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(54) **Title**: UV-LED-LIGHT SOURCE

(57) **Abstract**: The invention relates to a LED-light source comprising a UV-LED embedded in a reflector housing and optionally covered by a transparent material, wherein the reflector housing is made of a polymeric material comprising (A) a semi-crystalline aliphatic polyamide (PA),obtained from aliphatic diamines and aliphatic dicarboxylic acids, and optionally other monomeric building blocks in an amount of at most 10 mole %, relative to the total molar amount of monomeric building blocks in the polyamide, and (B) a UV-reflecting pigment or filler. The invention also relates to a water purification device comprising the LED-light source. The invention also relates to a lighting armature comprising a mixing chamber comprising multiple UV-LEDs embedded in a reflector housing and optionally covered by a transparent material, wherein the mixing chamber comprises a reflection wall, at least part thereof made of a polymeric material as mentioned hereabove.

UV-LED-LIGHT SOURCE

The present invention relates to a LED-light source comprising a UV-LED, respectively water purification device comprising a LED-light source.

Such a device is described, for example in US2005258108-A. The water purification device described, for example in US2005258108-A comprises a container for purifying a material comprising a body adapted to contain the material, a lid adapted to releasably seal the body, a purifying unit having a radiation source and a power source, wherein the radiation source is adapted to deliver radiation to the interior of the body for purifying the material. Preferably, the purifying unit is incorporated into the lid. Preferably, the radiation source is one or more LEDs that emit UV-C radiation. More preferably, the radiation has a wavelength in the range of approximately 200 to 265 nanometers. In the noted embodiments, the radiation source is preferably adapted to delivery approximately 10,000 microwatts per square centimeter to the material. US2005258108-A also comprises a method for purifying a material including the steps of providing a container having a releasable sealing lid and a purifying unit having a solar-powered rechargeable power source that energizes a UV-C emitting LED, placing a material in the container, and exposing the material to radiation from the LED until the material is purified.

Ultraviolet light disinfects rapidly without the use of heat or chemicals. Ultraviolet light treatment is a proven and accepted method for disinfecting drinking water. The most effect germicidal wavelengths occur in the UV-C range of 200 and 265 nanometers. Microorganisms encompass a wide variety of unique structures and can be grouped into five basic groups: bacteria, virus, fungi, protozoa, and algae. A microorganism is composed of the cell-wall, cytoplasmic membrane and the cell's genetic material, nucleic acid. It is this genetic material or DNA that is affected by UV radiation. As UV-C penetrates through the cell wall, it causes molecular rearrangement of the microorganism's DNA thus preventing reproduction. Due to individual cell makeup, different levels of radiation are required for destruction. The effectiveness of UV microbial destruction is a product of both time and intensity. The intensity of UV-C light is measured in micro-watts per square centimeter and the time is measured in seconds.

Thus, the dose is the amount of ultraviolet light necessary to kill a particular microorganism, and can be measured in units of micro-watt seconds per square centimeter.

US2006283786A describes a system for purifying a fluid using ultra violet (UV) light to inactivate micro-organisms present in the fluid. The system has an arrangement of UV light emitters on perforated plates. US2004018125A describes a sterilizing photo catalyst device of air conditioner, wherein one or more ultraviolet (UV) light-emitting diodes (LEDs) are installed. UV LED light sources can also be used for other purposes, for example for UV curing of thermoset materials. WO05116089A describes a UV curing apparatus and method for enhancing the distribution and application of UV light to photoinitiators in a UV curable ink, coating or adhesive. The apparatus comprises UV LED assemblies mounted on a panel.

A LED-light source or LED-construction is generally constituted of a light emitting diode (i.e. a semiconductor part that emits light) generally referred to as LED, a lead wire, a reflector that also serves as a housing (further herein referred as reflector housing), and optionally a transparent sealant that seals the semiconductor part. Of these components, the reflector housing may be made from a variety of materials such as ceramics or heat-resistant plastics. For visible light emitting LEDs filled plastic materials are used, such as LCP (liquid crystal polymer), PPS (polyphenylene sulfide), ceramics, epoxies and heat resistant polyamides, but the demands on the reflectivity and retention thereof are high. With heat-resistant plastics the problem is a decrease in optical reflectivity caused by the color change during the injection molding process, during the thermosetting of the sealant, or under the actual environmental condition in use.

A visible light LED-light source with a reflector housing made of a plastic material is described for example in US2004034152A. The plastic material used in US2004034152A is a polyamide composition comprising a semi-aromatic polyamide, more particular a polyamide-9,T and a titanium oxide with a specific particle size, en generally using light stabilizers, such as UV-absorbing compounds and compounds having radical trapping capabilities. The possible applications of this LED-light source mentioned in US2004034152A illumination, display devices including cellular phones and other mobile communications devices, displays, automobile instrument panels, signaling devices and other electric household appliances. These are all visible light applications. The LED-light source of US2004034152A is optimized for light stability, and is subjected to UV-light exposure.

A problem that has been encountered with LED-light sources wherein the plastic material of which the reflector housing is made comprises a semi-aromatic polyamide, is that these are not suited for UV-LEDs, because of degradations such as severe discoloration.

For UV-LEDs other materials have to be used. For these LEDs ceramic or metals are a more suitably material. However, with ceramics and metals productivity and cost is a problem, certainly not ideal for mass production.

The aim of the invention is therefore to provide a LED-light source comprising a UV-LED embedded in a reflector housing that can be produced by mass production and has a good performance in terms of light reflectance retention.

This aim has been achieved with the UV-LED-light source according to the invention, wherein the reflector housing is made of a polymeric material comprising

(A) a semi-crystalline aliphatic polyamide (PA), obtained from aliphatic diamines and aliphatic dicarboxylic acids, and optionally other monomeric building blocks in an amount of at most 10 mole %, relative to the total molar amount of monomeric building blocks in the polyamide, and

(B) a UV reflecting pigment or filler.

The effect of the UV-LED-light source according to the invention is a surprisingly low degradation, in particular in combination with UV-B and even more so with UV-C. This result is surprising since the performance of for example polyamide-4,6, a semi-crystalline aliphatic polyamide, as reported in US2004034152A was so much worse that that of the semi-aromatic polyamide polyamide-9,T. Although the type of UV-light used in US2004034152A is not reported, it might have been in the UV-A range, close to the visible light, by using for example UV lights with a cut-off filter, to better represent daily sunlight, which could then explain for the surprising discrepancy in the reported results. The UV-LED in the UV-LED-light source according to the invention is to emit UV radiation with a wavelength in the range of 200-365 nm, further away from the visible light.

The polyamide (A) in the light source according to the invention, suitably has a melting temperature of at least 250ºC, and preferably is at least 270 ºC. Electrical and electronic products such as LEDs have been becoming lighter, thinner and more compact in response to demands for more attractive designs, easier portability, and so forth. As a key technique to achieve this reduction in size and weight, SMT (surface mounting technology) has become very popular and is used in many electrical and electronic products. This has markedly increased the mounting density on electronic base, and has led to reductions in size and weight that had never been achieved. When SMT is applied, the electronic parts mounted on an electronic base are entirely subjected to heating and soldering. Therefore they must be made from a material stable at the soldering temperature (approximately 240 ºC). Furthermore, lead-free solder has recently become major due to environmental regulations, and tin-silver alloys and the like have come into use. These lead-free solders have a higher melting point than conventional lead solder, which means that the soldering temperature is made higher (approximately 260 ºC).

The melting temperature (Tm) is herein determined by the method according to ISO-11357-3.2, 2009, in an N2 atmosphere with heating and cooling rate of 10°C/min, from the peak value of the melting peak in the second heating cycle.

The semi-crystalline aliphatic polyamide (A) is an AA-BB polymer, obtained from aliphatic diamines (referred to as AA monomers) and aliphatic dicarboxylic acids (referred to as BB monomers). Small amounts of other building blocks may also be present. If present, the amount of other building blocks is at most 10 mole %, preferably at most 5 mole %, relative to the total molar amount of monomeric building blocks in the polyamide.

Examples of suitable other building blocks are for example lactams, referred to as AB monomers, monofunctional monomers and trifunctional and higher functional monomers. Monofunctional monomers, such as monocarboxylic acids or monoamines, may be used as chain stoppers. Trifunctional and higher functional monomers can be used as branching agent.Preferably, the other building blocks used in the polyamide in the LED-light source according to the present invention are aliphatic monomers, as well.

Suitable aliphatic diamines that can be used in the polyamide include 1,4-butane diamine, 1,5-pentane diamine, 1,6-hexane diamine, 1-7-heptane diamine, 1,8-octane diamine, 1,9-none diamine, 1,10 decane diamine, 1,11-undecane diamine, 1,12-docedace diamine. Although these linear diamines are preferred, these may also be combined with branched derivatives. Examples thereof are 2-methyl-1,5-pentane diamine and 2-methyl-1,8-octane diamine.

Suitable aliphatic dicarboxylic acids include adipic acid or hexane dicarboxylic acid, (C6), pimelinic acid or heptane dicarboxylic acid (C7), suberic acid or octane heptane dicarboxylic acid (C8), and sebacinic acid or decane dicarboxylic acid (C10). Although these linear dicarboxylic acids are preferred, these may also be combined with branched or cyclic derivatives. An example thereof is 1,4-cyclohexane dicarboxylic acid.

The polyamide (A) is suitably selected from the group consisting of PA-4,4, PA-4,6, PA-4,8, PA-4,10 and PA-6,6, and any copolymer thereof, preferably PA-4,10. Herein PA is the generally used abbreviation for polyamide, the first number refers to the number of carbon atoms in the diamine and the second number refers to the number of carbon atoms in the dicarboxylic acid.

Preferred is PA4,6 and copolymers of PA-4,6 with one or more other aliphatic polyamide, wherein the 1,4-butane diamine and adipic acid together constitute at least 80 mole %, more preferably at least 90 mole %, relative to the total molar amount of monomeric building blocks in the polyamide. This PA-4,6 or copolyamide thereof is advantageously applied in LEDs to be subjected to a lead free soldering process.

Also preferred is PA4,10 and copolymers of PA-4,10 with one or more other aliphatic polyamide, wherein the 1,4-butane diamine and sebacinic acid together constitute at least 80 mole %, more preferably at least 90 mole %, relative to the total molar amount of monomeric building blocks in the polyamide. This PA-4,6 or copolyamide thereof has the advantage of a very good UV-stability and very good retention of properties under humid conditions and is advantageously applied in LEDs to be assembled on a PCB by means of a socket mounting step.

The UV reflecting pigment or filler (B) in the light source according to the invention, may have a particle size varying over a wide range. Preferably (B) has a mass median weight particle size in the range of 0.05 - 5 μm, more practically even in the range of 0.1 - 1 μm.

The UV reflecting pigment or filler is suitably selected from the group consisting of silica, silica alumina, alumina, titanium dioxide, zinc oxide, wollastonite, boron nitride and aluminium nitride. Preferably UV reflecting pigment or filler is a white pigment or filler, and more preferably comprises or even consists of rutile titanium dioxide.

The ratio in which the components (A) and (B) are present may vary, for example, the composition may comprise 2.5-250 pbw of (B) relative to 100 pbw of (A). Preferably, the composition comprises 5-200 pbw of (B), more preferably 20 -150 pbw of (B), and still more preferably 60-100 pbw of (B), relative to 100 pbw of (A). A higher minimum amount results in more the light reflection, whereas with a lower maximum amount the mechanical properties will be better.

The composition, from which the reflector housing in the light source according to the invention is made, may comprise further components other than (A) and (B). For example, the composition may consists of 100 pbw of (A), 2.5-150 pbw of (B) and 0 – 100 pbw of other components. Preferably, the composition consists of 100 pbw of (A), 5-100 pbw of (B) and 1 – 50 pbw of other components.

Among other components, the composition suitably comprises one or more of the following components

(C) fibrous reinforcing agents;

(D) powdery or needle like fillers other than (B);

(E) stabilizers; and

(F) other (auxiliary) additives.

As the stabilizer the composition suitably, but not necessarily so, comprises one ore more heat stabilizers and/or UV stabilizers.

These components are suitably present in the following amounts, either alone or in any combination of 2 or more:

(C) 0 – 100 pbw, preferably 5 – 50 pbw, of one or more fibrous reinforcing agents;

(D) 0 – 100 pbw, preferably 5 – 50 pbw, of one or more powdery or needle like fillers other than (B);

(E) 0 – 5 pbw, preferably 0.2 – 2 pbw of one or more stabilizers; and/or

(F) 0 – 5 pbw, preferably 0.2 – 2 pbw of one or more other (auxiliary) additives.

All the parts by weight (pbw) mentioned herein are relative 100 pbw of component (A).

The UV-LED used in the light source according to the invention, may emit UV radiation with a wavelength varying over a wide range. The UV radiation may have a wavelength in the range of 320-365 nm (UV-A radiation), 280-320 nm (UV-B radiation) and/or 200 – 280 nm (UV-C radiation). Preferably, the UV-LED emits UV-B and/or UV-C radiation, more preferably UV-radiation with a wavelength in the range of 250-280 nm.

The invention also relates to a device comprising a LED-light source according to the invention as described above, or any preferred embodiment thereof. In particular the device may be one selected from tanning devices, black-lights, devices for medical phototherapy, banknote detectors, photocatalytic air disinfection, UV curing apparatus, water & air purification and analytical instruments. The UV curing apparatus may be used for UV curing of other materials, i.e. chemical crosslinking of thermoset materials by means of UV radiation. The water & air purification may be for personal or residential purposes as well as for professional purposes.

In a preferred embodiment the device according to the invention is a water purification device comprising a UV-B or UV-C LED-light source according to the invention.

The invention is also related to a lighting armature comprising a mixing chamber comprising multiple UV-LEDs embedded in a reflector housing and optionally covered by a transparent material, wherein the mixing chamber comprises a reflection wall, at least part thereof made of a polymeric material comprising

(A) a semi-crystalline aliphatic polyamide (PA), obtained from aliphatic diamines and aliphatic dicarboxylic acids, and optionally other monomeric building blocks in an amount of at most 10 mole %, relative to the total molar amount of monomeric building blocks in the polyamide, and

(B) a UV-reflecting pigment or filler.

The reflection wall in the lighting armature, typically the inner side of the walls of the lighting armature, have the general purpose to reflect the light from the diode in the direction of the area and/or objects to be illuminated.

Preferably the polymer composition, of which the wall part in the lighting armature is made, is a composition or any preferred embodiment thereof as described here above.

Suitably, the UV-LEDs in the lighting armature emits UV radiation with a wavelength in the range of 320-380 nm (UV-A radiation), 280-320 nm (UV-B radiation) and/or 200 – 280 nm (UV-C radiation), preferably UV-C radiation with a wavelength in the range of 200-265 nm.

The invention I further illustrated with the following Example and Comparative Experiment.

Experimental Part

Determination of Tm by DSC (according to ISO-11357-3.2, 2009)

The measurements of the melting temperature Tm were carried out with a Mettler Toledo Star System (DSC) using a heating and cooling rate of 10°C/min. in an N2 atmosphere. For the measurements a sample of about 5 mg pre-dried powdered polymer was used. The pre-drying was carried out at high vacuum, i.e less than 50 mbar and a 105°C during 16 hrs. The sample was heated from 0°C to a temperature about 30°C above the melting temperature at 10°C/min, immediately cooled to 0°C at 10°C/min and subsequently heated to about 30°C above the melting temperature again at 10°C/min. For the melting temperature Tm the peak value of the melting peak in the second heating cycle was determined.

Materials

Aliphatic polyamide (I):	a PA-4,6 homopolymer with a melting temperature of 290ºC.
Aliphatic polyamide (II):	a PA4,10 homopolymer with a melting temperature of 250ºC.
Semi-aromatic polyamide:	a PA-4,T based polyamide copolymer with a melting temperature of 330ºC.

For each of the materials three grades were used, one unfilled and one filled with 30 wt.% rutile titanium dioxide (mass median particle size about 200 nm).

Test samples

From the materials films and tensile test bars were made.

UV treatment

A film and a tensile test bar of each the three materials were exposed for 72 hours to UV-light with a wavelength of 265 nm emitted by a Xenon lamp in a UV-apparatus from Hitachi. The test bar of the filled PA-4,T based copolymer material showed a yellowish discoloration, the test bar of the corresponding filled PA-4,6 and PA4,10 homopolymer materials did not show any discoloration. The films of all three unfilled materials did not show any sign of discoloration. However, upon inspection under a fluorescence light, a yellowish discoloration was observed for the PA-4,T based copolymer material, not for the PA-4,6 and PA4,10 homopolymer materials.

CLAIMS

1. LED-light source comprising a UV-LED embedded in a reflector housing and optionally covered by a transparent material, wherein the reflector housing is made of a polymeric material comprising
   (A) a semi-crystalline aliphatic polyamide (PA), obtained from aliphatic diamines and aliphatic dicarboxylic acids, and optionally other monomeric building blocks in an amount of at most 10 mole %, relative to the total molar amount of monomeric building blocks in the polyamide, and
   (B) a UV-reflecting pigment or filler.
2. Light source according to claim 1, wherein the PA has a melting temperature of at least 250ºC.
3. Light source according to claim 1 or 2, wherein (A) is selected from the group consisting of PA-4,4, PA-4,6, PA-4,8, PA-4,10 and PA-6,6, and any copolymer thereof, preferably PA-4,10.
4. Light source according to any of claims 1-3, wherein (B) has a median particle size in the range of 0.05 - 5 µm.
5. Light source according to any of claims 1-4, wherein (B) is selected from the group consisting of silica, silica alumina, alumina, titanium dioxide, zinc oxide and wollastonite, boron nitride and aluminium nitride.
6. Light source according to any of claims 1-5, wherein the composition further comprises one or more of the following components
   (C) fibrous reinforcing agents
   (D) powdery or needle like fillers other than (B)
   (E) stabilizers
   (F) other (auxiliary) additives
7. Light source according to any of claims 1-6, wherein the composition comprises 100 pbw of (A) and 5-200 pbw of (B).
8. Light source according to any of claims 1-7, wherein the composition consists of 100 pbw of (A) 5-200 pbw of (B) and 0 – 100 pbw of other components
9. Light source according to any of claims 1-8, wherein the UV-LED emits UV radiation with a wavelength in the range of 320-380 nm (UV-A radiation), 280-320 nm (UV-B radiation) and/or 200 – 280 nm (UV-C radiation), preferably UV-C radiation with a wavelength in the range of 200-265 nm.

10. Device comprising a UV-LED-light source according to any of claims 1-9.

11. Device according to claim 10, wherein the device is selected from tanning devices, black-lights, devices for medical phototherapy, banknote detectors, photocatalytic air disinfection, UV curing apparatus, water & air purification and analytical instruments.

12. Device according to claim 10, wherein the device is a water purification device comprising a UV-B or UV-C LED-light source.

13. Lighting armature comprising a mixing chamber comprising multiple UV-LEDs embedded in a reflector housing and optionally covered by a transparent material, wherein the mixing chamber comprises a reflection wall, at least part thereof made of a polymeric material comprising
    (A) a semi-crystalline aliphatic polyamide (PA), obtained from aliphatic diamines and aliphatic dicarboxylic acids, and optionally other monomeric building blocks in an amount of at most 10 mole %, relative to the total molar amount of monomeric building blocks in the polyamide, and
    (B) a UV-reflecting pigment or filler

14. Lighting armature according to claim 13, wherein the polymer composition is a composition as described in any of claims 2-8.

15. Lighting armature according to claim 13 or 14, wherein the UV-LEDs emit UV radiation with a wavelength in the range of 320-380 nm (UV-A radiation), 280-320 nm (UV-B radiation) and/or 200 – 280 nm (UV-C radiation), preferably UV-C radiation with a wavelength in the range of 200-265 nm.