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Moshtagh

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(54) **SHAPE FORMING HEAT SINK WITH FLEXIBLE HEAT ROD**

(75) Inventor: **Vahid S. Moshtagh**, San Jose, CA (US)

(73) Assignee: **Bridgelux, Inc.**, Livermore, CA (US)

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B23P 19/04 (2006.01)
H05K 7/20 (2006.01)

(52) **U.S. Cl.** **362/373**; 362/294

(58) **Field of Classification Search** 362/373, 362/294, 345, 580, 218, 126, 547, 800; 29/428; 361/707

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,419,719 A *	12/1983	Boer et al.	....	362/294
4,974,119 A	11/1990	Martin	....	361/386
5,782,555 A	7/1998	Hochstein	....	362/373
7,278,761 B2	10/2007	Kuan	....	362/294
7,641,363 B1 *	1/2010	Chang et al.	....	362/294
7,755,282 B2	7/2010	Sun et al.	....	313/512
7,784,970 B2	8/2010	Sun	....	362/294
7,800,909 B2	9/2010	Sun	....	361/709

* cited by examiner

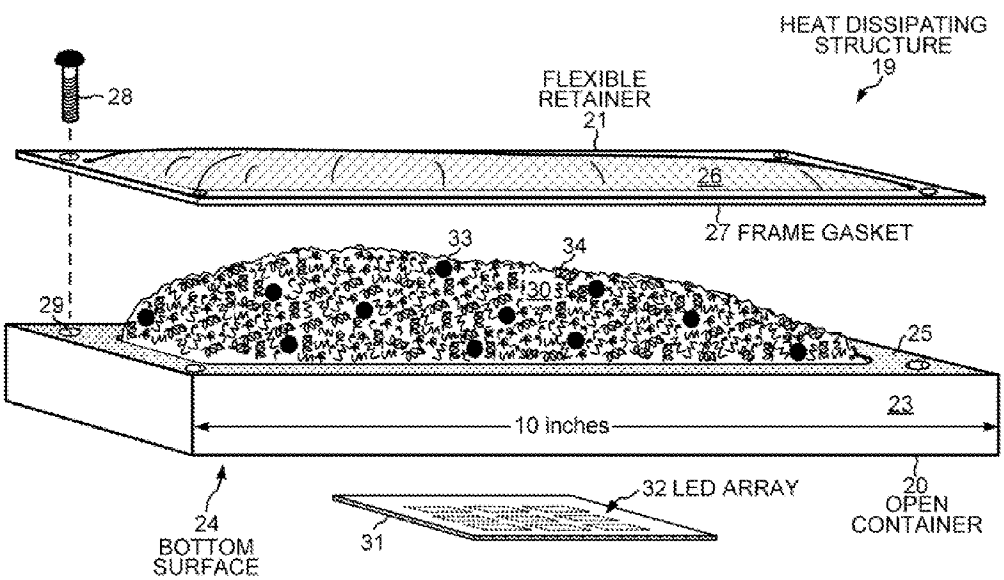
Primary Examiner — Bao Q Truong

(74) *Attorney, Agent, or Firm* — Imperium Patent Works; Darien K. Wallace

(57) **ABSTRACT**

A conforming heat dissipating structure transfers heat to an irregular surface from a heat source mounted on its bottom surface. The heat dissipating structure includes an open container filled with metal shavings and balls covered by a flexible retainer. The shavings and balls beneath the flexible retainer are pressed against the irregular surface and conform to its irregular shape. In one application, light emitting diodes are mounted to the bottom of the heat dissipating structure, and the shavings are compressed against the inside cover of a street light. A flexible heat rod enables heat to be transferred over a flexible path from a heat source on one heat dissipating structure to a heat sink pressed against another heat dissipating structure. The many strands that make up the flexible heat rod are spread out inside each open container and are pressed between the metallic shavings to achieve a good thermal contact.

20 Claims, 9 Drawing Sheets



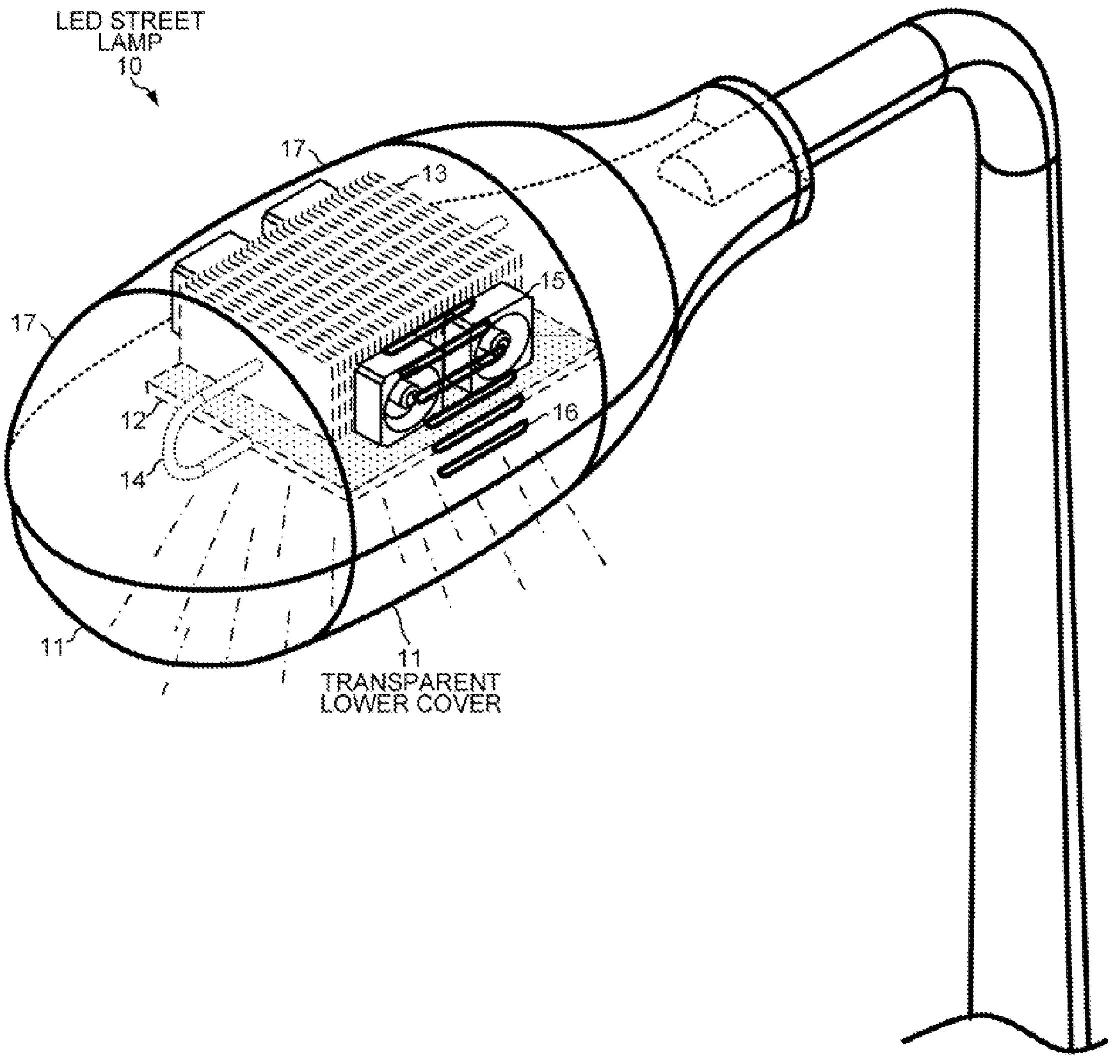


FIG. 1
(PRIOR ART)

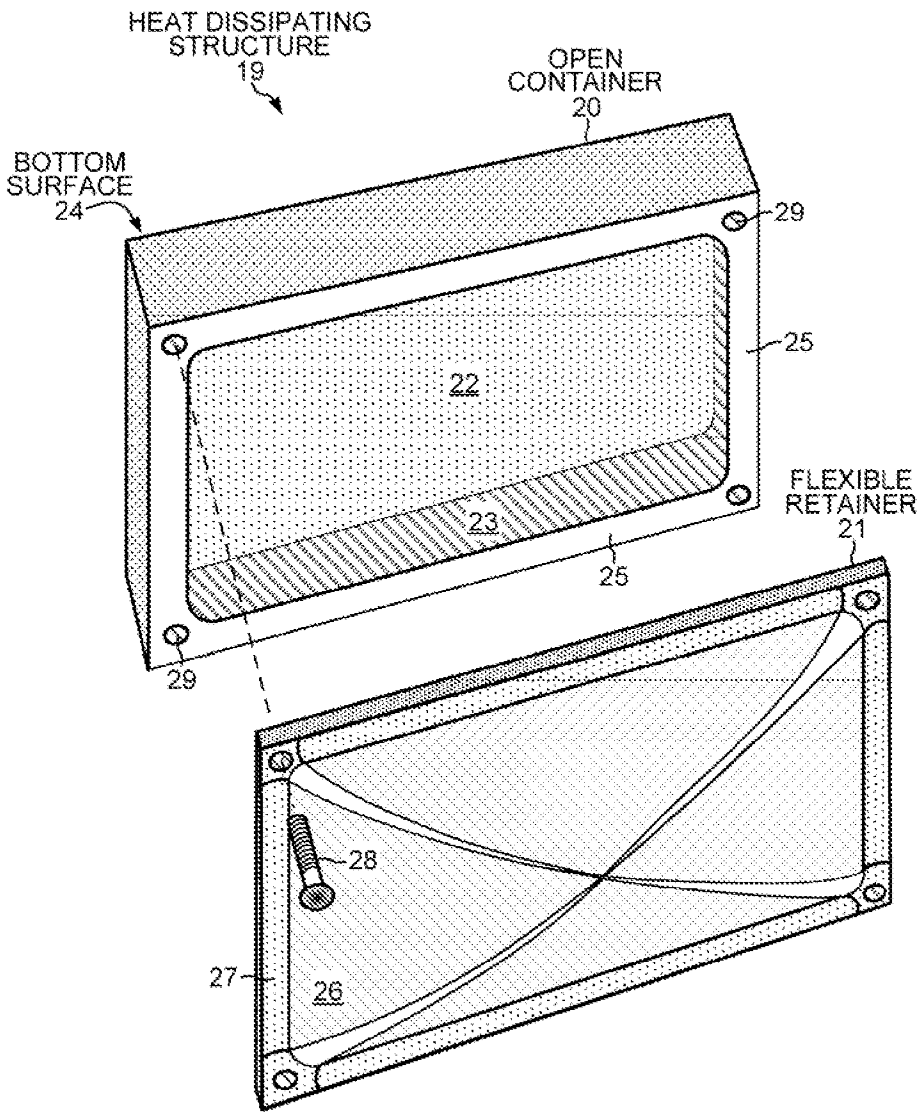

HEAT DISSIPATING STRUCTURE
19
OPEN CONTAINER
20
BOTTOM SURFACE
24
29
25
22
23
25
29
FLEXIBLE RETAINER
21
28
27
26

FIG. 2

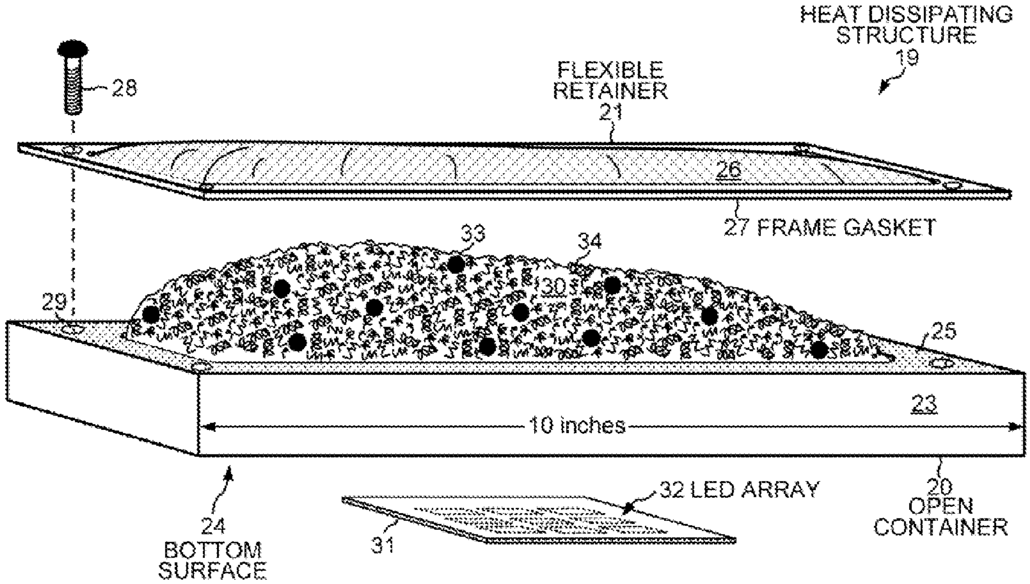

HEAT DISSIPATING
STRUCTURE
19
FLEXIBLE
RETAINER
21
28
26
27 FRAME GASKET
33
34
30
29
25
23
10 inches
32 LED ARRAY
20
OPEN
CONTAINER
24
BOTTOM
SURFACE
31

FIG. 3

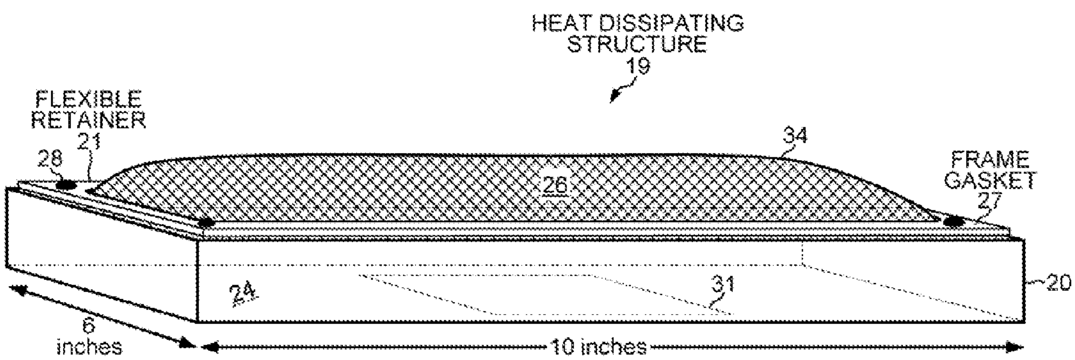

HEAT DISSIPATING
STRUCTURE
19
FLEXIBLE
RETAINER
21
28
34
26
FRAME
GASKET
27
24
31
20
6
inches
10 inches

FIG. 4

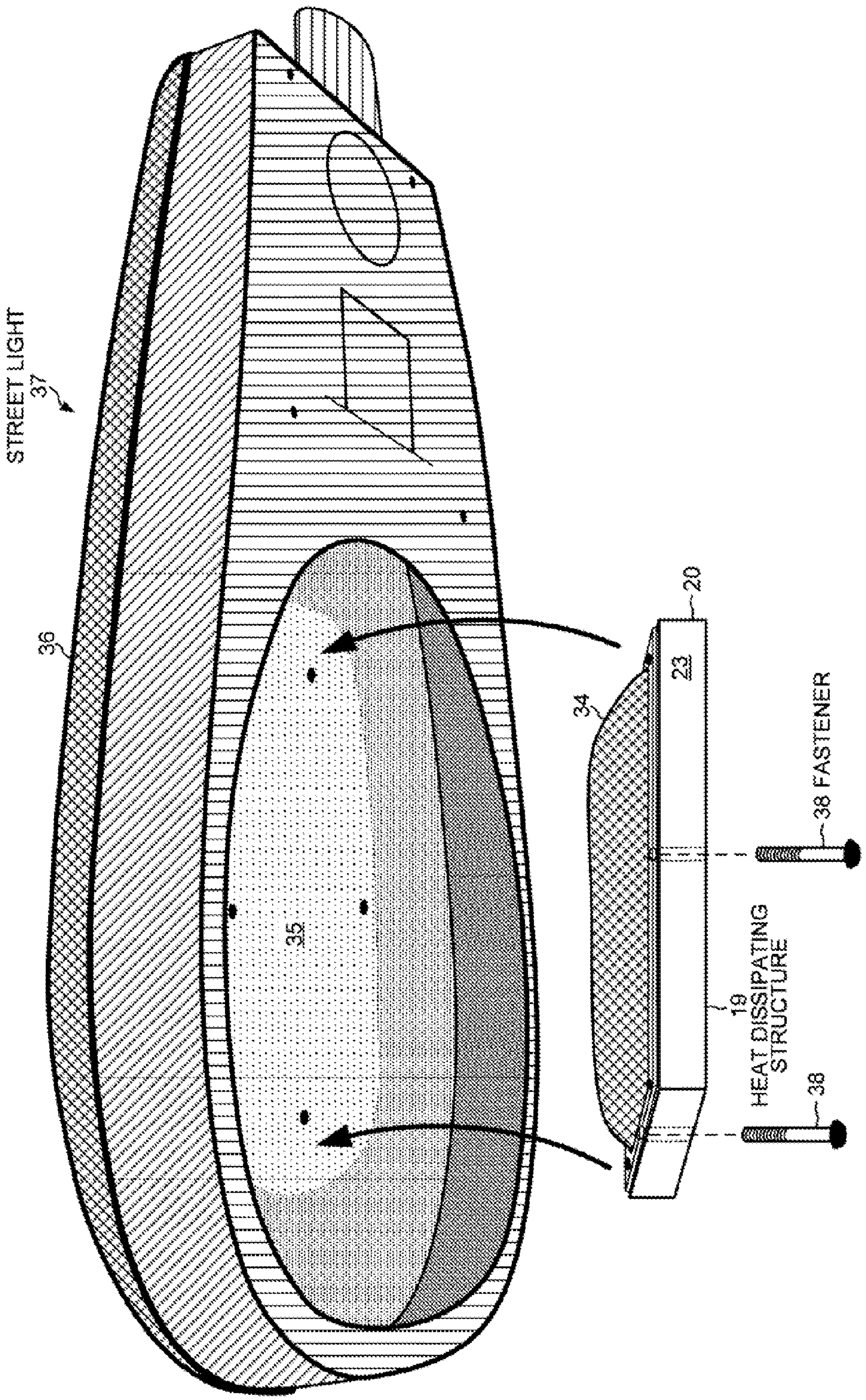

STREET LIGHT
37
36
35
34
20
23
38 FASTENER
19
HEAT DISSIPATING
STRUCTURE
38

FIG. 5

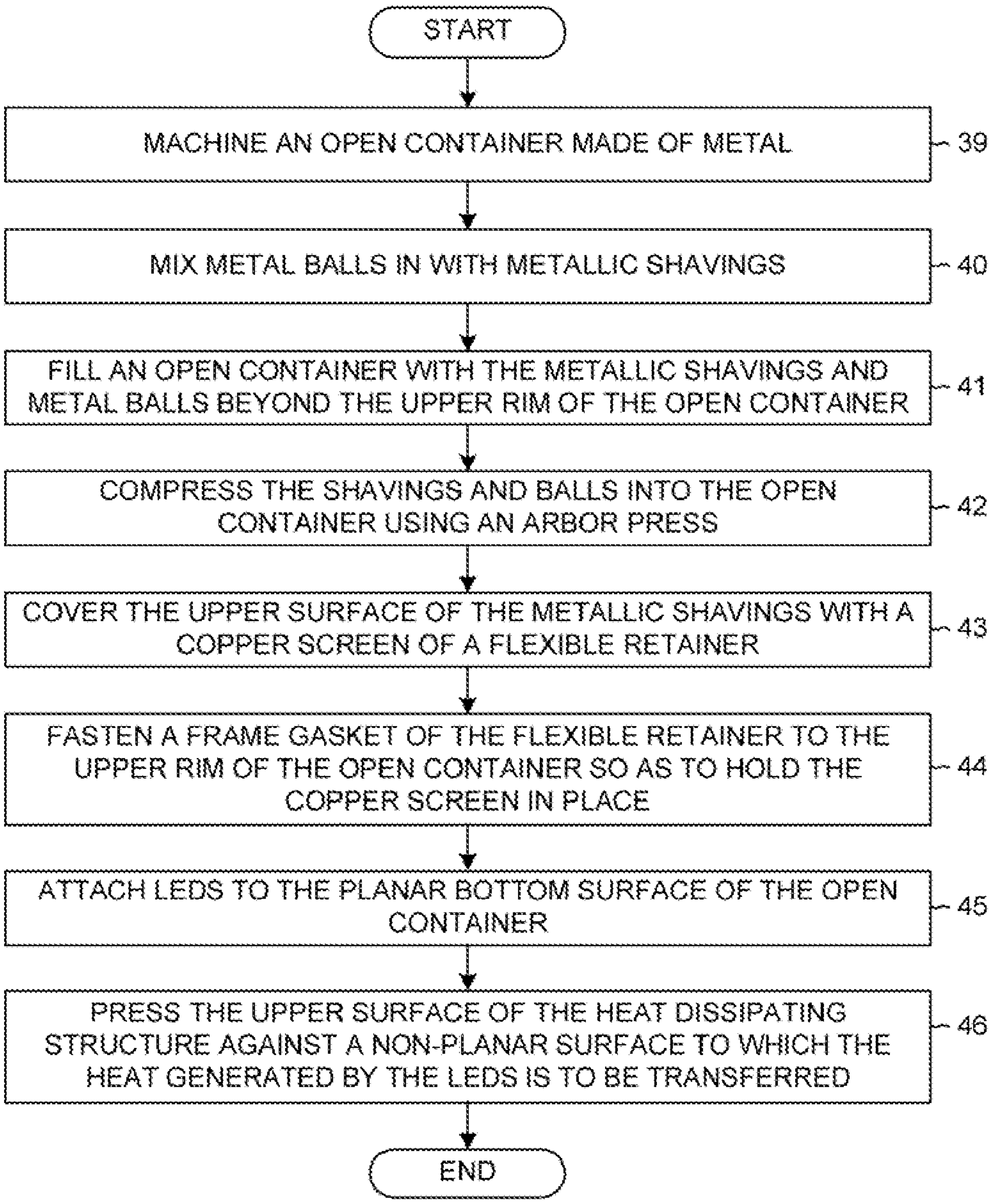

START
MACHINE AN OPEN CONTAINER MADE OF METAL
39
MIX METAL BALLS IN WITH METALLIC SHAVINGS
40
FILL AN OPEN CONTAINER WITH THE METALLIC SHAVINGS AND METAL BALLS BEYOND THE UPPER RIM OF THE OPEN CONTAINER
41
COMPRESS THE SHAVINGS AND BALLS INTO THE OPEN CONTAINER USING AN ARBOR PRESS
42
COVER THE UPPER SURFACE OF THE METALLIC SHAVINGS WITH A COPPER SCREEN OF A FLEXIBLE RETAINER
43
FASTEN A FRAME GASKET OF THE FLEXIBLE RETAINER TO THE UPPER RIM OF THE OPEN CONTAINER SO AS TO HOLD THE COPPER SCREEN IN PLACE
44
ATTACH LEDS TO THE PLANAR BOTTOM SURFACE OF THE OPEN CONTAINER
45
PRESS THE UPPER SURFACE OF THE HEAT DISSIPATING STRUCTURE AGAINST A NON-PLANAR SURFACE TO WHICH THE HEAT GENERATED BY THE LEDS IS TO BE TRANSFERRED
46
END

FIG. 6

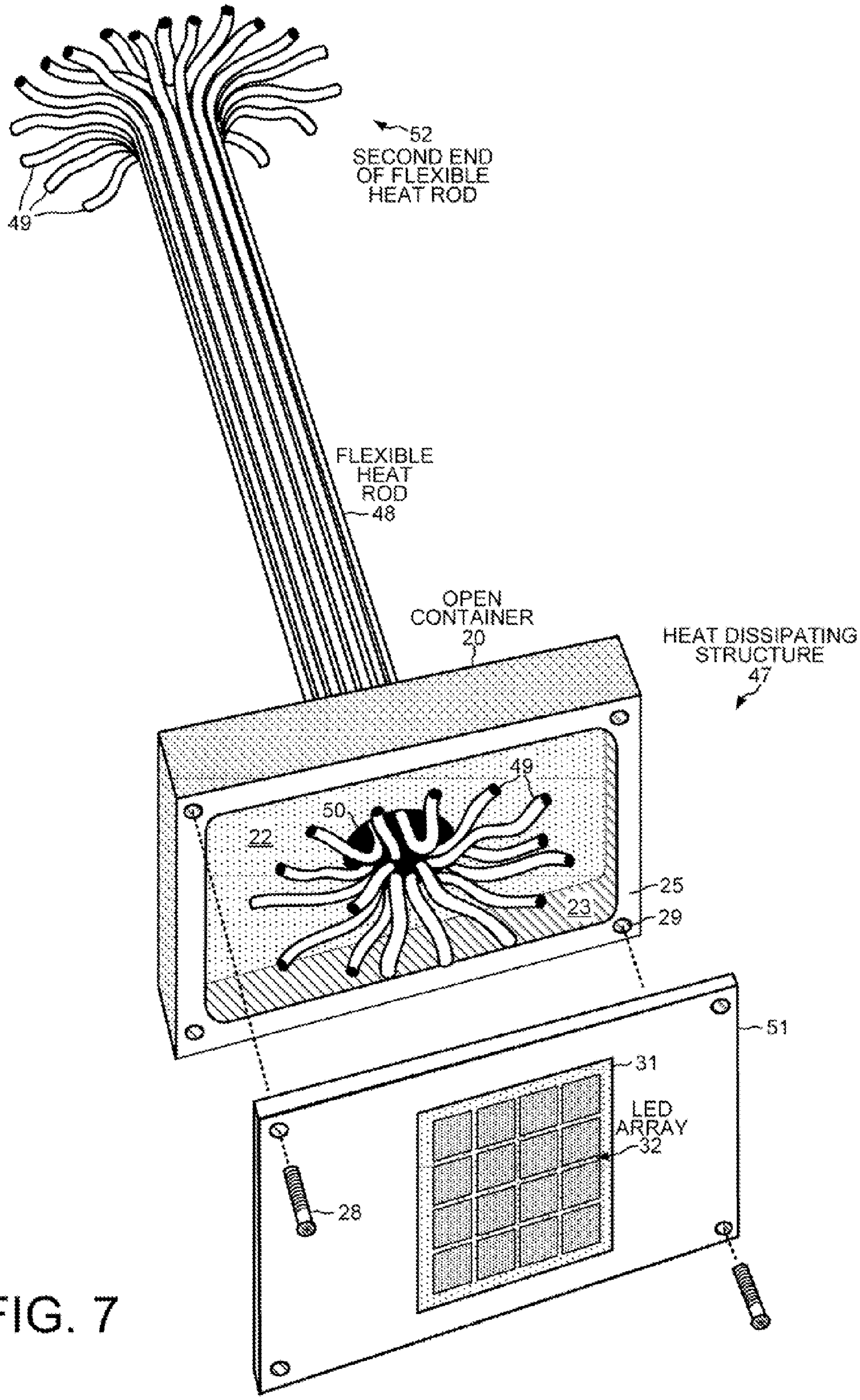

52
SECOND END
OF FLEXIBLE
HEAT ROD
49
FLEXIBLE
HEAT
ROD
48
OPEN
CONTAINER
20
HEAT DISSIPATING
STRUCTURE
47
49
50
22
25
23
29
51
31
LED
ARRAY
32
28

FIG. 7

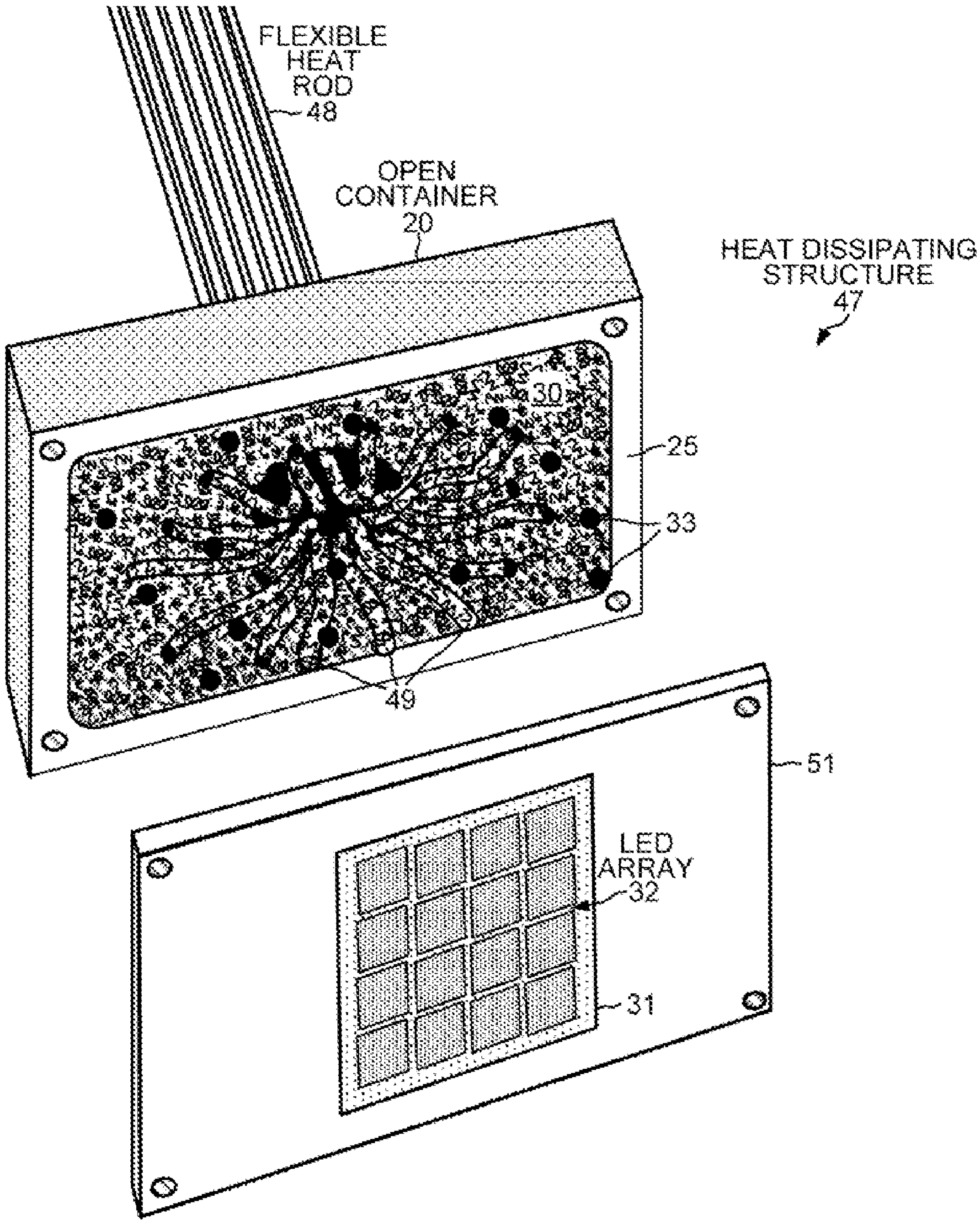

FLEXIBLE
HEAT
ROD
48
OPEN
CONTAINER
20
HEAT DISSIPATING
STRUCTURE
47
30
25
33
49
51
LED
ARRAY
32
31

FIG. 8

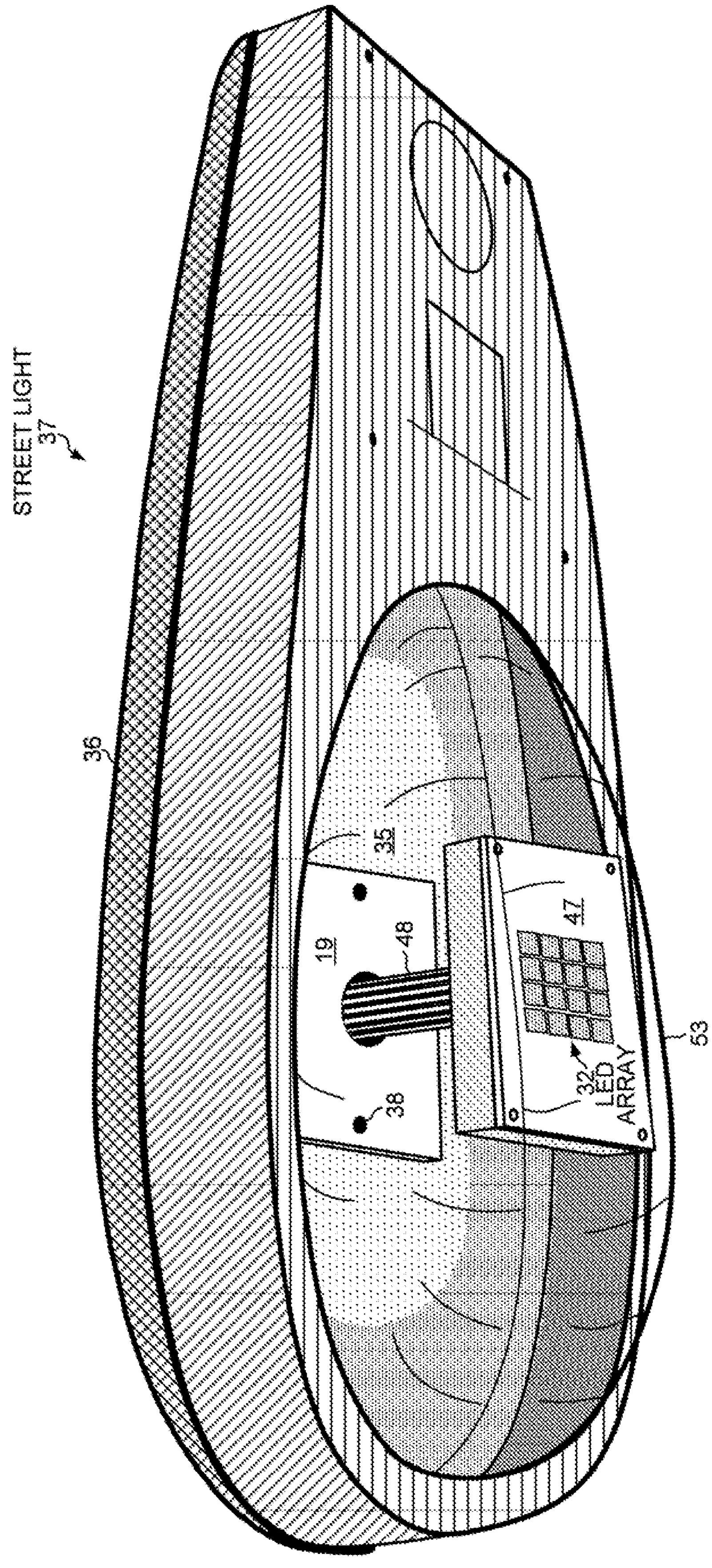


FIG. 9

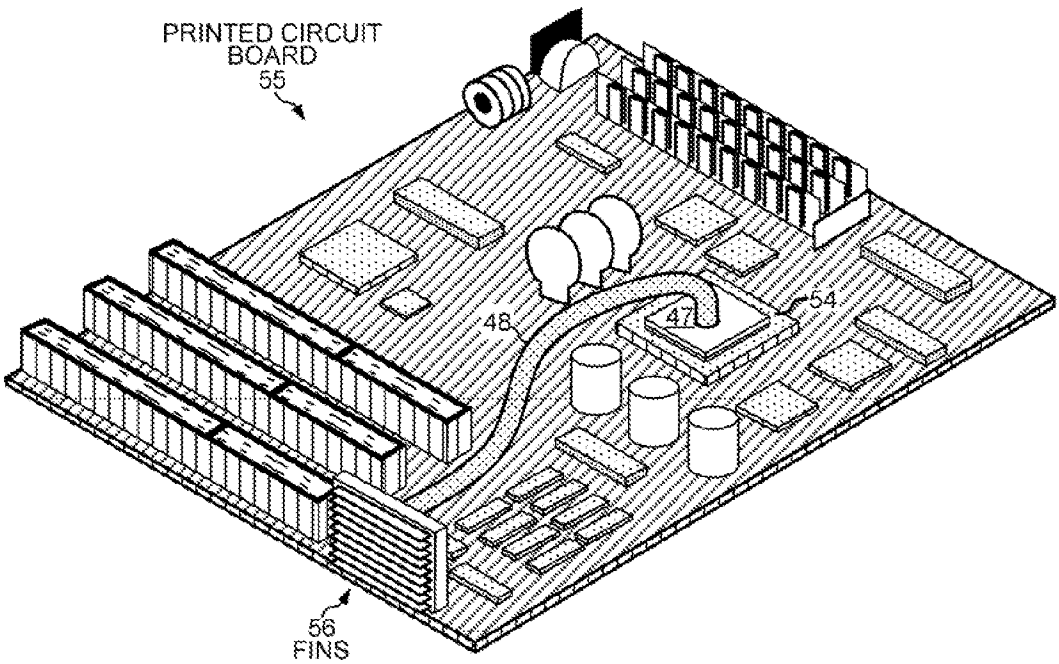


FIG. 10

SHAPE FORMING HEAT SINK WITH FLEXIBLE HEAT ROD

TECHNICAL FIELD

The present invention relates generally to heat sinks and, more specifically, to a heat dissipating structure that conforms to an irregular surface to which heat is to be transferred.

BACKGROUND INFORMATION

Light emitting diodes (LEDs) provide an energy-efficient light source and are increasingly being used instead of fluorescent and halogen gas lamps for high capacity lighting needs, such as street lamps. In order to increase the amount of light generated, LEDs are often incorporated into street lamps, which can lead to significant problems of overheating. The performance and lifetime of the LEDs is degraded if the operating temperature exceeds a threshold level. For example, the useful life of an LED street lamp is sometimes specified as the number hours of operation before which the luminous output of the lamp drops to half of its initial output. Empirical data suggests that there is an inverse exponential relationship between the useful life of an LED lamp and the amount by which the average operating temperature exceeds a threshold level, such as 25 degrees Celsius. Thus, dissipating the heat generated by the LEDs in the street lamp is a problem that must be solved.

The LEDs of a street lamp are enclosed by a covering. The covering typically has openings to allow the heat generated by the LEDs to escape the covering. However, the openings allow dust, moisture and insects to enter the covering and to block much of the light that is generated.

FIG. **1** (prior art) shows an existing LED street lamp **10** that does not permit dust, moisture and insects to obstruct the transparent lower cover **11** through which the generated light shines onto the street. Transparent lower cover **11** is kept free of dust, moisture and insects by completely sealing off the lower compartment below the LEDs. Consequently, most of the heat generated by the LEDs must be dissipated through the upper compartment. The heat is transmitted from the LEDs to a heat conducting plate **12**. The heat then passes on to heat-dissipating fins **13** via a heat guiding piece **14**. Heat is dissipated out of the upper compartment by fans **15** that blow heated air out of venting slots **16** in the upper cover **17**. For additional details on this prior art method of dissipating heat from a street lamp, see U.S. Pat. No. 7,278,761 to Kuan entitled "Heat Dissipating Pole Illumination Device."

This prior art method of dissipating heat from an LED street light has multiple disadvantages. First, although dust, moisture and insects are prevented from entering the lower compartment, they will nevertheless enter the upper compartment through the venting slots **16**. The dust, moisture and insects will likely clog the spaces between the fins **13** and reduce the ability of the fins to dissipate heat. Second, the fans **15** have moving parts and will likely malfunction, especially if they are subjected to the dust, moisture and insects that enter through the venting slots **16**. Moreover, the fans **15** also require a power supply, which might not be able to be shared with the LEDs. Finally, the fins **13** through which the heat guiding piece **14** extends and the fans **15** add to the cost of the street lamp.

A method is sought for dissipating heat from an LED street lamp that does not subject the inner compartments of the street lamp to dust, moisture and insects and that does not require fans or fins.

SUMMARY

A conforming heat dissipating structure transfers heat to a non-planar surface from a heat source mounted to the planar bottom surface of the heat dissipating structure. The heat dissipating structure includes an open container over-filled with metal balls that are interspersed among metallic shavings. The shavings and balls are made of a heat-conductive material, such as copper or aluminum. The upper surface of the shavings and balls is disposed above the upper rim of the open container. A flexible retainer with a copper screen covers the upper surface of the shavings and balls. The shavings and balls are pressed against the non-planar surface and are compressed so as to conform to the shape of the irregular surface. In an embodiment, the heat source is an array of light emitting diodes (LEDs) mounted to the bottom surface of the open container. And the heat sink is a dome-shaped concave surface of the upper cover of a street light. Fasteners attach the open container to the non-planar surface of the street light such that the upper surface of the metallic shavings is pressed against the non-planar surface. The fasteners can be bolts, screws, clamps, rivets or cables. The street light originally configured for gas bulbs can be retrofitted with LEDs by using the non-planar cover of the street light as a heat sink to dissipate the heat generated by the LEDs that are mounted to the bottom of the novel conforming heat dissipating structure.

A method of manufacturing the conforming heat dissipating structure involves the steps of filling an open container with metallic shavings and metal balls, covering the upper surface of the shavings and balls with a flexible retainer, and fastening a frame gasket to the open container in order to hold the flexible retainer in place over the shavings. The metal balls are interspersed among the metallic shavings. The open container is filled with copper shavings and balls beyond the upper rim of the open container to form an upper surface of the shavings. The frame gasket is fastened to the upper rim of the open container so as to hold the flexible retainer in place between the upper rim and the frame gasket. A heat source such as an array of LEDs is attached to the planar bottom surface of the open container. The open container is then attached to a non-planar surface such that the upper surface of the metallic shavings is pressed against the non-planar surface and assumes the irregular shape of the non-planar surface.

A novel conforming heat dissipating structure includes an open container and a heat source attached to the planar bottom surface of the structure. In addition, the heat dissipating structure includes a means for transmitting heat generated by the heat source to a non-planar surface above the upper rim of the open container. The means is disposed inside the open container as well as above the upper rim of the open container, and the means is adapted to be compressed between the open container and the non-planar surface. The means acquires the shape of the non-planar surface when the means is compressed.

A novel flexible heat rod enables heat to be transferred over a flexible path from a heat source to a heat sink. The flexible heat rod is made from a cable with many strands. One end of the flexible heat rod passes through a hole in the bottom of an open container, and the strands are spread out inside the open container. The open container is filled with metallic shavings and metal balls both above and below the strands. The open container, the metallic shavings, the metal balls and the flexible heat rod are made of copper. As the mixture of shavings and balls is compressed, the strands are pressed between the metallic shavings forming a good thermal contact between the flexible heat rod and the shavings. A retaining cover is

fastened to the upper rim of the open container and retains the shavings and balls inside the open container.

In an embodiment, the other end of the flexible heat rod passes through a hole in the bottom of a second open container. Strands from the other end of the flexible heat rod are spread out inside the second open container. The second open container is filled with additional shavings and balls around the strands as well as above the upper rim of the second open container. A flexible retainer covers the upper surface of the additional metallic shavings. The shavings and balls are pressed against a non-planar surface so as to conform to the shape of the surface. Fasteners attach the second open container to the non-planar surface such that the upper surface of the additional metallic shavings is pressed against the non-planar surface.

In one application, the heat source is LEDs mounted to the bottom surface of the first open container. The second open container is pressed against the inside cover of a street light such that the upper surface of the metallic shavings conforms to the shape of the street light cover. The flexible heat rod provides a means for transmitting heat generated by the LEDs on a first heat dissipating structure to the irregular-shaped street light cover that is pressed against the over-filled shavings in a second conforming heat dissipating structure. The flexible heat rod can easily bend to avoid obstacles in the path between the heat source and the heat sink. In another application, the flexible heat rod is used to conduct the heat generated by a field programmable gate array (FPGA) chip out from between cramped computer components to a location where a fan can blow air through fins attached to a second heat dissipating structure. The flexible heat rod can also be used to conduct heat away from other electronic components, such as a complex programmable logic device (CPLD), a central processing unit (CPU) or a stacked memory device.

Further details and embodiments and techniques are described in the detailed description below. This summary does not purport to define the invention. The invention is defined by the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, where like numerals indicate like components, illustrate embodiments of the invention.

FIG. **1** (prior art) is a perspective view of an existing LED street lamp that dissipates heat by blowing hot air out of venting slots.

FIG. **2** is an exploded perspective view of a conforming heat dissipating structure that includes an open container covered by a flexible retainer.

FIG. **3** is an exploded side view of the heat dissipating structure of FIG. **2** filled with metallic shavings and metal balls.

FIG. **4** is a side perspective view of the heat dissipating structure of FIG. **2** in which the metallic shavings are covered by a flexible retainer.

FIG. **5** is a perspective view of the heat dissipating structure of FIG. **2** being fit against the inside upper cover of a street light.

FIG. **6** is a flowchart of steps for manufacturing the conforming heat dissipating structure of FIG. **2**.

FIG. **7** is a perspective view of a heat dissipating structure with a flexible heat rod.

FIG. **8** is a perspective view of the flexible heat rod and heat dissipating structure of FIG. **7** filled with metallic shavings and metal balls.

FIG. **9** is a perspective view of the flexible heat rod of FIG. **7** connecting heat dissipating structures in a street light.

FIG. **10** is a perspective view of a flexible heat rod used on a printed circuit board to transfer heat away from a field programmable gate array chip.

DETAILED DESCRIPTION

Reference will now be made in detail to some embodiments of the invention, examples of which are illustrated in the accompanying drawings.

FIG. **2** is an exploded top perspective view of a conforming heat dissipating structure **19** that includes an open container **20** and a flexible retainer **21**. In an embodiment, open container **20** is a rectangular half box that is about ten inches long, six inches wide and one inch tall. Open container **20** has a bottom **22** and walls **23** that are about one-quarter inches thick. The bottom **22** of open container **20** has a planar bottom surface **24**. The walls form an upper rim **25**. Open container **20** is made of a material with a high thermal conductivity, such as copper, aluminum or a metal alloy such as aluminum 6061. Flexible retainer **21** includes a copper screen or wire mesh **26** that is held in place by a frame gasket **27**. Alternatively, instead of a metal screen, a graphite sheet can be used as the mesh **26**. Frame gasket **27** fits over upper rim **25** and is attached to open container **20** with fasteners **28** that screw into threaded holes **29**. In FIG. **2**, fasteners **28** are bolts. When frame gasket **27** is attached to open container **20**, a portion of wire mesh **26** is held between frame gasket **27** and upper rim **25**.

FIG. **3** is an exploded side perspective view of conforming heat dissipating structure **19** that includes flexible retainer **21**, open container **20** filled with metallic shavings **30** and a platform **31** upon which a heat source is mounted. FIG. **3** shows an array of nine individual light emitting diodes (LEDs) **32** mounted to the bottom surface of platform **31**. In other embodiments, an individual LED or an LED array are mounted to platform **31**. Platform **31** in turn is attached to bottom surface **24** of open container **20**. In an embodiment, platform **31** is made of soft aluminum to which the LEDs **32** are attached via a dielectric layer. In another embodiment, platform **31** is thermally conductive, yet electrically nonconductive. For example, platform **31** can be made of aluminum oxide (Al_2O_3) or aluminum nitride (AlN). Open container **20** is over-filled with the metallic shavings **30** such that the shavings are disposed in the open container as well as above upper rim **25**.

Interspersed among the metal shavings **30** are metal balls **33**. The metal balls add mass and thereby make the heat sink of structure **19** more efficient. The metal shavings **30** hold the metal balls **33** in place and form a malleable compress. In an embodiment, both metal shavings **30** and metal balls **33** are made of copper. The metal shavings **30** can be purchased from recycling companies that obtain the shavings from machine shops. Balls intended for bead blasting can be used as the metal balls **33**. For example, copper balls are used for bead blasting where a blasting medium that is softer than steel is required. Copper balls with a diameter of 3/16 inch can be dispersed among the copper shavings **30**. Balls of other sizes can also be used, for example, balls with a diameter of 1/16 inch (small), 5/64 inch (medium) or 3/32 inch (large). Flexible retainer **21** is then fastened down over upper rim **25** and holds the metal shavings **30** and metal balls **33** in place in open container **20**.

In another embodiment, a graphite powder is mixed in with the shavings **30** and balls **33**. The graphite powder fills in some of the air pockets between the shavings and balls and enhances the ability of the mixture to transfer heat. A graphite powder with good thermal conductivity is used, such as Primary Synthetic Graphite Powder GP55-B manufactured by GrafTech International of Clarksburg, W. Va. The graphite powder fills in more of the air pockets as the mixture of shavings, balls and powder is later compressed. In yet another embodiment, graphite balls are mixed into graphite powder instead of using metal shavings and balls. The graphite powder and ball mixture is then covered with a graphite sheet and compressed into open container **20** in a later step.

FIG. **4** is a side perspective view of conforming heat dissipating structure **19** that includes flexible retainer **21**, open container **20** filled with metallic shavings **30** and platform **31** upon which LEDs **32** are mounted. The shavings **30** and balls **33** have been compressed into open container **20** using an arbor press such that the air pockets between the shavings and balls comprise less than 50% of the volume of the mixture of shavings and balls. Nevertheless, the upper surface of the compress of shavings and balls still protrudes well above upper rim **25** of open container **20**. Flexible retainer **21** is fastened down over upper rim **25** such that the upper surface **34** of the metallic shavings **30** and metal balls **33** is pillow shaped. Four fasteners **28** pass through holes in frame gasket **27** of flexible retainer **21** and screw into holes **29** in the walls **23** of open container **20**. The pillow top of conforming heat dissipating structure **19** acts like a sand bag and molds to any shape that upper surface **34** is pushed against.

Conforming heat dissipating structure **19** can be used as a heat transfer element to retrofit street lights by replacing halogen lights with LEDs. Typically, the retrofitted street lights do not have adequate vents or heat sinks to dissipate the heat produced by the LEDs. If the heat generated by the LEDs is to be transferred to the housing of the street light, there should be a large area of contact between the structure holding the LEDs and the housing in order to convey the heat generated by the LEDs to the outside surface of the street light housing. It is difficult to obtain the exact measurements of the concave surface of the street light housing in order to construct a solid metal heat sink that fits up against the inside of the upper cover of the street light housing. Constructing the solid metal heat sink would typically require a solid model to be made. In addition, a different solid metal heat sink to have to be constructed to match the specific shape of each type of street light. Alternatively, a malleable thermal compound could be molded like putty to an irregular surface. But with time and heat, thermal compounds tend to dry out, turn into powder and lose their thermal conductivity. Conforming heat dissipating structure **19** is the solution to making a tight, long-term contact between a heat dissipating structure and a large area of a non-planar surface that can absorb heat from the dissipating structure. For example, the pillow top of conforming heat dissipating structure **19** molds against any shape of the inside upper cover of a street light housing. Even though the mixture of shavings **30** and balls **33** has already been compressed once into open container **20** by the arbor press, the remaining air pockets between the shavings and balls are compressed further and permit the compress of shavings and balls to conform to the shape of the non-planar surface of the street light housing. Thereafter, the compress of copper shavings and balls maintains its shape when exposed to extreme heat over time.

FIG. **5** shows conforming heat dissipating structure **19** being fit against the dome-shaped concave surface **35** of the upper cover **36** of a street light **37**. Upper surface **34** of the metallic shavings **30** and metal balls **33** is pressed against concave surface **35** of street light **37**. In an embodiment, an arbor press is used to press structure **19** against upper cover **36** and thereby compress the metallic shavings **30** and metal balls **33** and decrease the size of the air pockets between the shavings and balls. The volume occupied by air allows the copper shavings **30** and copper balls **33** to conform to the non-planar surface **35** as the shavings and balls are compressed. As the size of the air pockets decreases, the density of the shavings and balls increases. In an embodiment, a density is achieved in which the air pockets comprise less than 50% of the volume of the compress of shavings and balls. A compress of copper shavings and balls having less than 50% air pockets has a thermal conductivity that is greater than solid aluminum 6061, considering that copper has a thermal conductivity of 390 W/mK and aluminum 6061 has a thermal conductivity of 180 W/mK (Watts per meter-Kelvin). In an embodiment in which a graphite powder is added to the mixture of shavings and balls, air pockets comprise much less than 50% of the volume of the compress. In the embodiment in which graphite balls are mixed into graphite powder, there are practically no large air pockets remaining after the mixture is compressed.

After conforming heat dissipating structure **19** is pressed against upper cover **36**, structure **19** is fastened to upper cover **36** by bolts **38** that pass through structure **19** and screw into holes in upper cover **36**. Either the holes in upper cover **36** are threaded, or nuts on used to secure bolts **38** on the outside of upper cover **36**. Bolts **38** act as fasteners to attach open container **20** to the non-planar surface **35** such that upper surface **34** of the metallic shavings **30** remains pressed against non-planar surface **35**. By maintaining a large area of contact between structure **19** and upper cover **36**, the heat generated by the LEDs **32** is dissipated out of the body of street light **37** without using fins, fans or venting slots. The LEDs **32** are able to achieve a longer service life because the heat they generated is dissipated out of the street light **37** through the upper cover **36**.

In addition to retrofitting street lights, conforming heat dissipating structure **19** can be used to dissipate heat from a heat source to a non-planar cover of other lamps, such as traffic lights, yard lamps, bay lights and spot lights.

FIG. **6** is a flowchart illustrating steps **39**-**45** of a method of manufacturing conforming heat dissipating structure **19**.

In a first step **39**, open container **20** made of metal is machined. For example, open container **20** is machined from a solid rectangular piece of copper. Four threaded holes **29** are drilled into open container **20** to accept the four fasteners **28**, such as bolts.

In step **40**, metal balls **33** are mixed in with metal shavings **30**. Larger metal balls **33** are used for larger dimensioned open containers.

In step **41**, open container **20** is filled with the mixture of metal shavings **30** and metal balls **33**. Optionally, a final layer of just metal shavings is added on top of the mixture. Open container **20** is filled beyond upper rim **25** to form upper surface **34** of a mound of metallic shavings.

In step **42**, the shavings **30** and balls **33** are compressed into open container **20** using an arbor press such that the air pockets between the shavings and balls comprise less than 50% of the volume of the mixture of shavings and balls. Nevertheless, upper surface **34** of the compress of shavings and balls still protrudes well above upper rim **25** of open container **20**.

In step **43**, upper surface **34** of metallic shavings **30** is covered with flexible retainer **21**. Copper screen **26** is pulled down over the mound of metal shavings **30** and metal balls **33** and forms a pillow top.

In step **44**, frame gasket **27** is fastened to upper rim **25** of open container **20** so as to hold copper screen **26** in place between upper rim **25** and frame gasket **27**. Frame gasket **27** is fastened to upper rim **25** by screwing the bolts **28** into the threaded holes **29**. Performing steps **39-43** produces conforming heat dissipating structure **19**.

In step **45**, an array of LEDs **32** is attached to the planar bottom surface **24** of open container **20**. An aluminum platform **31** upon which the LEDs **32** are mounted is attached using thermal glue to bottom surface **24**. Power wires used to provide the LEDs **32** with current are then attached to platform **31**.

In step **46**, heat dissipating structure **19** and the mounted LEDs **32** are attached to a non-planar surface to which the heat generated by the LEDs is to be transferred. For example, open container **20** is pressed against the inside dome-shaped concave surface **35** of the upper cover **36** of street light **37** (as shown in FIG. **5**). An arbor press is used to press open container **20** against surface **35** so that the size of the air pockets between the shavings **30** and the balls **33** is reduced. In an embodiment, the mixture of shavings **30** and balls **33** is compressed between open container **20** and surface **35** until the air pockets between the shavings and balls occupy less than 50% of the volume of the space between open container **20** and surface **35**. As the mixture is compressed, the metal shavings **30** at upper surface **34** mold to the contour of concave surface **35**. When street light **37** is operating, heat generated by the LEDs **32** flows through bottom **22** of open container **20**, through shavings **30** and balls **33**, through copper screen **26** and to upper cover **36** of street light **37**. The heat then escapes into the atmosphere from the outer, upper surface of upper cover **36**.

FIG. **7** is a perspective view of a heat dissipating structure **47** that is adapted to transfer heat over a flexible path from a heat source to a heat sink. The heat source is often located some distance away from where the heat is to be dissipated. For example, structural beams or walls may be located between the dome-shaped surface **35** of upper cover **36** of street light **37** and the most desirable location to place the LEDs **32**. Or it may be necessary to locate the ac/dc driver block for the LEDs **32** between the LEDs and upper cover **36**. A means is needed to direct the flow of heat around obstacles from a heat source, such as LEDs **32**, to a heat sink, such as surface **35**. A flexible heat rod **48** is used to transfer heat from heat dissipating structure **47** to heat dissipating structure **19**. Heat dissipating structure **19** is located at the opposite end of flexible heat rod **48** from structure **47**, but is not shown in FIG. **7**.

Flexible heat rod **48** is a thick copper wire made of many strands **49**. Flexible heat rod **48** can be made using a high-power transmission cable or the wire used to ground the lightning rod on a building. In the embodiment of FIG. **7**, flexible heat rod **48** has a diameter of about one inch. One end of flexible heat rod **48** passes through a hole **50** in bottom **22** of heat dissipating structure **47**. Hole **50** is formed to have the same diameter as the diameter of flexible heat rod **48**. The other end of flexible heat rod **48** passes through another hole in the bottom of the open container of heat dissipating structure **19**. FIG. **7** shows that the ends of the strands **49** are spread apart in a circular pattern inside open container **20**. The strands **49** are dispersed throughout the volume of open container **20**. Then the volume of open container **20** is filled around the strands **49** with a mixture of metallic shavings **30** and metal balls **33**.

FIG. **8** shows that metallic shavings **30** and metal balls **33** are disposed both beneath and over the strands **49**. Heat dissipating structure **47** includes a planar retaining cover **51** upon which platform **31** and an array of LEDs **32** are mounted. Platform **31** is attached to retaining cover **51** using thermal glue. Retaining cover **51** is fastened to upper rim **25** of open container **20** and retains metallic shavings **30** and metal balls **33** inside open container **20**. Open container **20** is first over-filled with the mixture of shavings and balls, and then the mixture is compressed between retaining cover **51** and bottom **22** such that the air pockets between the shavings and balls occupy less than 50% of the volume of the space between retaining cover **51** and bottom **22**. In the compressed state, the metallic shavings **30** make contact with flexible heat rod **48** all along the sides of the individual strands **49** that are spread out inside open container **20**. A much larger contact surface between the shavings and the sides of the multiple strands **49** allows a larger heat transfer than would be achievable by routing a solid rod of the same diameter as flexible heat rod **48** through the shavings. Retaining cover **51** is fastened to open container **20** by threaded bolts **28** that screw into holes **29** in open container **20**, as shown in FIG. **7**.

The second end **52** of flexible heat rod **48** passes through a hole in the bottom **22** of an open container **20** of a heat dissipating structure of the type shown in FIG. **2**. The ends of the strands **49** are spread apart in a circular pattern inside the open container **20** of structure **19**. Inside structure **19**, metallic shavings **30** and metal balls **33** are also filled in around the strands **49** such that metallic shavings **30** make contact all along the sides of the individual strands **49** when the shavings and balls are compressed. Open container **20** of structure **19** is also over-filled with the mixture of shavings beyond upper rim **25** of the open container **20** of structure **19**. Flexible retainer **21** covers the upper surface **34** of the shavings and balls.

FIG. **9** is a perspective view of the heat dissipating structures **19** and **47** being mounted in street light **37**. As with the structure **19** of FIG. **5** that does not include flexible heat rod **48**, the heat dissipating structure **19** of FIG. **9** that is attached to flexible heat rod **48** is also pressed against a non-planar surface to which heat is to be transferred. The shavings and balls that are held in place in structure **19** by copper screen **26** are pressed against concave surface **35** of street light **37** and assume the contour of surface **35**. Bolts **38** act as fasteners to attach the open container **20** of structure **19** to non-planar surface **35**. Flexible heat rod **48** allows an LED, an LED array, or an array of individual LEDs **32** to be positioned lower in street light **37** and closer to the glass lens **53**. Flexible heat rod **48** could easily be bent to go around obstructions inside street light **37** between structures **47** and **19**.

Flexible heat rod **48** is used in other applications besides retrofitting street light **37**. For example, flexible heat rod **48** is used to lower the location of the LEDs in a bay light such that light is generated at the optimal position in the parabolic curve of the bay light. Yet the heat generated by the LEDs can be transmitted to the covering of the bay light, where it is dissipated into the atmosphere.

FIG. **10** shows flexible heat rod **48** used in an application in which the heat source is not related to lighting. In an electronics application, flexible heat rod **48** is attached to a micro heat dissipating structure **47** that covers the top of a computer processing element, such as a large field-programmable gate array (FPGA) **54** mounted on a printed circuit board **55**. Flexible heat rod **48** conducts the heat generated by FPGA **54** out from between cramped computer components to a location at which a fan can blow air through fins **56** attached to a heat dissipating structure at the opposite end of flexible heat rod **48**. Flexible heat rod **48** can also be used to conduct heat away from other electronic components, such as a complex programmable logic device (CPLD), a central processing unit (CPU) or a stacked memory device.

Although certain specific embodiments are described above for instructional purposes, the teachings of this patent document have general applicability and are not limited to the specific embodiments described above. Although open container **20** of the heat dissipating structures is described above as having a rectangular box shape, open container **20** can have other shapes, such as an open oval box shape or a circular open box shape. Moreover, bottom **22** of open container **20** is described above as having one hole **50** through which one flexible heat rod **48** passes. In order to transfer more heat from each heat dissipating structure **47**, multiple heat rods can be attached to the structure **47** through multiple holes. Accordingly, various modifications, adaptations, and combinations of various features of the described embodiments can be practiced without departing from the scope of the invention as set forth in the claims.

What is claimed is:

1. An apparatus, comprising:

an open container with an upper rim and a planar bottom surface;

metallic shavings disposed in the open container as well as above the upper rim, wherein the metallic shavings disposed above the upper rim have an upper surface;

a flexible retainer covering the upper surface of the metallic shavings; and

fasteners adapted to attach the open container to a non-planar surface such that the upper surface of the metallic shavings is pressed against the non-planar surface.

2. The apparatus of claim **1**, further comprising:

metal balls, wherein the metal balls are interspersed among the metallic shavings.

3. The apparatus of claim **1**, wherein the open container and the metallic shavings are made of copper.

4. The apparatus of claim **1**, further comprising:

a frame gasket, wherein a portion of the flexible retainer is held between the frame gasket and the upper rim.

5. The apparatus of claim **1**, wherein the non-planar surface is an inside surface of a street lamp.

6. The apparatus of claim **1**, wherein a heat source is attached to the planar bottom surface of the open container.

7. The apparatus of claim **6**, wherein the heat source is a light-emitting diode.

8. The apparatus of claim **1**, wherein the open container is machined from a solid piece of copper.

9. A method of manufacturing, comprising:

filling an open container with metallic shavings, wherein the open container has an upper rim and a planar bottom surface, and wherein the open container is filled with the metallic shavings beyond the upper rim to form an upper surface of metallic shavings;

covering the upper surface of metallic shavings with a flexible retainer; and

fastening a frame gasket to the upper rim of the open container so as to hold the flexible retainer in place between the upper rim and the frame gasket.

10. The method of claim **9**, wherein the filling the open container includes filling the open container with metal balls that are interspersed among the metallic shavings.

11. The method of claim **9**, further comprising:

attaching the open container to a non-planar surface such that the upper surface of the metallic shavings is pressed against the non-planar surface.

12. The method of claim **9**, wherein the open container includes fasteners adapted to attach the open container to a non-planar surface such that the upper surface of the metallic shavings is pressed against the non-planar surface.

13. The method of claim **12**, wherein the non-planar surface is an inside surface of a street lamp.

14. The method of claim **9**, wherein the open container and the metallic shavings are made of copper.

15. The method of claim **9**, further comprising:

attaching a heat source to the planar bottom surface of the open container.

16. The method of claim **15**, wherein the heat source is a light-emitting diode.

17. An apparatus comprising:

an open container with an upper rim and a planar bottom surface;

a heat source attached to the planar bottom surface; and

means for transmitting heat generated by the heat source to a non-planar surface above the upper rim, wherein the means is disposed in the open container as well as above the upper rim, and wherein the means is adapted to be compressed between the open container and the non-planar surface.

18. The apparatus of claim **17**, further comprising:

fasteners adapted to attach the open container to the non-planar surface such that the means is pressed against the non-planar surface.

19. The apparatus of claim **17**, wherein the means includes metallic shavings.

20. The apparatus of claim **17**, further comprising:

a flexible retainer that covers the means.

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