may not be printed with conductive lines or broader bands, but if the boards are printed with conductors (not shown) this may support the power supply (described below) and current distribution.

In figure 2, application of bands 7 of copper paint is shown, schematically represented as using a paint brush 8. Other materials than cooper paint may alternatively be applied. The bands 7 of electrically conductive copper paint are arranged along opposite sides of the rectangular carrier 1 in the form of possibly a printed circuit board (PCB). Thus, when the bands 7 of copper paint are connected to opposing sides of a power source 14 (as in figure 4), a voltage is applied over the CNT coating 11.

To allow connection of a power source 14 to the bands 7, cable or wire shaped conductors 9 are arranged on the bands 7, for example by soldering, using a soldering tool 10. The conductors may alternatively be flat. The conductors may be electrically connected to the bands using conductive glue, or any other suitable means. The conductors 9 comprise branches 17, to allow more evenly distributed input of current over the length of the bands 7. The conductors may be point welded, or may be attached to the bands over a length L in figure 4 over a top surface of the bands. The conductors 9 and/or the branches 17 thereof may be embedded in the bands 7.

The conductors 9 may connect the bands to a switch 13, which is controlled by a micro control 15, to regulate connection of the bands 7 to a power source 14. When the switch 13 is closed and power is supplied to the bands 7, a voltage is applied over the CNT coating 11 between the bands at opposing sides of the carrier 1. To this end, at least one and possibly more than one temperature sensors 19 may be provided. In the embodiment of figures 3 and 4, temperature sensors 19 are arranged on the back of carrier 1. The control 15 is connected with the temperature
sensors 19 to drive switch 13 to allow the carrier 1 to reach a desired temperature, and preferably prevent that the carrier 1 is heated to a higher temperature than a threshold value.

The control 15 may be a simple design, programmable chip, also referred to as a logic module, which may be wirelessly controlled remotely through a point-to-point network and/or a mesh-based network, WiFi, 3G/4G, or any other suitable connection, even a hardwired network connection.

Via the network, a device may be loaded with software to regulate control 15. Such a device may be a mobile device such as a smart phone or tablet computer, a lap top, a terminal, a server or the like. As such the device may perform functions of a thermostat to set turn-on and turn-off times, desired heat production, threshold temperatures and the like.

The sensor 19 is shown in figure 4 to be embedded in the surface of carrier 1, but may alternatively be arranged on a back surface of the carrier 1. Likewise, the control 15 chip may be embedded in or arranged on a surface, preferably a back surface of carrier 1.

The CNT coating may be configured to emit IR radiation, when the voltage is applied over the CNT coating 11. More preferably, the CNT coating may be configured to emit IR-C radiation, when the voltage is applied over the CNT coating.

The controller 15 may regulate a temperature of the CNT coating 11 defining a radiating surface of the heating element, in a range between 50°C and 110°C, preferably between 60°C and 100°C and more preferably between 75°C and 95°C. However, the coating 11 may also be designed to ensure that the temperature does not exceed a predetermined level, even when no controlled switch is provided.

Preferably, the carrier exhibits no or at least hardly any thermal compression or expansion in the temperature range at least between 0°C and 100°, preferably between 0° and 150°C, and most preferably between 0°C and at least 200°C.

As shown in figure 5, the heating element may comprise a front plate 18. Such a front plate 18 may be arranged over the CNT coating, and/or the front plate 18 may be arranged on the CNT coating. Therefore the application direction of arrow B is shown, but not the end position of the front plate 18.

The front plate may be any one or more than one material from a group comprising ceramic material, slate, epoxy, plastic, and the like. Preferably the front plate is as impervious to temperature variations as the carrier. Therefore, the front plate 18 is preferably at least one of rigid; plate-like; electrically insulating; and having a low thermal expansion coefficient in a predetermined temperature range, preferably in a temperature range between at least 0°C and at least 100°C. The front plate 18 may cover more than one carrier 1 or span an interface between neighbouring heating elements.
It is noted that an electrical connection may comprise at least one of the bands 7 and the conductors 9 and/or the branches 17 thereof. The bands 7 are in figures 2 and 3 arranged along a opposing sides of the carrier 1 over the CNT coating 11. In an alternative embodiment, a single band may be provided along one side of the carrier, to provide an alternative for a band at an opposing side. Bands 7 may be mirrored underneath the CNT coating 11 by electrically conductive printing on the circuit board forming the carrier 1.

As shown in figure 4, an insulating or even reflecting layer 12 may be included in the carrier 1.

As shown in figure 5, at least one side of the carrier 1 may comprise a coupling configuration configured to couple the heating element and an adjacent heating element. In the embodiment of figure 5, a pin-hole coupling 16 is employed. The pin may be a thread wire, to be engaged by a bolt (not shown) which may be accommodated in a shallow depression at a rear surface of the carriers 1.

To provide a decorative effect, a light source may be provided at a back surface of carrier 1. In a preferred embodiment, the light source 1 may be a LED based illumination. Preferably carrier 1 is mounted at a short distance from a wall, ceiling or other structural component of a building. In this manner light may appear to radiate from the heating element. In an embodiment wherein the light is LED based, control thereof may be linked to the control 15, so that colour of the light source may vary with a sensed temperature of carrier 1. Additionally or alternatively, light intensity may be varied in stead of colour, and varying may be based on current supplied to the heating element instead of being based on temperature of the heating element.

Based on the foregoing disclosure both in terms of specific embodiments and the features and expressions of the appended claims, any skilled reader will understand that many modifications and alterations relative to the specifically disclosed embodiments are within the scope of protection according to the appended claims, up to and including obvious alternatives for features in the appended claims. For instance, the carrier may be made from other material than epoxy, the front plate may be omitted, and an actual practical embodiment may exhibit any one or more than one of the alterations and modifications already referred to in the above description.
CLAIMS

1. A heating element, comprising:
   - a rigid, plate-like, electrically insulating carrier having a low thermal expansion coefficient in a
     predetermined temperature range;
   - a CNT coating on the carrier, comprising carbon nano tubes; and
   - an electrical connection in contact with the CNT coating to apply a voltage over the CNT coating.
   CHARACTERISED IN THAT
   the electrical connection comprises at least one electrically conductive, elongate member in the
   form of a strip of copper paint, applied on and extending over the CNT coating.

2. The heating element of claim 1, wherein the carrier comprises at least one element from
   a group comprising: a printed circuit board; a slate plate; a stone plate, a plastic plate, a resin plate;
   and the like.

3. The heating element of claim 1 or 2, wherein the carrier is an epoxy based printed circuit
   board.

4. The heating element of claim 1, 2 or 3, wherein the CNT coating is arranged on the
carrier in the form of a CNT dispersion.

5. The heating element of any one or more than one of the preceding claims, wherein the
   CNT coating is configured to emit IR radiation, when the voltage is applied over the CNT coating.

6. The heating element of claim 5, wherein the CNT coating is configured to emit IR-C
   radiation, when the voltage is applied over the CNT coating.

7. The heating element of any one or more than one of the preceding claims, wherein a
temperature of the CNT coating defining a radiating surface of the heating element, is in a range
between 50°C and 110°C, preferably between 60°C and 100°C and more preferably between 75°C
and 95°C.

8. The heating element of any one or more than one of the preceding claims, wherein the
   carrier exhibits no or at least hardly any thermal compression or expansion in the temperature
range at least between 0°C and 100°, preferably between 0° and 150°C, and most preferably
between 0°C and at least 200°C.

9. The heating element of any one or more than one of the preceding claims, further
   comprising a front plate.

10. The heating element of claim 9, wherein the front plate is arranged over the CNT
     coating.

11. The heating element of claim 9 or 10, wherein the front plate is arranged on the CNT
     coating.
12. The heating element of claim 9, 10 or 11, wherein the front plate any one or more than one material from a group comprising ceramic material, slate, epoxy, plastic, and the like.

13. The heating element of any one or more than one of the preceding claims 9 - 12, wherein the front plate is at least one of rigid; plate-like; electrically insulating; and having a low thermal expansion coefficient in a predetermined temperature range, preferably in a temperature range between at least 0°C and at least 100°C.

14. The heating element of any one or more than one of the preceding claims, wherein the elongate member is arranged along a side of the carrier over the CNT coating.

15. The heating element of claim 14, wherein the carrier comprises an opposing side opposite the side with the electrically conductive elongate member, and an additional electrically conductive elongate member is arranged on the CNT coating along the opposing side and a power source is connected with the member and the additional member to apply the voltage over the CNT coating.

16. The heating element of any one or more than one of the preceding claims, wherein at least one side of the carrier comprises a coupling configuration configured to couple the heating element and an adjacent heating element.

17. The heating element of any one or more than one of the preceding claims, wherein the carrier comprises at least one of thermal insulation and reflection, for instance in a layer.

18. The heating element of any one or more than one of the preceding claims, wherein a control is connected with the electrical connection, to selectively apply the voltage over the CNT coating.

19. The heating element of any one or more than one of the preceding claims, further comprising at least one temperature sensor.

20. The heating element of claim 19, wherein the temperature sensor is at least one of embedded in and arranged on a surface of the carrier, preferably a back surface of the carrier.

21. The heating element of claim 18 and at least one of claims 19 and 20, wherein the temperature sensor is connected to the control.

22. The heating element of any one or more than one of the preceding claims, further comprising at least one light source.

23. The heating element of claim 22, wherein the light source is a controllable light source with respect to at least one aspect from a group comprising light intensity, light colour and the like.

24. The heating element of claim 23, wherein the light source is controlled with respect to the at least one aspect in correspondence with at least one of a temperature of the heating element, current supplied to the heating element, and the like.
**INTERNATIONAL SEARCH REPORT**

**International application No**
PCT/NL2017/050366

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### A. CLASSIFICATION OF SUBJECT MATTER
INV. H05B3/14 H05B3/26

According to International Patent Classification (IPC) or to both national classification and IPC

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### B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H05B

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

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### C. DOCUMENTS CONSIDERED TO BE RELEVANT

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16 October 2017

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25/10/2017

**Name and mailing address of the ISA/**
European Patent Office, P.B. 5818 Patentlaan 2
NL-2280 HV Rijswijk
Tel. (+31-70) 340-2040,
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