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(54) IN-LINE REFLECTIVE LEAD-PAIR FOR LIGHT-EMITTING DIODES

(71) We, HEWLETT-PACKARD COMPANY, of 1501 Page Mill Road, Palo Alto, California 94303, United States of America, a corporation organised and existing under the laws of the State of California, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to an in-line lead pair for light emitting diodes having improved luminous efficiency.

Some light-emitting semiconductor materials used in the fabrication of light-emitting diode (LED) chips radiate light in all directions from the junction thereof. Such materials include gallium phosphide. Reflectors are used to improve the light emission characteristics of LED devices by capturing and reflecting the side-emitted light. Prior art devices, such as that disclosed in United States Patent No. 3,764,862 issued to Alfred S. Jankowski on October 9, 1973, have a recessed, reflective cavity formed in one lead of the two-lead device and in which the semiconductor chip is mounted.

In addition to reflector size constraints owing to lead thickness and cost considerations, the prior art reflective-cavity mountings for LED chips required many and time-consuming assembly steps including careful alignment of the chip to assure parallel emission of light along the lens axis. Furthermore, a very large, costly cavity would be required to house the additional semiconductor chips which are included in more sophisticated LED assemblies.

The present invention provides an in-line lead pair for light-emitting diodes having improved luminous efficiency said lead pair comprising first and second leads with a common longitudinal axis each having thickness and width dimensions, said first and second leads further having lateral extensions projecting therefrom, and said first lead being spaced apart from said second lead by a preselected distance; and said first lead having a mounting area in a plane determined by the width dimensions and the longitudinal axis of the lead pair for mounting at least one light-emitting diode chip thereon; said mounting area having a reflector formed by bending the lateral extensions of said first and second leads along a line essentially parallel to the longitudinal axis thereof and towards said mounting area to reflect non-axially emitted light from said diode chip along an axis orthogonal to said mounting area.

An embodiment of the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a top view of a lead frame according to the preferred embodiment of the present invention showing side-extensions of each pair prior to bending,

Figure 2a is a side view of a lead pair with bent side extensions and mounted diode chips,

Figure 2b is a top view of the lead pair of Figure 2a,

Figure 3 is an end view of the lead pair of Figure 2 after encapsulation, and

Figure 4 is a diagram for explaining the term "aspect ratio".

Figure 1 shows lead frame 10 having a plurality of substantially identical, flat LED lead pairs including lead pair 12. Lead frame 10 is constructed of an electrically conductive material such as steel or alloys of iron and nickel or iron and copper. To enhance adhesion between the diode chip and the leads, flatness of the planar surface of the lead pair is held to approximately .002". Lateral extensions 13 of the width dimension of lead pair 12 comprise the reflective sides of a reflector surrounding the mounting location of the light-emitting chip. To form the reflector, the longitudinal projections 14 on each of the ends of extensions 13 are bent along bend lines 16 to an angle of approximately 45° relative to planar mounting surface 15 of in-line lead pair 12. Extensions 13 are then bent along bend lines 18 to an angle of approximately 45° relative

to mounting surface 15 of in-line lead pair 12 to form reflector 20 as shown in Figure 2a and 2b. The angle of 45° is selected to reflect non-axially emitted light along an optical axis orthogonal to mounting surface 15.

Very small LED devices are often desired to reduce the distance between centers of adjacent devices in an array. For subminiature devices (of about .100 inch diameter), comparatively thin lead frame material must be used to provide the proper aspect ratio for manufacturing purposes. Referring to Figure 4, the aspect ratio is defined as t_s/t, where t_s is the width of the narrowest amount of material to be removed (for example separation 19 between anode and cathode leads), and t is the thickness of the material. The aspect ratio should be not less than one in order to reliably maintain manufacturing tolerances. Therefore, for devices each approximately .100 inches in diameter having a lead separation of .005 inches, the lead frame material should be approximately .005 inches thick. A lead separation of greater than .005 inches may allow some light to escape therethrough.

The lead pair, including at least extensions 13 and the portions of in-line lead pair 12 contained within reflector 20 when formed, is coated with a reflective, electrically-conductive material such as gold or silver. The coating should be relatively thin, but sufficient to assure uniformity thereof.

Figure 2a is a side view of cup 20 showing the location of diode chip 22 on one lead of in-line lead pair 12. Figure 2b is a top view of cup 20 of Figure 2a. After mounting the chip by conventional bonding techniques such as eutectic or conductive epoxy die attached techniques, a wire which may be gold or aluminum is attached between chip 22 and the other lead of lead pair 12 to form the electrical circuit of the LED. Where other semiconductor chips are included more than one wire interconnection may be required.

Since the reflector is formed from extensions of mounting surface 15 on both sides of separation 19 of lead pair 12, additional semiconductor devices including integrated circuit chips can be mounted on one lead with the LED chip or on the other lead of lead pair 12. Separation 19 of lead pair 12 could also evenly divide reflector 20 and mounting surface 15. This configuration, having a flat chip-mounting surface within a deep reflecting cup, also facilitates the manufacturing process by providing easy access for chip and wire bonding tools. In addition, the bent side portions block side emitted light that would partially illuminate adjacent LED's which would not otherwise be illuminated within an array of LED's.

When encapsulated as shown in Figure 3, reflector 20 is centered under dome lens 31, the major diameter of which is approximately equal to the major dimensions of the reflector 20. In this way, nearly all reflected light collected and radiated by reflector 20 is directed through lens 31 coaxially therewith and orthogonally to mounting surface 15. A transparent material such as a two part epoxy resin or thermo-setting plastic to which dyes and light diffusers such as fine glass fragments or spheres can be added is used to encapsulate the devices. Various colored dyes are used to filter the spectrum of light emitted from the diode chip and to enhance on-off contrast of adjacent devices. Since light emitted coaxially with the optical axis of lens 31 is more intense than off-axis emissions, a light diffuser can be used to scatter such light to provide a more uniform emission of light from the device.

WHAT WE CLAIM IS:—

1. An in-line lead pair for light-emitting diodes having improved luminous efficiency, said lead pair comprising first and second leads with a common longitudinal axis each having thickness and width dimensions, said first and second leads further having lateral extensions projecting therefrom, and said first lead being spaced apart from said second lead by a preselected distance; and said first lead having a mounting area in a plane determined by the width dimension and the longitudinal axis of the lead pair for mounting at least one light-emitting diode chip thereon; said mounting area having a reflector formed by bending the lateral extensions of said first and second leads along a line essentially parallel to the longitudinal axis thereof and towards said mounting area to reflect non-axially emitted light from said diode chip along an axis orthogonal to said mounting area.

2. An in-line lead pair as in claim 1 wherein said lateral extensions are bent to an angle of approximately 45° relative to the plane defined by the mounting area, and said lateral extensions each have longitudinal projections which are bent to an angle of approximately 45° relative to the planes defined by the respective lateral extensions.

3. An in-line lead pair as in claim 1 wherein the first and second leads further have a reflective coating.

4. An in-line lead pair as in claim 1 wherein the preselected distance is approximately equal to the thickness dimension.

5. An in-line lead pair as in claim 1 wherein the first lead forms a greater portion of the reflector than the second lead.

6. An in-line lead pair as in claim 1 further including moulded encapsulation wherein said encapsulation is formed into a lens with a periphery having a major dimension which is approximately equal to the

to mounting surface 15 of in-line lead pair 12 to form reflector 20 as shown in Figure 2a and 2b. The angle of 45° is selected to reflect non-axially emitted light along an optical axis orthogonal to mounting surface 15.

Very small LED devices are often desired to reduce the distance between centers of adjacent devices in an array. For subminiature devices (of about .100 inch diameter), comparatively thin lead frame material must be used to provide the proper aspect ratio for manufacturing purposes. Referring to Figure 4, the aspect ratio is defined as t_s/t, where t_s is the width of the narrowest amount of material to be removed (for example separation 19 between anode and cathode leads), and t is the thickness of the material. The aspect ratio should be not less than one in order to reliably maintain manufacturing tolerances. Therefore, for devices each approximately .100 inches in diameter having a lead separation of .005 inches, the lead frame material should be approximately .005 inches thick. A lead separation of greater than .005 inches may allow some light to escape therethrough.

The lead pair, including at least extensions 13 and the portions of in-line lead pair 12 contained within reflector 20 when formed, is coated with a reflective, electrically-conductive material such as gold or silver. The coating should be relatively thin, but sufficient to assure uniformity thereof.

Figure 2a is a side view of cup 20 showing the location of diode chip 22 on one lead of in-line lead pair 12. Figure 2b is a top view of cup 20 of Figure 2a. After mounting the chip by conventional bonding techniques such as eutectic or conductive epoxy die attached techniques, a wire which may be gold or aluminum is attached between chip 22 and the other lead of lead pair 12 to form the electrical circuit of the LED. Where other semiconductor chips are included more than one wire interconnection may be required.

Since the reflector is formed from extensions of mounting surface 15 on both sides of separation 19 of lead pair 12, additional semiconductor devices including integrated circuit chips can be mounted on one lead with the LED chip or on the other lead of lead pair 12. Separation 19 of lead pair 12 could also evenly divide reflector 20 and mounting surface 15. This configuration, having a flat chip-mounting surface within a deep reflecting cup, also facilitates the manufacturing process by providing easy access for chip and wire bonding tools. In addition, the bent side portions block side emitted light that would partially illuminate adjacent LED's which would not otherwise be illuminated within an array of LED's.

When encapsulated as shown in Figure 3, reflector 20 is centered under dome lens 31, the major diameter of which is approximately equal to the major dimensions of the reflector 20. In this way, nearly all reflected light collected and radiated by reflector 20 is directed through lens 31 coaxially therewith and orthogonally to mounting surface 15. A transparent material such as a two part epoxy resin or thermo-setting plastic to which dyes and light diffusers such as fine glass fragments or spheres can be added is used to encapsulate the devices. Various colored dyes are used to filter the spectrum of light emitted from the diode chip and to enhance on-off contrast of adjacent devices. Since light emitted coaxially with the optical axis of lens 31 is more intense than off-axis emissions, a light diffuser can be used to scatter such light to provide a more uniform emission of light from the device.

WHAT WE CLAIM IS:—

1. An in-line lead pair for light-emitting diodes having improved luminous efficiency, said lead pair comprising first and second leads with a common longitudinal axis each having thickness and width dimensions, said first and second leads further having lateral extensions projecting therefrom, and said first lead being spaced apart from said second lead by a preselected distance; and said first lead having a mounting area in a plane determined by the width dimension and the longitudinal axis of the lead pair for mounting at least one light-emitting diode chip thereon; said mounting area having a reflector formed by bending the lateral extensions of said first and second leads along a line essentially parallel to the longitudinal axis thereof and towards said mounting area to reflect non-axially emitted light from said diode chip along an axis orthogonal to said mounting area.

2. An in-line lead pair as in claim 1 wherein said lateral extensions are bent to an angle of approximately 45° relative to the plane defined by the mounting area, and said lateral extensions each have longitudinal projections which are bent to an angle of approximately 45° relative to the planes defined by the respective lateral extensions.

3. An in-line lead pair as in claim 1 wherein the first and second leads further have a reflective coating.

4. An in-line lead pair as in claim 1 wherein the preselected distance is approximately equal to the thickness dimension.

5. An in-line lead pair as in claim 1 wherein the first lead forms a greater portion of the reflector than the second lead.

6. An in-line lead pair as in claim 1 further including moulded encapsulation wherein said encapsulation is formed into a lens with a periphery having a major dimension which is approximately equal to the

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major dimension of the reflector to direct the emitted light orthogonal to the plane defined by the mounting area.

7. An in-line lead pair as in claim 6 wherein the encapsulation includes light diffusers.

8. An in-line lead pair for light emitting diodes substantially as herein described with reference to the accompanying drawings.

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