DESCRIPTION

TITLE OF INVENTION: TRANSFERRING METHOD

TECHNICAL FIELD

[0001]

The present invention relates to a transferring method.

BACKGROUND ART

[0002]

Recently, along with miniaturization of semiconductor devices, microstructure-transferring technology using a pressure sensitive adhesive resin is attracting attention as a means of assembling electric and electrical application products using semiconductor devices. In particular, development of a technology for manufacturing LED displays for use in signage, TVs, medical applications, in-vehicle displays, smartphones, etc. is becoming active, which involves transferring a large number, such as tens of thousands, of mini-LEDs (LED devices with a short side of 100 μm or more to several hundred μm) or micro LEDs (LED devices with a short side of 100 μm or less, further 50 μm or less) at once.

[0003]

A method for transferring microstructures, such as micro LEDs, using a silicone pressure-sensitive-adhesive cured product as a donor substrate or a stamp material for transferring, and a method for mounting them on a circuit board have been developed so far (for example, Patent Document 1).

[0004]

Furthermore, a technology has also been proposed that mitigates impact during transferring, enabling a semiconductor chip to be transferred with high accuracy (for example, Patent Document 2).

CITATION LIST

PATENT DOCUMENT

[0005]

Patent Document 1: JP 2021-34610 A
Patent Document 2: JP 2019-67892 A

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0006]

Incidentally, in order to improve the yield of transferring, it is important to prevent occurrence of chipping or cracking in microstructures when the microstructures are detached from a base member such as a substrate.

[0007]

The present invention has been made to solve the above problem, and has an object to provide a transferring method capable of preventing occurrence of chipping or cracking in microstructures when the microstructures are transferred from a base member.

SOLUTION TO PROBLEM

[0008]

In order to solve the above problem, the present invention provides a transferring method for transferring a plurality of microstructures provided on a base member from the base member by virtue of laser irradiation,

wherein at least a space between the microstructures adjacent to each other is filled with a polymer material,

the transferring method comprises:

a first laser-irradiation step of irradiating the microstructures with a laser through the base member; and

a second laser-irradiation step of irradiating the polymer material with a laser through the base member, and

in the first laser-irradiation step, regions corresponding to the microstructures are irradiated with the laser directed to the microstructures.

[0009]

With such a transferring method, in which the two-stage irradiation including the first laser-irradiation step of irradiating the microstructures with the laser and the second laser-irradiation step of irradiating the polymer material with the laser is performed with the space between the microstructures being filled with the polymer material, the microstructures can be transferred from the base member while preventing occurrence of chipping or cracking in the microstructures.

[0010]

For example, the second laser-irradiation step is preferably performed after the first laser-irradiation step.

[0011]

By performing the second laser-irradiation step after the first laser-irradiation step, for example, the polymer material can be detached in the second laser-irradiation step without the polymer material being

detached in the first laser-irradiation step. Thus, the microstructures can be transferred from the base member while more reliably preventing occurrence of chipping or cracking in the microstructures.

[0012]

In the second laser-irradiation step, the polymer material and the microstructures may be irradiated with the laser.

[0013]

In the second laser-irradiation step, the polymer material may be irradiated with the laser, but the microstructures may be irradiated with the laser. In the second laser-irradiation step, the entire base member may be irradiated with the laser.

[0014]

For example, the first laser-irradiation step may be performed at an energy density at which the polymer material is sufficiently ablated.

[0015]

For example, the laser irradiation in the first laser-irradiation step may be performed at a high energy density at which the polymer material is sufficiently ablated.

[0016]

For example, the plurality of microstructures are provided on the base member via GaN, and

the first laser-irradiation step may be performed at an energy density at which GaN is thermally decomposed.

[0017]

In such a first laser-irradiation step, the microstructures provided on the base member via GaN can be reliably detached from the base member.

[0018]

Additionally, for example, the second laser-irradiation step may be performed at an energy density lower than the energy density at which the polymer material is sufficiently ablated.

[0019]

In the second laser-irradiation step, the laser irradiation may be performed at the energy density lower than the energy density at which the polymer material is sufficiently ablated.

[0020]

For example, the second laser-irradiation step may be performed at an energy density at which the polymer material is vaporized.

[0021]

By performing such a second laser-irradiation step, the polymer material can be vaporized.

[0022]

Preferably, the second laser-irradiation step is performed at an energy density at which generation of carbon-based debris derived from the polymer material can be reduced.

[0023]

The second laser-irradiation step is preferably performed while thus reducing the generation of carbon-based debris.

[0024]

For example, the laser irradiation in the first laser-irradiation step and the laser irradiation in the second laser-irradiation step may be performed by an excimer laser with a wavelength of 248 nm,

an energy density of the laser irradiation in the first laser-irradiation step may be 700 mJ/cm^2 or more,

and

an energy density of the laser irradiation in the second laser-irradiation step may be 30 to 500 mJ/cm^2.

[0025]

The wavelength and the energy density of the laser may be set, for example, as described above.

[0026]

The second laser-irradiation step may be performed a plurality of times.

[0027]

The second laser-irradiation step may be performed at least once, or may be performed a plurality of times.

[0028]

For example, the base member on which the plurality of microstructures are provided may be covered with the polymer material so as to cover the plurality of microstructures.

[0029]

A coating of the polymer material may be formed so as to cover the plurality of microstructures.

ADVANTAGEOUS EFFECTS OF INVENTION

[0030]

As described above, the transferring method of the present invention can transfer the microstructures from the base member while preventing occurrence of chipping or cracking in the microstructures.

BRIEF DESCRIPTION OF DRAWINGS

[0031]

[FIG. 1] FIG. 1 is a schematic sectional view of a composite to be irradiated with a laser in an example of a transferring method of the present invention.

[FIG. 2] FIG. 2 is a schematic plan view of the composite in FIG. 1 as viewed from a base member side.

[FIG. 3] FIG. 3 is a schematic cross-sectional view illustrating a first laser-irradiation step in an example of the transferring method of the present invention.

[FIG. 4] FIG. 4 is a schematic cross-sectional view illustrating a second laser-irradiation step in an example of the transferring method of the present invention.

[FIG. 5] FIG. 5 is an optical micrograph in Example 1.

[FIG. 6] FIG. 6 is an optical micrograph in Comparative Example.

DESCRIPTION OF EMBODIMENTS

[0032]

As described above, there has been a demand for development of a transferring method capable of preventing occurrence of chipping or cracking in microstructures when the microstructures are transferred from a base member.

[0033]

The present inventors have intensively studied the above problem, and found that by virtue of performing the two-stage irradiation including a first laser-irradiation step of irradiating microstructures with a laser and a second laser-irradiation step of irradiating a polymer material with a laser with a space between the microstructures being filled with the polymer material, the microstructures can be transferred from a base member while preventing occurrence of chipping or cracking in the microstructures, thereby completing the

present invention.

[0034]

That is, the present invention provides a transferring method for transferring a plurality of microstructures provided on a base member from the base member by virtue of laser irradiation,

wherein at least a space between the microstructures adjacent to each other is filled with a polymer material,

the transferring method includes:

a first laser-irradiation step of irradiating the microstructures with a laser through the base member; and

a second laser-irradiation step of irradiating the polymer material with a laser through the base member, and

in the first laser-irradiation step, regions corresponding to the microstructures are irradiated with the laser directed to the microstructures.

[0035]

The present invention will be described in detail below, but the present invention is not limited thereto.

[0036]

[Object to be Irradiated with Laser]

First, with reference to FIGS. 1 and 2, an object to be irradiated with a laser in an example of the transferring method of the present invention will be described. FIG. 1 is a schematic sectional view of a composite to be irradiated with a laser in an example of the transferring method of the present invention. FIG. 2 is a schematic plan view of the composite in FIG. 1 as viewed from a base member side. However, the object to be irradiated with a laser in the transferring method of

the present invention is not limited to the composite in FIGS. 1 and 2.

[0037]

The composite 10 in FIGS. 1 and 2 includes a base member 1 and a plurality of (four in this example) microstructures 2 provided on the base member 1. Also, the composite 10 includes a polymer material 3. The polymer material 3 includes at least a portion 31 filling a space between microstructures 2 adjacent to each other. Specifically, at least the space between the microstructures 2 adjacent to each other is filled with the polymer material 3.

[0038]

Such a composite 10 can be obtained, for example, by a step of forming the plurality of microstructures 2 on the base member 1 and a step of filling at least the space between the microstructures 2 adjacent to each other with the polymer material 3.

[0039]

As shown in FIGS. 1 and 2, the polymer material 3 may further include a portion 32 covering a top of the microstructures 2 and/or a portion 33 covering an outside of the microstructures 2. That is, the base member 1 on which the plurality of microstructures 2 are provided may be covered with the polymer material 3 so as to cover the plurality of microstructures 2. However, in the object to be irradiated with a laser in the transferring method of the present invention, the polymer material 3 is required to include at least the portion 31 filling the space between the microstructures 2 adjacent to each other, and may not include the portion 32 covering the top of the microstructures 2 and the portion 33 covering the outside of the

microstructures 2. In terms of mitigation of impact on the microstructures 2, the polymer material 3 preferably includes not only the portion 31 filling the space between the microstructures 2 adjacent to each other but also the portion 33 covering the outside of the microstructures 2. Further, by the polymer material 3 including the portion 32 covering the top of the microstructures 2, the impact on the microstructures 2 can be further mitigated. When a final product does not require the portion 32 of the polymer material 3 covering the top of the microstructures 2, the portion 32 may be removed by, for example, washing or polishing in a step after the transferring step.

[0040]

When each microstructure 2 has a rectangular shape, the polymer material 3 is preferably provided around its entire outer periphery, that is, on the outside of four sides. However, even when the polymer material 3 is provided on a part of the outer periphery of the microstructure 2, for example, only on the outside of one side of the rectangular microstructure 2, the impact on the microstructure 2 can be mitigated as compared to when no polymer material is provided. Additionally, when the polymer material 3 is provided on the outside of two opposing sides, the impact on the microstructure 2 can be mitigated as compared to when the polymer material 3 is provided only on the outside of one side.

[0041]

A material of the base member 1 is not particularly limited as long as the microstructure 2 and/or the polymer material 3 can be irradiated with a laser through the base member 1 of the material in the first laser-irradiation step and the second laser-irradiation

step described below. Preferred examples of the material of the base member 1 may include an inorganic transparent substrate such as a sapphire substrate, a GaAs substrate (gallium arsenide substrate), an Si substrate, an SiC substrate, and a quartz substrate. Alternatively, an organic transparent substrate having resistance to laser irradiation may be used.

[0042]

A thickness of the base member 1 may be, but not particularly limited to, for example, 0.001 mm or more and 3 mm or less. The base member 1 may be rigid or flexible. The base member 1 typically has, for example, a square shape or a circular shape, but may have an oval shape, a polygonal shape other than the square shape, a shape in which a side of a polygon is partially replaced with a curved line, or the like, or may have a long tape shape. As necessary, an orientation flat or a notch is provided in an outer edge of the base member, facilitating handling and position adjustment.

[0043]

The microstructure 2 is not particularly limited, and may be, for example, an LED chip such as a micro LED and a mini-LED, a semiconductor chip, or other electronic components.

[0044]

A planar shape of the microstructure 2 is generally a square shape, but is not particularly limited, and may be a circular shape, an oval shape, a polygonal shape other than the square shape, a shape in which a side of a polygon is partially replaced with a curved line, or the like.

[0045]

When the microstructure 2 has the square shape, an

upper limit of a length of one side of the microstructure 2 may be, for example, 2.5 mm. According to the transferring method of the present invention, for example, even a 1-mm-square microstructure 2 can be transferred without occurrence of chipping or cracking. A detailed reason therefor will be described below. A lower limit of the length of one side of the microstructure 2 may be, but not particularly limited to, for example, 0.001 mm. Preferably, the length of one side of the microstructure 2 is 0.005 mm or more and 2 mm or less. Of course, the present invention may be applied to a microstructure having a length of one side of more than 2.5 mm or less than 0.001 mm. A thickness of the microstructure may be, but not particularly limited to, generally 200 μm or less, and may be 100 μm or less or 50 μm or less. In particular, when the thickness is 50 μm or less, even minor chipping in the microstructure is more likely to cause a critical breakage in a subsequent step, and the transferring method of the present invention can be effectively applied. Further, when the thickness is 30 μm or less, the transferring method of the present invention can be further effectively applied. A lower limit of the thickness is reduced with development of technology, but is about 1 μm.

[0046]

A material of the microstructure 2 is not particularly limited, but the microstructure 2 may contain, on a surface on the base member 1 side, for example, gallium nitride (GaN), gallium phosphide (GaP), or indium phosphide (InP). Typically, the plurality of microstructures 2 are provided on the base member 1 via an inorganic material such as GaN 21. More

specifically, the microstructure 2 may be an LED chip manufactured on an epitaxial substrate such as a sapphire substrate. Of course, the microstructure may be a microstructure provided on the various inorganic transparent substrates or the organic transparent substrate described above via an adhesive or the like.

[0047]

Several tens of thousands to several hundreds of thousands of microstructures are generally provided on the base member in a matrix depending on sizes of the microstructure and the base material. The microstructures adjacent to each other are placed with being spaced apart from each other. In the space, no microstructure is placed and the base member is exposed, and the space may be referred to as a street. A width of the street often depends on a size of an LED chip or a type of dicing. For a micro LED chip or chemical dicing, a street width is often small, and is generally about several μm (about 1 to 10 μm). For a mini-LED or mechanical dicing, the street width is often slightly larger, and is generally about several ten μm (about 10 to 100 μm).

[0048]

The polymer material 3 is not particularly limited, and may be, for example, a resin of a material selected from the group consisting of polyimide, silicone, polystyrene, and an acrylic resin, a composition containing the resin, or a cured product thereof. In terms of mitigation of the impact on the microstructure 2, a material having a certain level of elasticity such as a rubbery material is preferable. Examples of the silicone include straight silicone such as dimethyl silicone and methylphenyl silicone, modified silicone

such as acrylic-modified silicone and methacrylic-modified silicone, and combinations thereof. The polymer material 3 may be of any of a side chain type, a single terminal type, and a both terminal type.

[0049]

The space may be filled with the polymer material by, for example, applying a liquid resin or the like. The resin may be applied using a spin coater, a dispenser, or the like. A material that is easy to apply is one that has sufficient fluidity so as to fill the space between the adjacent microstructures during application and can exhibit the reduced fluidity after the application as necessary. Therefore, a thermoplastic material, a thermosetting material, a photocurable material, a dissolved material obtained by dissolving these materials in a solvent, or the like are useful. In particular, for a resin such as a thermoplastic resin soluble in a solvent or a dissolved material obtained by dissolving the resin in a solvent, a polymer compound after transferring can be more easily removed by the solvent. Incidentally, the space between the adjacent microstructures may be filled with the polymer material so as not to form air bubbles or voids, or so as to leave voids on the base member side. In terms of mitigation of the impact on the microstructure, the space may be filled with the polymer material to a half or more of the thickness of the microstructure. Even in filling so as not to form air bubbles, air bubbles, which are difficult to avoid in a manufacturing process, may enter.

[0050]

Incidentally, in the case where the thermosetting material or the photocurable material is used as the

polymer material 3 and the thermosetting material or the photocurable material is firmly cured after the transferring, the polymer material 3 may be sometimes difficult to remove from the microstructure 2 after the transferring. In such a case, a curable material that becomes rubbery after curing may be used, the curable material may be cured so as to reduce a reaction rate, for example, so as to enter a B-stage, or a rubber component may be contained in a composition of the curable material to increase flexibility of a cured product.

[0051]

Additionally, a photocurable material having an adhesive force reduced by light irradiation may also be used. A photocurable material having an adhesive force (pressure sensitive adhesive force) to be reduced by UV irradiation is widely used as a dicing tape, and typically contains a base resin such as a (meth) acrylic copolymer, a photocurable component such as a polyfunctional (meth) acrylate, and a photoinitiator such as a photoradical generator. In this case, a photoinitiator is preferably used having sufficiently low absorption of laser wavelength used in the transferring method.

[0052]

A receiving substrate to which the microstructure 2 is transferred is not particularly limited, and an inorganic transparent substrate such as a sapphire substrate, a GaAs substrate (gallium arsenide substrate), an Si substrate, an SiC substrate, or a quartz substrate may be preferably used. When no laser irradiation is performed through the receiving substrate in steps subsequent to the transferring method of the

present invention, the substrate may be opaque. Similarly, when the receiving substrate is not subjected to excessive heating or excessive chemical treatment in the subsequent steps, an organic substrate may be used. The receiving substrate typically has, for example, a square shape or a circular shape, but may have an oval shape, a polygonal shape other than the square shape, a shape in which a side of a polygon is partially replaced with curved lines, or the like, or may have a long tape shape. As necessary, an orientation flat or a notch is provided in an outer edge of the base member, facilitating handling and position adjustment.

[0053]

Additionally, a surface (transferring surface) of the receiving substrate to which the microstructure 2 is transferred may have, for example, partially or entirely, an adhesive layer that temporarily or permanently holds the transferred microstructure. Here, when the microstructure 2 and the polymer material 3 are transferred together, the microstructure 2 can be held on the receiving substrate by the polymer material 3.

[0054]

In the present invention, for example, a polymer material may be applied onto a base member on which a plurality of microstructures are provided, and a receiving substrate may be brought into contact with the side provided with the polymer material to obtain a laminate, and the laminate can be irradiated with a laser. As necessary, a solvent drying step may be provided after the application. Similarly, a curing step may be provided before or after contacting of the receiving substrate as necessary. Additionally, the laser irradiation may be performed in a state where the

receiving substrate is separated from the side provided with the polymer material of the base member, that is, in a non-contact state, instead of a state where the receiving substrate is in contact with the side provided with the polymer material of the base member. When the laminate in which the receiving substrate is in contact with the side provided with the polymer material of the base member is used, the base member and the receiving substrate preferably have the same shape.

[0055]

Additionally, the polymer material may be applied onto the receiving substrate and the applied polymer material may be pressed against the plurality of microstructures provided on the base member, thereby filling the space between the adjacent microstructures with the polymer material. In this case, the fluidity of the polymer material can be reduced after the filling rather than after the application, as necessary.

[0056]

[First Laser-Irradiation Step]

In the first laser-irradiation step in the transferring method of the present invention, for example, as shown in FIG. 3, the microstructure 2 is irradiated with a laser L1 through the base member 1.

[0057]

In the first laser-irradiation step in the transferring method of the present invention, a region 12 corresponding to the microstructure 2 is irradiated with the laser L1 directed to the microstructure 2.

[0058]

Here, the region 12 corresponding to the microstructure 2 may include only the microstructure 2, or may include the microstructure 2 and a portion 34 of

the polymer material 3 adjacent to the microstructure 2 as shown in FIG. 3. The region 12 may also be inside an outer edge of the microstructure 2 as long as the microstructure 2 can be detached from the base member 1 in the second laser-irradiation step. Therefore, an area of the region corresponding to the microstructure 2 is preferably about 90% to 120%, more preferably about 95% to 110%, and particularly preferably 98% to 105% of an area of the microstructure 2.

[0059]

In the first laser-irradiation step, the region 12 corresponding to the microstructure 2 is not necessarily irradiated with the laser only once. For example, by performing irradiation a plurality of times while changing an irradiation region, the impact on the microstructure 2 can be mitigated. Additionally, by performing irradiation a plurality of times at a low energy density insufficient to detach the microstructure 2 from the base member 1 such that the irradiation regions overlap with each other, the impact on the microstructure 2 can be mitigated and generation of foreign matter can be also reduced. Further, the entire microstructure may be irradiated with the laser after the region inside the outer edge of the microstructure 2 is irradiated with the laser.

[0060]

By virtue of the irradiation with the laser L1 in the first laser-irradiation step in this example, the microstructure 2 can be detached from the base member 1 while the portion 31 of the polymer material 3 filling the space between the adjacent microstructures 2 remains on the base member 1 (without being detached). By virtue of the presence of the portion 31 of the polymer

material 3, the microstructure 2 can be kept in a state not separated from the base member 1.

[0061]

Irradiation conditions for the laser L1 in the first laser-irradiation step will be described later.

[0062]

[Second Laser-Irradiation Step]

In the second laser-irradiation step, for example, as shown in FIG. 4, the polymer material 3 is irradiated with a laser L2 through the base member 1.

[0063]

In the second laser-irradiation step, the polymer material 3 is required to be irradiated with the laser L2, but the microstructure 2 may be further irradiated with the laser L2 as shown in FIG. 4. Further, the plurality of microstructures 2 may be irradiated with the laser L2, or the entire composite 10 may be irradiated with the laser L2. Incidentally, a high-power laser oscillator is required when the composite has a large area , and therefore, the laser is preferably shaped into a linear shape or a rectangular shape so as to avoid too large an irradiation region.

[0064]

By virtue of irradiation with the laser L2 in the second laser-irradiation step in this example, the portion 31 of the polymer material 3 filling the space between the microstructures 2 adjacent to each other can be detached from the base member 1.

[0065]

Typically, the second laser-irradiation step is performed after the first laser-irradiation step. As described above, after the first laser-irradiation step, the microstructure 2 is detached from the base member 1,

but can be kept in the state not separated from the base member 1.

[0066]

The present invention is particularly effective when a minimum energy density A required to detach the microstructure 2 from the base member 1 is larger than a minimum energy density B required to detach the polymer material 3 from the base member 1. In this case, when the transferring step is performed uniformly at the minimum energy density A, the impact on the microstructure 2 is prone to increase due to the high energy density, which is likely to cause chipping or cracking in the microstructure 2. In the present invention, by virtue of the presence of the polymer material 3, even when the microstructure is irradiated with the laser at the minimum energy density A at which the impact on the microstructure 2 is prone to increase or at an energy density higher than that, the impact can be mitigated, thereby preventing occurrence of chipping or cracking in the microstructure 2. The energy density can be increased, and a success rate of transfer can be improved.

[0067]

Additionally, there is an advantage that even when the microstructure 2 is irradiated with the laser at the energy density less than the minimum energy density A in the first laser-irradiation step, the microstructure is also irradiated with the laser in the second laser-irradiation step to allow the transferring. Thus, the impact due to the laser irradiation on the microstructure can be mitigated. As such, even when the microstructure 2 is not completely detached from the base member 1 in the first laser-irradiation step, or

even when the detached microstructure 2 is re-fixed to the base member 1 due to a subsequent temperature decrease, the microstructure 2 can be transferred by the second laser-irradiation step.

[0068]

The second laser-irradiation step may be performed a plurality of times as necessary. Additionally, after the second laser-irradiation step is performed once to separate one microstructure 2 from the base member 1, the first laser-irradiation step may be performed on another microstructure 2.

[0069]

Hereinafter, preferred aspects and specific examples of the irradiation conditions for the laser L1 and the laser L2 in the first laser-irradiation step and the second laser-irradiation step will be described.

[0070]

The wavelength of each of the laser L1 and the laser L2 in the first laser-irradiation step and the second laser-irradiation step may be appropriately set in consideration of the material of the microstructure 2 and the polymer material 3. For example, an excimer laser with a wavelength of 248 nm, an excimer laser with a wavelength of 266 nm, an excimer laser with a wavelength of 193 nm, or an excimer laser with a wavelength of 351 nm may be used, but the wavelength is not particularly limited.

[0071]

For example, the first laser-irradiation step may be performed at an energy density (for example, 700 mJ/cm^2 or more and 2000 mJ/cm^2 or less) at which the polymer material 3 is sufficiently ablated.

[0072]

Here, the ablation is generally a phenomenon in which, when a surface of a solid or a liquid is irradiated with a laser beam, a surface component is explosively released upon plasma generation. In general, when a polymer material is ablated, the polymer material is thermally decomposed and photolyzed. Additionally, when the polymer material 3 is ablated, a part of the polymer material may become soot-like carbon-based debris.

[0073]

When the polymer material 3 is polyimide, for example, the energy density in the first laser-irradiation step is preferably 40 mJ/cm^2 or more and 400 mJ/cm^2 or less, more preferably 80 mJ/cm^2 or more and 300 mJ/cm^2 or less, at a wavelength of 248 nm and a pulse width of 20 ns. When the polymer material 3 is silicone, for example, the energy density in the first laser-irradiation step is preferably 100 mJ/cm^2 or more and 500 mJ/cm^2 or less, more preferably 200 mJ/cm^2 or more and 400 mJ/cm^2 or less, at the wavelength of 248 nm and the pulse width of 20 ns. When the polymer material 3 is an acrylic resin, for example, the energy density in the first laser-irradiation step is preferably 40 mJ/cm^2 or more and 700 mJ/cm^2 or less, more preferably 80mJ/cm^2 or more and 400 mJ/cm^2 or less, at the wavelength of 248 nm and the pulse width of 20 ns.

[0074]

When the plurality of microstructures 2 are provided on the base member 1 via GaN 21, for example, the first laser-irradiation step may be performed at an energy density (for example, 0.8 J/cm^2 or more and 2 J/cm^2 or less at the wavelength of 248 nm and the pulse width of 20 ns) at which GaN is thermally decomposed.

[0075]

In such a first laser-irradiation step, the microstructures 2 provided on the base member 1 via GaN 21 can be reliably detached from the base member 1.

[0076]

The second laser-irradiation step may be performed, for example, at an energy density lower than the energy density at which the polymer material 3 is sufficiently ablated. Specifically, the energy density of the laser L2 in the second laser-irradiation step may be smaller than the energy density of the laser L1 in the first laser-irradiation step. In order to reduce the influence on a region provided in the microstructure 2, the energy density in the second laser-irradiation step is preferably sufficiently lower than the energy density in the first laser-irradiation step. The difference between the energy densities is preferably 100 mJ/cm^2 or more, more preferably 300 mJ/cm^2 or more, and particularly preferably 500 mJ/cm^2 or more at the wavelength of 248 nm and the pulse width of 20 ns. An upper limit of the difference between the energy densities may be, but not particularly limited to, for example, 1200 mJ/cm^2. Incidentally, the phrase "lower than the energy density at which the polymer material is sufficiently ablated" means, in other words, that the energy density is lower than an energy density at which the microstructure can be transferred. By performing irradiation at such a sufficiently low energy density a plurality of times, the transferring can be performed while reducing generation of carbon-based debris. By performing irradiation at a lower energy density a larger number of times, the generation of carbon-based debris can be more effectively reduced; however, in

terms of improved throughput, the number of times of irradiation is preferably about 2 to 20, and more preferably about 2 to 10.

[0077]

On the other hand, when the generation of carbon-based debris is allowed or a polymer material from which carbon-based debris is not easily generated is used, irradiation may be performed at an energy density at which the polymer material is sufficiently ablated, in other words, at an energy density equal to or higher than the minimum energy density B described above.

[0078]

For example, the second laser-irradiation step may be performed at an energy density at which the polymer material 3 is vaporized.

[0079]

By performing such a second laser-irradiation step, the polymer material 3 can be vaporized.

[0080]

Preferably, the second laser-irradiation step is performed at an energy density at which the generation of carbon-based debris derived from the polymer material 3 can be reduced.

[0081]

Preferably, the second laser-irradiation step is performed while the generation of carbon-based debris is being thus reduced. Most preferably, the second laser-irradiation step is performed at an energy density at which no debris is generated (for example, 0.08 J/cm^2 or less). On the other hand, in terms of a success rate of transferring, the energy density may be increased such that an amount of debris generated is 10% or less of an amount of debris generated when the polymer material 3

is sufficiently ablated.

[0082]

Specifically, the energy density of the laser irradiation in the second laser-irradiation step may be, for example, 30 to 500 mJ/cm^2.

[0083]

Specifically, for example, when the polymer material 3 is polyimide and the laser L2 with the wavelength of 193 nm is used, the energy density is preferably about 20 mJ/cm^2 or more, and more preferably about 20 to 200 mJ/cm^2. Similarly, when the laser L2 with the wavelength of 248 nm is used, the energy density is preferably about 30 mJ /cm^2 or more, and more preferably about 30 to 500 mJ/cm^2. When the laser L2 with the wavelength of 266 nm is used, the energy density is preferably about 40 mJ/cm^2 or more, and more preferably about 40 to 400 mJ/cm^2. When the laser L2 with the wavelength of 351 nm is used, the energy density is preferably about 80 mJ/cm^2 or more.

[0084]

When the laser L2 with the wavelength of 193 nm is used and the polymer material 3 is polystyrene, the energy density is preferably about 10 mJ/cm^2 or more. When the laser L2 with the wavelength of 193 nm is used and the polymer material 3 is an acrylic resin, the energy density is preferably about 60 mJ/cm^2 or more.

[0085]

The transferring method of the present invention may be, for example, a type of laser lift-off (LLO) or laser induced forward transfer (LIFT). A specific apparatus configuration, an operation method, and the like used in the transferring method of the present invention can be implemented with reference to, for

example, WO 2019/244362 A1.

[0086]

By using the transferring step of the present invention, the impact on the microstructure 2 can be mitigated in the transferring step, and thus the present invention can be effectively applied to the microstructure 2 that is fragile and easily cracked. Examples of the microstructure 2 that is fragile and easily cracked include a red LED chip, and an LED chip having an uneven surface such as bumps. When the LED chip has the bumps, such bumps are further formed on electrodes, which increases unevenness, and thus such an LED chip is easily broken. Additionally, the microstructure having a MESA region generally has electrodes formed at opposite ends of the MESA region, and thus has a shape with minute unevenness and is easily broken.

[0087]

Additionally, for a mini-LED chip (an LED device with a short side of 100 μm or more to several hundred μm) having a larger size than a micro LED chip (an LED device with a short side of 100 μm or less, further 50 μm or less), such a chip is often cracked when being transferred. Also, the micro LED chip is easily broken when it has an uneven surface as described above. The red LED chip has an element group different from that of a blue or green LED chip, and is thus relatively fragile and easily cracked. Therefore, the red LED chip may be similarly cracked in the transferring step.

[0088]

A thickness of a body of the microstructure 2 is not particularly limited, but is preferably about 3 to 10 μm. A thickness of the electrode is not particularly

limited, but is preferably 2 μm or less. A thickness of the bump is not particularly limited, but is preferably about 1 to 10 μm.

[0089]

The polymer material 3 in the present invention is useful as a protective material provided to protect the plurality of microstructures 2 provided on the base member 1 from the impact during transferring when the microstructures 2 are transferred from the base member 1 by virtue of laser irradiation. Preferably, the protective material is removed after the microstructures 2 are transferred because the microstructures 2 themselves can be easily used.

[0090]

The concept of the present invention can also be effectively applied to the transferring methods, but can also be applied to a detachment method. For example, a detachment method is exemplified for detaching a plurality of microstructures provided on a base member from the base member by virtue of laser irradiation, wherein at least a space between the microstructures adjacent to each other is filled with a polymer material, the detachment method includes: a first laser-irradiation step of irradiating the microstructures with a laser through the base member; and a second laser-irradiation step of irradiating the polymer material with a laser through the base member, and in the first laser-irradiation step, regions corresponding to the microstructures are irradiated with the laser directed to the microstructures. Components, conditions, and the like used in the detachment method may be the same as those in the transferring method described above.

[0091]

The polymer material 3 in the present invention is useful as a protective material provided to protect the plurality of microstructures 2 provided on the base member 1 from the impact during detachment when the microstructures 2 are detached from the base member 1 by virtue of laser irradiation. Preferably, the protective material is removed after the microstructures 2 are detached because the microstructures 2 themselves can be easily used. On the other hand, the protective material may be used temporarily or permanently as a support for the microstructures without being removed after the microstructures 2 are detached.

EXAMPLES

[0092]

Hereinafter, the present invention will be specifically described with reference to Examples and Comparative Examples. However, the present invention is not limited thereto.

[0093]

(Example 1)

[Preparation of Composite]

First, a composite having the same structure as the composite 10 described with reference to FIGS. 1 and 2 was provided. In the provided composite 10, a base member 1 was a sapphire substrate having a thickness of 700 μm and a diameter of 4 inches, and a plurality of microstructures 2 were each a 0.38-mm-square LED chip provided on the base member 1 via GaN 21. About 50000 microstructures were arranged in a matrix on the base material with a street having a width of 75 μm therebetween. A polymer material 3 was polyimide, and included at least a portion 31 filling a space between

adjacent microstructures 2, a portion 32 covering a top of the microstructures 2, and a portion 33 covering an outside of the microstructures 2, as shown in FIGS. 1 and 2. Then, a quartz substrate having the same shape as the base member was provided as a receiving substrate, and brought into contact with the side of the composite provided with the polymer material 3 and bonded thereto to obtain a laminate. The obtained laminate was fixed by suction to a stage of a laser-irradiation apparatus.

[0094]

[First Laser-Irradiation Step]

In this state, as shown in FIG. 3, regions 12 corresponding to the microstructures 2 were irradiated with a laser L1 from the base member 1 side of the composite 10. The laser L1 was an excimer laser with a wavelength of 248 nm and a pulse width of 20 ns, and an energy density (irradiance density) of the laser L1 was 1100 mJ/cm^2. By this first laser-irradiation step, the microstructures 2 were detached from the base material, but were kept in a state not separated from the base member 1 due to the presence of the polymer material 3.

[0095]

[Second Laser-Irradiation Step]

As shown in FIG. 4, the microstructures 2 and the polymer material 3 were irradiated with a laser L2. The laser L2 was an excimer laser with a wavelength of 248 nm, and an energy density (irradiation density) of the laser L2 was 150 mJ/cm^2. By this second laser-irradiation step, the microstructures 2 were separated from the base member 1 and transferred to the receiving substrate.

[0096]

About 50000 microstructures on the receiving substrate after the transferring were checked, and then no noticeable cracking or chipping of the microstructures 2 due to the transferring was found. FIG. 5 shows an optical micrograph.

[0097]

(Example 2)

The microstructures 2 were transferred from the composite 10 in the same manner as in Example 1 except that the polymer material 3 was silicone, the laser L2 in the second laser-irradiation step was the excimer laser with the wavelength of 248 nm, and the energy density (irradiation density) of the laser L2 was 300 mJ/cm^2. About 50000 microstructures on the receiving substrate after the transferring were checked, and then no noticeable cracking or chipping of the microstructures 2 due to the transferring was found.

[0098]

(Example 3)

The microstructures 2 were transferred from the composite 10 in the same manner as in Example 1 except that the polymer material 3 was an acrylic resin, the laser L2 in the second laser-irradiation step was the excimer laser with the wavelength of 248 nm, and the energy density (irradiation density) of the laser L2 was 200 mJ/cm^2. About 50000 microstructures on the receiving substrate after the transferring were checked, and then no noticeable cracking or chipping of the microstructures 2 due to the transferring was found.

[0099]

(Example 4)

The microstructures 2 were transferred from the composite 10 in the same manner as in Example 1 except

that the laser L2 in the second laser-irradiation step was an excimer laser with a wavelength of 193 nm, and the energy density (irradiation density) of the laser L2 was 100 mJ/cm^2. About 50000 microstructures on the receiving substrate after the transferring were checked, and then no noticeable cracking or chipping of the microstructures 2 due to the transferring was found.

[0100]

(Example 5)

The microstructures 2 were transferred from the composite 10 in the same manner as in Example 1 except that the laser L2 in the second laser-irradiation step was an excimer laser with a wavelength of 308 nm, and the energy density (irradiation density) of the laser L2 was 200 mJ/cm^2. The receiving substrate after the transferring was checked, and then no cracking or chipping of the microstructures 2 due to the transferring was found.

[0101]

(Example 6)

The microstructures 2 were transferred from the composite 10 in the same manner as in Example 1 except that the laser L2 in the second laser-irradiation step was an excimer laser with a wavelength of 351 nm, and the energy density (irradiation density) of the laser L2 was 200 mJ/cm^2. About 50000 microstructures on the receiving substrate after the transferring were checked, and then no noticeable cracking or chipping of the microstructures 2 due to the transferring was found.

[0102]

(Comparative Example)

The microstructures 2 were transferred from the composite 10 in the same manner as in Example 1 except

that all of the microstructures 2 and the polymer material 3 were irradiated with the laser L1 in the first laser-irradiation step, and the second laser-irradiation step was not performed. About 50000 microstructures on the receiving substrate after the transferring were checked, and then cracking were found in most of the microstructures 2 due to the transferring. FIG. 6 shows an optical micrograph.

[0103]

From the above results, it was confirmed that the transferring method of the present invention can transfer the microstructures 2 while preventing occurrence of cracking or chipping.

[0104]

Additionally, no debris derived from the polymer material 3 remained on the base member 1 after the transferring in each of Examples 1 to 6.

[0105]

The present description includes the following embodiments.

[1] A transferring method for transferring a plurality of microstructures provided on a base member from the base member by virtue of laser irradiation,

wherein at least a space between the microstructures adjacent to each other is filled with a polymer material,

the transferring method comprises:

a first laser-irradiation step of irradiating the microstructures with a laser through the base member; and

a second laser-irradiation step of irradiating the polymer material with a laser through the base member, and

in the first laser-irradiation step, regions corresponding to the microstructures are irradiated with the laser directed to the microstructures.

[2] The transferring method according to [1], wherein the second laser-irradiation step is performed after the first laser-irradiation step.

[3] The transferring method according to [1] or [2], wherein in the second laser-irradiation step, the polymer material and the microstructures are irradiated with the laser.

[4] The transferring method according to any one of [1] to [3], wherein the first laser-irradiation step is performed at an energy density at which the polymer material is sufficiently ablated.

[5] The transferring method according to any one of [1] to [4], wherein the plurality of microstructures are provided on the base member via GaN, and

the first laser-irradiation step is performed at an energy density at which GaN is thermally decomposed.

[6] The transferring method according to any one of [1] to [5], wherein the second laser-irradiation step is performed at an energy density lower than the energy density at which the polymer material is sufficiently ablated.

[7] The transferring method according to [6], wherein the second laser-irradiation step is performed at an energy density at which the polymer material is vaporized.

[8] The transferring method according to [7], wherein the second laser-irradiation step is performed at an energy density at which generation of carbon-based debris derived from the polymer material can be reduced.

[9] The transferring method according to any one of [1]

to [8], wherein the laser irradiation in the first laser-irradiation step and the laser irradiation in the second laser-irradiation step are performed by an excimer laser with a wavelength of 248 nm,

an energy density of the laser irradiation in the first laser-irradiation step is 700 mJ/cm^2 or more,

an energy density of the laser irradiation in the second laser-irradiation step is 30 to 500 mJ/cm^2.

[10] The transferring method according to any one of [1] to [9], wherein the second laser-irradiation step is performed a plurality of times.

[11] The transferring method according to any one of [1] to [10], wherein the base member on which the plurality of microstructures are provided is covered with the polymer material so as to cover the plurality of microstructures.

[0106]

It should be noted that the present invention is not limited to the above-described embodiments. The embodiments are just examples, and any examples that substantially have the same feature and demonstrate the same functions and effects as those in the technical concept disclosed in claims of the present invention are included in the technical scope of the present invention.

CLAIMS

[Claim 1] A transferring method for transferring a plurality of microstructures provided on a base member from the base member by virtue of laser irradiation,

wherein at least a space between the microstructures adjacent to each other is filled with a polymer material,

the transferring method comprises:

a first laser-irradiation step of irradiating the microstructures with a laser through the base member; and

a second laser-irradiation step of irradiating the polymer material with a laser through the base member, and

in the first laser-irradiation step, regions corresponding to the microstructures are irradiated with the laser directed to the microstructures.

[Claim 2] The transferring method according to claim 1, wherein the second laser-irradiation step is performed after the first laser-irradiation step.

[Claim 3] The transferring method according to claim 1 or 2, wherein in the second laser-irradiation step, the polymer material and the microstructures are irradiated with the laser.

[Claim 4] The transferring method according to any one of claims 1 to 3, wherein the first laser-irradiation step is performed at an energy density at which the polymer material is sufficiently ablated.

[Claim 5] The transferring method according to any one of claims 1 to 4, wherein the plurality of microstructures are provided on the base member via GaN, and

the first laser-irradiation step is performed at an energy density at which GaN is thermally decomposed.

[Claim 6] The transferring method according to any one of claims 1 to 5, wherein the second laser-irradiation step is performed at an energy density lower than the energy density at which the polymer material is sufficiently ablated.

[Claim 7] The transferring method according to claim 6, wherein the second laser-irradiation step is performed at an energy density at which the polymer material is vaporized.

[Claim 8] The transferring method according to claim 7, wherein the second laser-irradiation step is performed at an energy density at which generation of carbon-based debris derived from the polymer material can be reduced.

[Claim 9] The transferring method according to any one of claims 1 to 8, wherein the laser irradiation in the first laser-irradiation step and the laser irradiation in the second laser-irradiation step are performed by an excimer laser with a wavelength of 248 nm,

an energy density of the laser irradiation in the first laser-irradiation step is 700 mJ/cm^2 or more,

an energy density of the laser irradiation in the second laser-irradiation step is 30 to 500 mJ/cm^2.

[Claim 10] The transferring method according to any one of claims 1 to 9, wherein the second laser-irradiation step is performed a plurality of times.

[Claim 11] The transferring method according toany one of claims 1 to 10, wherein the base member on which the plurality of microstructures are provided is covered with the polymer material so as to cover the plurality of microstructures.