LED-BASED FIXTURES AND RELATED METHODS FOR THERMAL MANAGEMENT

Background

[0001] Advent of digital lighting technologies, i.e. illumination based on semiconductor light sources, such as light-emitting diodes (LEDs), offers a viable alternative to traditional fluorescent, HID, and incandescent lamps. Functional advantages and benefits of LEDs include high energy conversion and optical efficiency, robustness, lower operating costs, and many others. For example, LEDs are particularly suitable for applications requiring small or low-profile light fixtures. The LEDs' smaller size, long operating life, low energy consumption, and durability make them a great choice when space is at a premium.

[0002] A "downlight" is a light fixture that is installed into a hollow opening in a ceiling and often referred to as a "recessed light" or "can light." When installed, it appears to concentrate light in a downward direction from the ceiling as a broad floodlight or narrow spotlight. Generally, there are two parts to recessed lights, the trim and housing. The trim is the visible portion of the light and includes the decorative lining around the edge of the light. The housing is the fixture itself that is installed inside the ceiling and contains the light socket.

[0003] An alternative to recessed lights is a surface-mount or suspended downlight, combining the general functionality of a downlight with flexibility and ease of installation over conventional junction boxes, particularly where disposal of the recessed light housing in the ceiling is impractical. In this regard, architects, engineers and lighting designers are often under considerable pressure to use low-profile, shallow-depth fixtures. Fundamentally, in connection with multiple-floor buildings, floor-to-floor heights are limited by developers looking to maximize their floor-to-area ratio; yet designers often want to maximize the volume of the space by including the tallest ceilings possible. This contradiction sets up a conflict between various utilities, including lighting, that are competing for the limited recess depth found between the finished ceiling and the structural slab above.

[0004] Designers have also shunned most surface-mounted general-illumination solutions; the size of the primary light sources, along with required optics and glare shielding techniques, quickly makes the fixtures too large to be aesthetically acceptable by most designers. Also, the compromises made to achieve low profile mounting heights in fixtures with traditional light sources typically negatively impacts overall fixture efficacy. In fact, total fixture efficacy for many surface mounted compact fluorescent units averages only 30 lumens/Watt.

Summary

[0005] In view of the foregoing, Applicants have recognized and appreciated that it is desirable to provide a downlight fixture employing LED-based light sources that addresses a number of disadvantages of conventional downlight fixtures, particularly those associated with thermal management, light output, and ease of installation. Accordingly, one object of the technology disclosed herein is to provide a shallow surface-mount fixture – as shallow as 1"-2" overall height – to alleviate the undesirable constraints of shallow recess depths for many designers; in fact, it could help many projects reclaim up to 6" of ceiling height. Additionally, it would offer an elegant solution to projects with no recess cavity at all (mounting directly to concrete slabs). Another object is to achieve an overall fixture efficacy of about 30 lumens/Watt or better in order to set various implementations of this technology on an equal plane with fluorescent sources, yet at output levels normally associated with incandescent fixtures, thus setting this fixture up well for environments with low ambient light levels.

[0006] Additionally, Applicants have recognized and appreciated that maintaining a proper LED junction temperature is an important component to developing an efficient LED-based lighting system, as the LEDs perform with a higher efficacy when run at cooler temperatures. The use of active cooling via fans and other mechanical air moving systems, however, is typically discouraged in the general lighting industry primarily due to its inherent noise, cost and high maintenance needs. Thus, it is desirable to achieve air flow rates comparable to that of an actively cooled system without the noise, cost or moving parts.

[0007] Accordingly, the technology disclosed herein generally relates to lighting fixtures employing LED-based light sources that are suitable for general illumination in surface-mount or suspended installations, as well as other fixture types. More specifically, this technology is directed to improving heat dissipation properties of such fixtures by generally decreasing a thermal resistance between one or more LEDs associated with the fixture (particularly the LED junctions). In contrast to conventional naturally-cooled heat sink designs relying solely on considerations of form factor, surface area, and mass to dissipate a generated thermal load, in its various inventive aspects and particular implementations, the technology disclosed herein additionally contemplates creating and maintaining a "chimney effect" within the fixture, employed alone or in combination with other factors relating to decreased thermal resistance, such as increased surface area of heat dissipating elements (e.g., one or more heat sinks) and improved thermal coupling between the LED(s) of the fixture and one or more heat dissipating elements. The resulting high flow rate, natural convection cooling system is capable of efficiently dissipating the waste heat from an LED lighting module without active cooling.

[0008] The technique for enhancing the air flow through a heat sink disclosed herein can be used with different kinds of LED-based lighting fixtures. In some exemplary embodiments, the air flow enhancement techniques disclosed herein can be implemented with particular efficiency for fixtures configured to project light unidirectionally, in particular, downward (i.e. in a substantially vertical orientation). Such fixtures include downlights, pendants, track lights, and sconces.

[0009] In one implementation, a low-profile downlight fixture for unicolor, for example, white illumination, is disclosed, capitalizing on the low profile of LED lighting modules to create a surface-mounted fixture thinner than any other fixture utilizing conventional light sources. The fixture also capitalizes upon the directionality and optic capabilities of LEDs to create a total fixture efficacy that matches or surpasses even fluorescent sources. A unique thermal venting design maintains appropriate thermal dissipation while creating a "clean" minimalist, contemporary appearance.

[0010] In another implementation, this disclosure features a hanging spot pendant, particularly suitable for the general ambient illumination of a small, intimate environment, such as a dining, kitchen island, or conference room setting. It could also be used for task lighting, low ambient mood lighting, accent lighting and other purposes.

[0011] In still another implementation, this disclosure features a track head fixture suitable for general illumination and accent lighting of objects and architectural features and configured for installation with a conventional open architecture track.

Relevant Terminology

[0012] As used herein for purposes of the present disclosure, the term "LED" should be understood to include any electroluminescent diode or other type of carrier injection/junction-based system that is capable of generating radiation in response to an electric signal. Thus, the term LED includes, but is not limited to, various semiconductor-based structures that emit light in response to current, light emitting polymers, organic light emitting diodes (OLEDs), electroluminescent strips, and the like.

[0013] In particular, the term LED refers to light emitting diodes of all types (including semi-conductor and organic light emitting diodes) that may be configured to generate radiation in one or more of the infrared spectrum, ultraviolet spectrum, and various portions of the visible spectrum (generally including radiation wavelengths from approximately 400 nanometers to approximately 700 nanometers). Some examples of LEDs include, but are not limited to, various types of infrared LEDs, ultraviolet LEDs, red LEDs, blue LEDs, green LEDs, yellow LEDs, amber LEDs, orange LEDs, and white LEDs (discussed further below). It also should be appreciated that LEDs may be configured and/or controlled to generate radiation having various bandwidths (e.g., full widths at half maximum, or FWHM) for a given spectrum (e.g., narrow bandwidth, broad bandwidth), and a variety of dominant wavelengths within a given general color categorization.

[0014] For example, one implementation of an LED configured to generate essentially white light (e.g., a white LED) may include a number of dies which respectively emit different spectra of electroluminescence that, in combination, mix to form essentially white light. In another implementation, a white light LED may be associated with a phosphor material that converts electroluminescence having a first spectrum to a different second spectrum. In one example of this implementation, electroluminescence having a relatively short wavelength and narrow bandwidth spectrum "pumps" the phosphor material, which in turn radiates longer wavelength radiation having a somewhat broader spectrum.

[0015] It should also be understood that the term LED does not limit the physical and/or electrical package type of an LED. For example, as discussed above, an LED may refer to a single light emitting device having multiple dies that are configured to respectively emit different spectra of radiation (e.g., that may or may not be individually controllable). Also, an LED may be associated with a phosphor that is considered as an integral part of the LED (e.g., some types of white LEDs). In general, the term LED may refer to packaged LEDs, non-packaged LEDs, surface mount LEDs, chip-on-board LEDs, T-package mount LEDs, radial package LEDs, power package LEDs, LEDs including some type of encasement and/or optical element (e.g., a diffusing lens), etc.

[0016] The term "light source" should be understood to refer to any one or more of a variety of radiation sources, including, but not limited to, LED-based sources (including one or more LEDs as defined above), incandescent sources (e.g., filament lamps, halogen lamps), fluorescent sources, phosphorescent sources, high-intensity discharge sources (e.g., sodium vapor, mercury vapor, and metal halide lamps), lasers, other types of electroluminescent sources, pyro-luminescent sources (e.g., flames), candle-luminescent sources (e.g., gas mantles, carbon arc radiation sources), photo-luminescent sources (e.g., gaseous discharge sources), cathode luminescent sources using electronic satiation, galvano-luminescent sources, crystallo-luminescent sources, kine-luminescent sources, thermo-luminescent sources, triboluminescent sources, sonoluminescent sources, radioluminescent sources, and luminescent polymers.

[0017] A given light source may be configured to generate electromagnetic radiation within the visible spectrum, outside the visible spectrum, or a combination of both. Hence, the terms "light" and "radiation" are used interchangeably herein. Additionally, a light source may include as an integral component one or more filters (e.g., color filters), lenses, or other optical components. Also, it should be understood that light sources may be configured for a variety of applications, including, but not limited to, indication, display, and/or illumination. An "illumination source" is a light source that is particularly configured to generate radiation having a sufficient intensity to effectively illuminate an interior or exterior space. In this context, "sufficient intensity" refers to sufficient radiant power in the visible spectrum generated in the space or environment (the unit "lumens" often is employed to represent the total light output from a light source in all directions, in terms of radiant power or "luminous flux") to provide ambient illumination (i.e., light that may be perceived indirectly and that may be, for example, reflected off of one or more of a variety of intervening surfaces before being perceived in whole or in part).

[0018] The term "spectrum" should be understood to refer to any one or more frequencies (or

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