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(54) **INJECTABLE HEAT SINK**

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H05K 7/20	(2006.01)
C08J 9/12	(2006.01)
C09K 5/14	(2006.01)
F28D 21/00	(2006.01)
F28F 13/00	(2006.01)

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CPC ***H05K 7/2039*** (2013.01); ***C08J 9/122*** (2013.01); ***C09K 5/14*** (2013.01); ***F28D 21/00*** (2013.01); *C08J 2201/022* (2013.01); *C08J 2203/06* (2013.01); *C08J 2363/00* (2013.01); *F28F 2013/001* (2013.01); *F28F 21/02* (2013.01); *F28F 21/06* (2013.01); *F28F 2255/143* (2013.01)

(58) **Field of Classification Search**

CPC ... H05K 7/2039; H05K 7/20854; C08J 9/122; C08J 2201/022; C08J 2203/06; C08J 2363/00; C08J 2203/02; C08J 9/02; C09K 5/14; F28D 21/00; F28F 21/02; F28F 21/06; F28F 2013/001; F28F 2255/143

See application file for complete search history.

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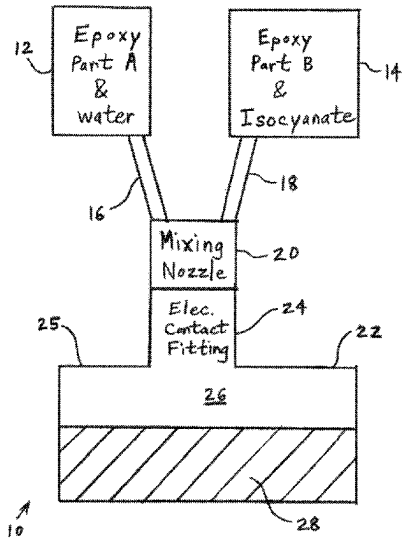
(57) **ABSTRACT**

A heat sink arrangement includes a housing associated with an electronic heat source. The housing has a cavity adjacent to the heat source. A thermally conductive, electrically insulating foam heat sink is disposed in the cavity and draws heat out of the heat source. The foam heat sink may be formed of a two-part epoxy.

20 Claims, 3 Drawing Sheets



(51) **Int. Cl.**
F28F 21/02 (2006.01)
F28F 21/06 (2006.01)

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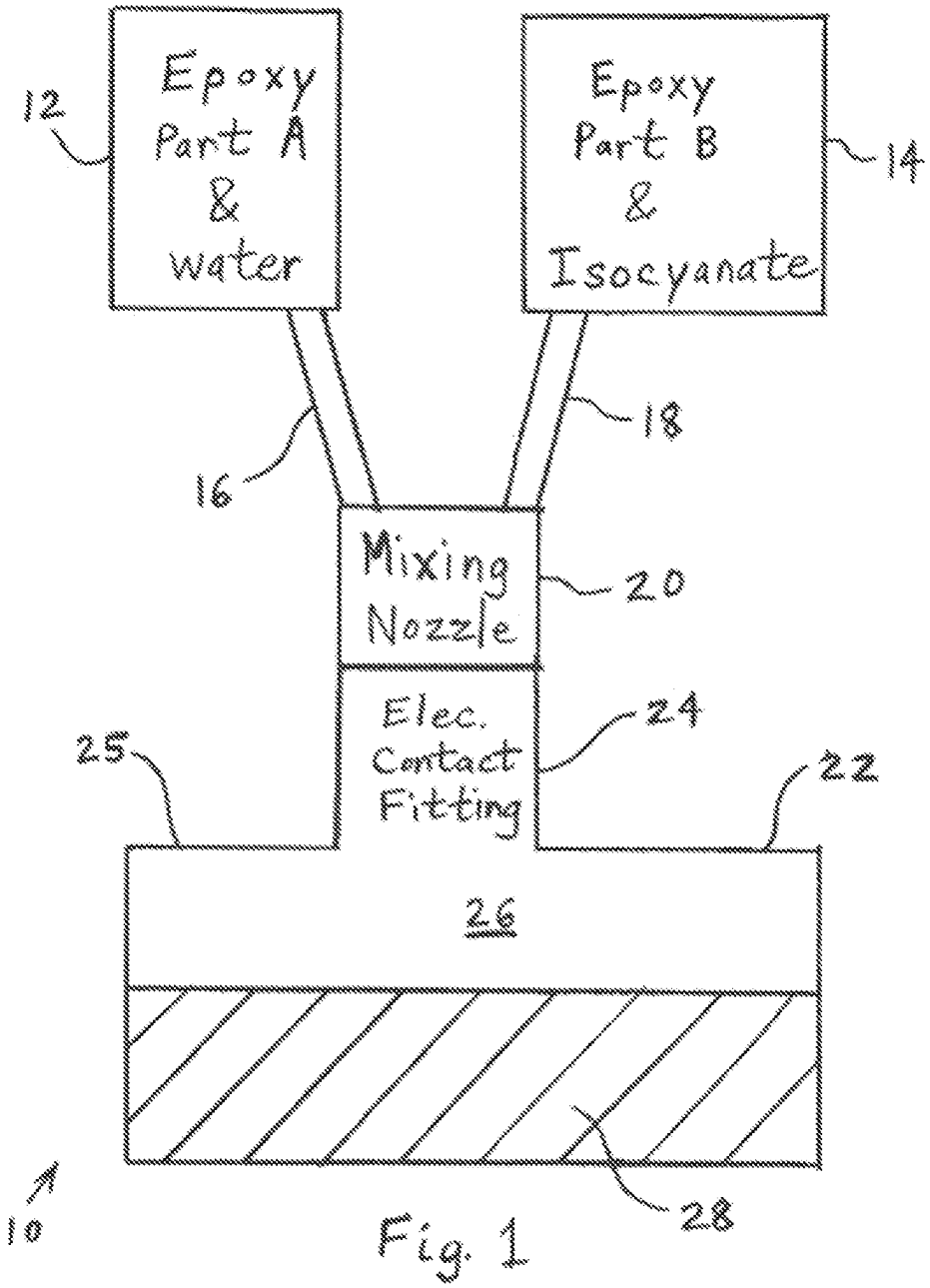
Epoxy Part A & water
12
Epoxy Part B & Isocyanate
14
16
18
Mixing Nozzle
20
Elec. Contact Fitting
24
25
22
26
28
10

Fig. 1

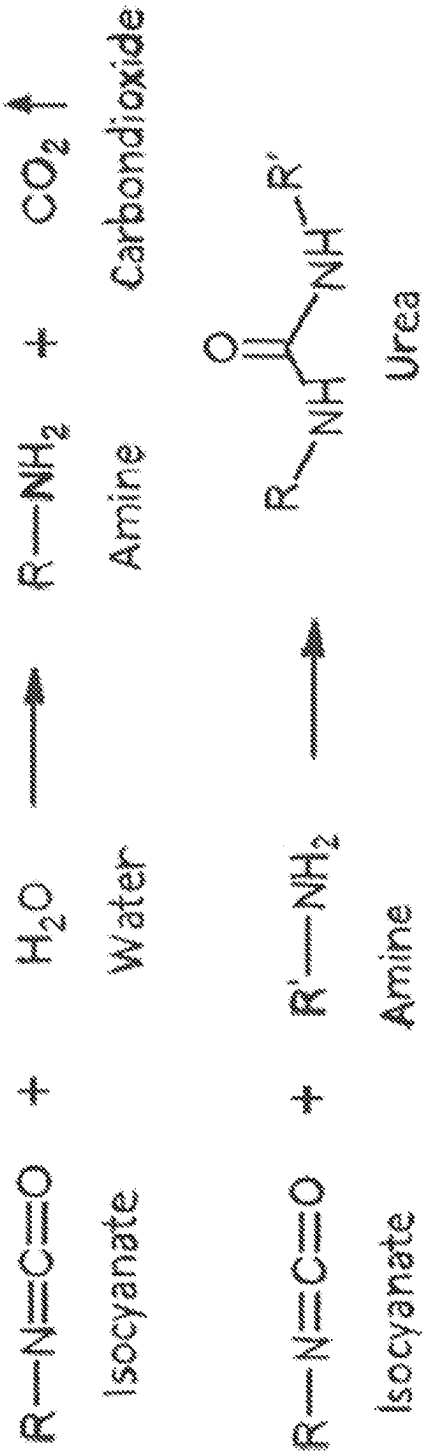
R—N=C=O + H2O → R—NH2 + CO2↑
Isocyanate Water Amine Carbondioxide
R—N=C=O + R'—NH2 →
Isocyanate Amine
O
R—NH NH—R'
Urea

Fig. 2

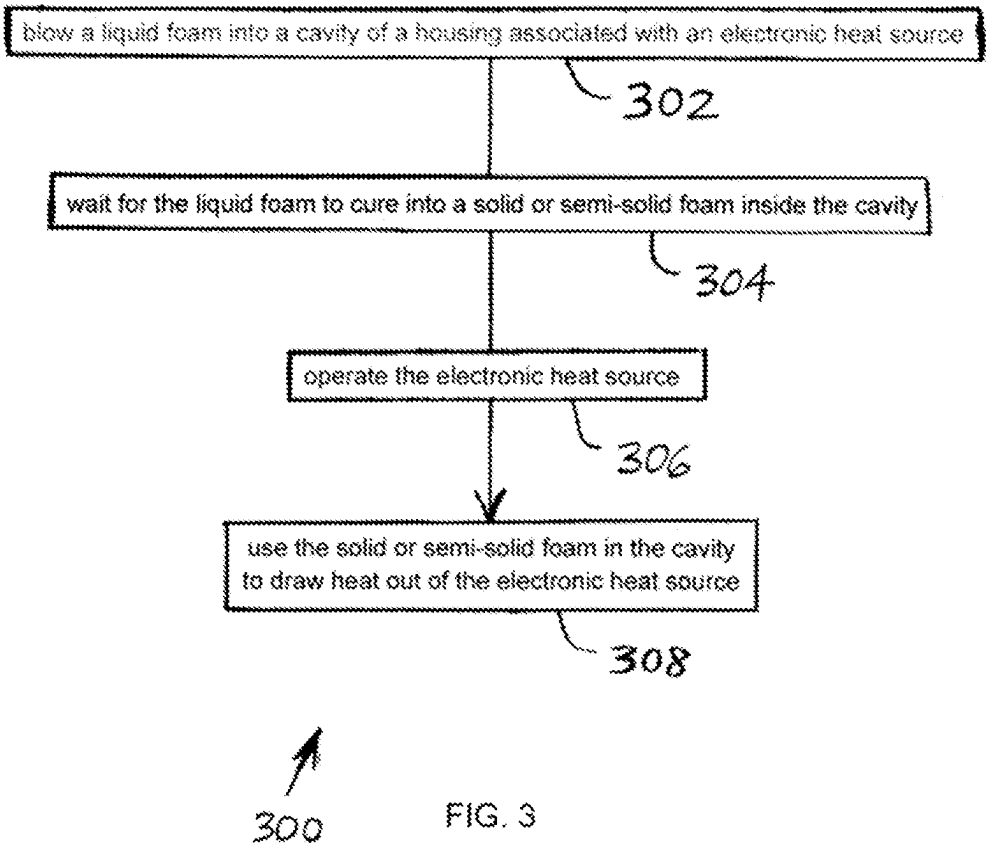
blow a liquid foam into a cavity of a housing associated with an electronic heat source
302
wait for the liquid foam to cure into a solid or semi-solid foam inside the cavity
304
operate the electronic heat source
306
use the solid or semi-solid foam in the cavity to draw heat out of the electronic heat source
308
300

FIG. 3

INJECTABLE HEAT SINK

CROSS-REFERENCED TO RELATED APPLICATIONS

This application claims benefit of U.S. Provisional Application No. 63/084,805, filed on Sep. 29, 2020, the disclosure of which is hereby incorporated by reference in its entirety for all purposes.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a heat sink, and, more particularly, to a heat sink for dissipating heat from a component in a motor vehicle.

2. Description of the Related Art

Heat sinks are known to physically engage and carry heat away from electronic components that otherwise may be damaged by the heat. The heat sink typically is made of aluminum and has a base with a surface that contacts the electronic component. The heat sink also typically has a series of fins extending from the base in a direction away from the electronic component. The fins provide a large surface area within a limited three-dimensional space to thereby increase the rate of convection of heat from the heat sink to the air.

Traditionally, heat sinks are either cast or extruded and require expensive tooling to produce.

SUMMARY OF THE INVENTION

The invention may provide a method for redistributing heat from a heat source utilizing an expanding foam-based injectable heat sink. The injectable heat sink may be injected into a cavity in an assembly to remove heat from the assembly without a need for specific heat sink tooling.

The injection may be performed using a system including a customized injection nozzle or customized plugs to ensure that the foam is injected and kept where it will be most useful for heat dissipation purposes.

The heat sink may be formed of a compound based on an electrically insulating and thermally conductive two-part epoxy and a foaming agent. The epoxy components may be fully mixed with the foaming agents.

One example of a foaming agent is the combination of isocyanate and water. This combination generates carbon dioxide which, in turn, is trapped within the curing epoxy. Although the created carbon dioxide pockets have a lower thermal conductivity than the displaced air, the combination of the high thermal conductivity of the epoxy and the carbon dioxide should, even at a ratio of 5:1 carbon dioxide to epoxy by final volume, yield an order of magnitude improvement in thermal conductivity over the displaced air.

Plugs may be used to contain the foam within the cavity. The plugs may be shaped such that they allow some of the foam to escape from the cavity in a controlled manner. The escaped foam may then be exposed to an air flow which may improve the thermal dissipation properties of the injectable heat sink. Even if air flow exposure is not possible, the increased thermal mass may distribute the heat more evenly within the cavity and thereby protect the electrical components from overheating for a longer duration.

The invention comprises, in one form thereof, a heat sink arrangement including a housing associated with an electronic heat source. The housing has a cavity adjacent to the heat source. A thermally conductive, electrically insulating foam heat sink is disposed in the cavity and draws heat out of the heat source. The foam heat sink may be formed of a two-part epoxy.

The invention comprises, in another form thereof, a method of removing heat from an electronic heat source that is associated with a housing having a cavity. A fluid foam is blown into the cavity. After the liquid foam has cured into a solid or semi-solid foam inside the cavity, the electronic heat source is operated. The solid or semi-solid foam in the cavity is used to draw heat out of the electronic heat source.

The invention comprises, in yet another form thereof, a heat sink arrangement including an electronic assembly having a housing containing a high-power electronic component that produces heat during operation. The housing has a cavity. A first container contains a first epoxy part and a first blowing agent part. A second container contains a second epoxy part and a second blowing agent part. A nozzle blows a mixture of contents of the first container and contents of the second container into the cavity of the housing to thereby form a thermally conductive, electrically insulating foam heat sink in the cavity for drawing heat out of the electronic component.

An advantage of the present invention is that it may enable the implementation of a heat sink into a partially enclosed space without the need for dedicated heat sink tooling and heat sink fastening.

Another advantage of the present invention is it may reduce the investment costs associated with implementing a heat sink as well as enable the implementation of a heat sink late in a product development cycle if thermal problems are detected.

BRIEF DESCRIPTION OF THE DRAWINGS

The above-mentioned and other features and objects of this invention, and the manner of attaining them, will become more apparent and the invention itself will be better understood by reference to the following description of embodiments of the invention taken in conjunction with the accompanying drawings, wherein:

FIG. **1** is a schematic diagram of one embodiment of a heat sink arrangement of the present invention.

FIG. **2** is a diagram of the blowing agent chemistry of one embodiment of a heat sink arrangement of the present invention.

FIG. **3** is a flow chart of a method of the present invention for removing heat from an electronic heat source that is associated with a housing having a cavity.

DETAILED DESCRIPTION

The embodiments hereinafter disclosed are not intended to be exhaustive or limit the invention to the precise forms disclosed in the following description. Rather the embodiments are chosen and described so that others skilled in the art may utilize its teachings.

FIG. **1** illustrates one embodiment of a heat sink arrangement **10** of the present invention, including a two-part foam injection system with a customized injection nozzle. More particularly, arrangement **10** includes a first container tank **12**, a second container tank **14**, a first hose **16**, a second hose **18**, a mixing injection nozzle **20**, and an electronic assembly **22**. First tank **12** contains a mixture of water and epoxy part

A, which is one part of a two-part, thermally conductive, electrically insulating epoxy. Second tank **14** contains a mixture of isocyanate and epoxy part B, which is the other part of the two-part epoxy. Isocyanate has the formula R—N═C═O.

First hose **16** carries the mixture from first tank **12** to nozzle **20**, and second hose **18** carries the mixture from second tank **14** to nozzle **20**. The water from first hose **16** and the isocyanate from second hose **18** mix together in nozzle **20** to form a carbon dioxide blowing agent. The formation of carbon dioxide may create high pressure in nozzle **20** for blowing the contents of nozzle **20** out of nozzle **20**. FIG. **2** describes in molecular terms the chemical formulation of the blowing agent in nozzle **20**.

Electronic assembly **22** includes an electrical contact fitting **24**, a housing **25** having a cavity **26**, and a heat source **28**. Heat source **28** is schematically depicted in FIG. **1** as a shaded area, but may include any electronic source of heat, such as transistors, power amplifiers, integrated circuits, etc.

During use, nozzle **20** is inserted into a housing of electronic assembly **22**. More specifically, nozzle **20** is inserted into electrical contact fitting **24** in the embodiment of FIG. **1**. Nozzle **20** can then be opened to thereby commence a flow of fluid foam from a mixture of the contents of tanks **12** and **14** into the open space of cavity **26**. The foam may completely fill cavity **26** and cure/solidify and expand into a solid or semi-solid heat sink foam within cavity **26**. After the foam has expanded in cavity **26**, nozzle **20** may be removed from electrical contact fitting **24**.

During the operation of electronic assembly **22**, the foam, thermally conductive, electrically insulating heat sink within cavity **26** may absorb or draw heat from heat source **28**, and thereby cool heat source **28**.

FIG. **3** is a flow chart of a method **300** of the present invention for removing heat from an electronic heat source that is associated with a housing having a cavity. In a first step **302**, a liquid foam is blown into the cavity. For example, nozzle **20** can blow a liquid foam into cavity **26**.

In a next step **304**, waiting takes place for the liquid foam to cure into a solid or semi-solid foam inside the cavity. For example, it is possible that no positive actions occur while the foam cures/solidifies into a solid or semi-solid foam that functions as a heat sink within cavity **26**.

Next, in step **306**, the electronic heat source is operated. For example, voltage may be applied to the electronics of heat source **28**, thereby causing the electronics to operate and create heat.

In a final step **308**, the solid or semi-solid foam in the cavity is used to draw heat out of the electronic heat source. For example, the foam heat sink within cavity **26** may absorb or draw heat from heat source **28**.

While this invention has been described as having an exemplary design, the present invention may be further modified within the spirit and scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptations of the invention using its general principles. Further, this application is intended to cover such departures from the present disclosure as come within known or customary practice in the art to which this invention pertains.

What is claimed is:

1. A heat sink arrangement, comprising:
- an electronic assembly including:
  - a high-power electronic component that produces heat during operation; and
  - a housing containing the electronic component, the housing having a cavity;
- a first container containing a first epoxy part and a first blowing agent part;
- a second container containing a second epoxy part and a second blowing agent part; and
- a nozzle configured to blow a mixture of contents of the first container and contents of the second container into the cavity of the housing to thereby form a foam heat sink in the cavity for drawing heat out of the electronic component, wherein the first blowing agent part and the second blowing agent part form a blowing agent in the form of high-pressure gaseous carbon dioxide.

2. The heat sink arrangement of claim **1** wherein the electronic component comprises a transistor, a power amplifier, and/or an integrated circuit.

3. The heat sink arrangement of claim **1** wherein the heat sink is thermally conductive and electrically insulating, and substantially fills the cavity.

4. The heat sink arrangement of claim **1** wherein gaseous carbon dioxide is trapped within the foam heat sink.

5. The heat sink arrangement of claim **4** wherein the heat sink is expanded within the cavity by the gaseous carbon dioxide.

6. The heat sink arrangement of claim **1** wherein the heat sink cures into a solid or semi-solid foam after the mixture of contents is blown into the into the cavity of the housing as a liquid foam.

7. A heat sink arrangement, comprising:
- an electronic assembly including:
  - a high-power electronic component that produces heat during operation;
  - a housing containing the electronic component, the housing having a cavity; and
  - an electrical contact fitting connected to the housing;
- a first container containing a first epoxy part and a first blowing agent part;
- a second container containing a second epoxy part and a second blowing agent part; and
- a nozzle configured to blow a mixture of contents of the first container and contents of the second container through the electrical contact fitting into the cavity of the housing to thereby form a foam heat sink in the cavity for drawing heat out of the electronic component.

8. The heat sink arrangement of claim **7** wherein the electronic component comprises a transistor, a power amplifier, and/or an integrated circuit.

9. The heat sink arrangement of claim **7** wherein the heat sink is thermally conductive and electrically insulating, and substantially fills the cavity.

10. The heat sink arrangement of claim **7** wherein gaseous carbon dioxide is trapped within the foam heat sink.

11. A heat sink arrangement, comprising:
- an electronic assembly including:
  - a high-power electronic component that produces heat during operation; and
  - a housing containing the electronic component, the housing having a cavity; and
- a nozzle configured to blow a mixture of contents of a first container and contents of a second container into the cavity of the housing to thereby form a foam heat sink in the cavity for drawing heat out of the electronic component, wherein the first container contains a first epoxy part and a first blowing agent part, and the second container contains a second epoxy part and a second blowing agent part, wherein the first blowing agent part and the second blowing agent part form a blowing agent.

12. The heat sink arrangement of claim 11 wherein the heat sink is thermally conductive and electrically insulating, and substantially fills the cavity.

13. The heat sink arrangement of claim 11 wherein the electronic component comprises a transistor, a power amplifier, and/or an integrated circuit.

14. The heat sink arrangement of claim 11 wherein gaseous carbon dioxide is trapped within the foam heat sink.

15. The heat sink arrangement of claim 14 wherein the heat sink is expanded within the cavity by the gaseous carbon dioxide.

16. The heat sink arrangement of claim 11 wherein the heat sink cures into a solid or semi-solid foam after the mixture of contents is blown into the into the cavity of the housing as a liquid foam.

17. A heat sink arrangement, comprising:

an electronic assembly including:

a high-power electronic component that produces heat during operation;

a housing containing the electronic component, the housing having a cavity; and

an electrical contact fitting connected to the housing; and

a nozzle configured to blow a mixture of contents of a first container and contents of a second container into the cavity of the housing through the electrical contact fitting to thereby form a foam heat sink in the cavity for drawing heat out of the electronic component.

18. A heat sink arrangement, comprising:

an electronic assembly including:

an electronic component that produces heat during operation; and

a housing containing the electronic component, the housing having a cavity; and

an electrical contact fitting connected to the housing; and

a nozzle configured to blow a mixture of a two-part epoxy and a blowing agent into the cavity of the housing through the electrical contact fitting to thereby form a foam heat sink in the cavity for drawing heat out of the electronic component.

19. The heat sink arrangement of claim 18 wherein the heat sink is thermally conductive and electrically insulating, and substantially fills the cavity.

20. The heat sink arrangement of claim 18, wherein the heat sink cures into a solid or semi-solid foam after the mixture of the two-part epoxy and the blowing agent is blown into the into the cavity of the housing as a liquid foam.

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