Method and Device for Producing a Plurality of Microlenses

Specification

This invention relates to a method for producing a plurality of microlenses from a lens material. Furthermore this invention relates to a device for producing a plurality of microlenses from a lens material.

Microlenses are used primarily for devices which require an optical focusing apparatus, such as for example cameras of mobile phones. As a result of miniaturization pressure the functional areas are becoming smaller and smaller. The farther the microlenses are to be miniaturized, the more difficult their optically correct production becomes because at the same time there is enormous cost pressure for the microlenses which are ideally to be manufactured in mass production. In the prior art microlenses are produced on a carrier substrate by different production methods, such as shown for example in US 6,846,137 B1, US 5,324,623, US 5,853,960 and US 5,871,888. It is common to all the aforementioned methods that dictated by principle a certain thickness is necessary and the light which passes through the microlens must pass not only through the lens, but the carrier substrate. Due to the simultaneously required high quality and demands for higher resolution with simultaneously higher brilliance which depends among others on the thickness and the number of optics along the optical axis, therefore the beam path, further optimization of the microlenses is desirable.

The fidelity of shape of a microlens is especially important. This is defined as the microlens having to be the exact negative of the die. Very often the fidelity of shape of a microlens during

the curing process of the microlens is not maintained since the microlens shrinks and therefore a differential volume arises between the die and the microlens.

Another important property of a good microlens is the optical axis. The elimination of a wedge fault of the die relative to the carrier is especially important for a correct optical axis of the microlens, since in the presence of the wedge fault during embossing the optical axis cannot be embossed exactly perpendicular to the carrier.

Embodiments of this invention disclose a device and a method with which microlenses can be produced especially in mass production and have high production precision, especially a very high fidelity to shape and an exactly aligned optical axis.

According to a first aspect, there is provided a method for producing a plurality of microlenses from a lens material with the following steps, especially with the following sequence:

- application of the lens material which is intended for the embossing of the microlenses in fluid form, to a plurality of first lens molds distributed on a first embossing side of a first die for embossing of the microlenses,
- turning the first die by 180°,
- moving the first die and a second die located essentially parallel, specifically in an X-Y plane, and opposite the first die, towards one another in a Z-direction which runs essentially perpendicular to the X-Y plane, especially by position control,
- embossing the microlenses by shaping and curing the lens material, the shaping taking place by moving the first and second embossing sides towards one another,

wherein an embossing force is measured during embossing, by means of which the embossing, especially at least during the curing, can be influenced, especially by force control, preferably in addition to the position control.

According to a second aspect, there is provided a device for producing a plurality of microlenses from a lens material with the following:

- a first die with first lens molds distributed on one embossing side of the first die,
- a first receiving apparatus for accommodating the first die on one receiving side which faces away from the embossing side, wherein the first die can be turned by 180° by means of the first receiving apparatus,
- a second receiving apparatus for accommodating a second die on its receiving side which faces away from its embossing side,
- application means for application of the lens material which is intended for embossing of the microlenses, especially a curable fluid, preferably polymer, in fluid form to first lens molds,
- embossing means for embossing of the microlenses by shaping and curing the lens material, the shaping taking place by movement of the first die and of the second die towards one another in the Z-direction, especially by means for position control of the first and second die relative to one another,

wherein there are measurement means for measuring an embossing force during embossing, by means of which the embossing, especially at least during the curing, can be influenced, especially by force control, preferably in addition to the position control.

All combinations of at least two of the features given in the specification, the claims and/or the figures also fall within the scope of the invention. At the given value ranges, values within the indicated limits will also be considered to be disclosed as boundary values and will be claimed in any combination.

The idea underlying embodiments of the invention is to emboss and cure at the same time the plurality of microlenses (microlens field) produced in one method pass, but to cure the individual microlenses spatially separate from one another. In this way any faults produced by the embossing and curing are limited to the respective microlens so that the faults are not cumulative. This furthermore has the positive consequence that the separation step for separation of the microlenses from one another can be omitted. The separation takes place more or less as dictated by the system, especially by separate application or by spatial separation by means of the die.

The separation of the microlenses from one another is also the prerequisite for the active,

force-regulated die control as per embodiments of the invention which at first ensures the fidelity of shape of all microlenses. If the microlenses were not separated from another, when the microlenses cure and in the course of the shrinkage process which begins with this the material would contract over the entire length of the wafer and thus would produce shrinkage of varying intensity depending on the position, which shrinkage could not be compensated at least over the entire wafer.

The contour accuracy can be obtained as per embodiments of the invention if it is ensured that the die during the curing process actively, therefore in a controlled manner, continues the embossing process until it is ensured that a change in the shape of the microlens no longer occurs since the curing process has been completely terminated.

The following method steps are provided as per embodiments of the invention, especially in the following sequence:

- application of the lens material which is intended for the embossing of the microlenses, especially a curable fluid, preferably polymer, in fluid form, to a plurality of first lens molds distributed on a first embossing side of a first die for embossing of the microlenses,
- moving the first die and a second die located essentially parallel, specifically in an X-Y plane, and opposite the first die, on top of one another in a Z direction which runs essentially perpendicular to the X-Y plane,
- recording an averaged force value from at least three actuators which control one of the two diees, at the start of the embossing process after complete filling of the die molds by the embossing material,
- curing the lens material and simultaneous re-adjustment of the distance of the two diees to one another by further movement on top of one another so that the force value which has

been determined at the start of curing remains the same or becomes at least greater during the curing process in order to ensure that any shrinkage of the lens material is compensated by movement of the diees on top of one another for all cases.

The device as per embodiments of the invention has in particular the following features:

- a first die with first lens molds distributed on one embossing side of the first die,
- a first receiving apparatus for accommodating the first die on one receiving side which faces away from the embossing side,
- a second receiving apparatus for accommodating a second die on its receiving side which faces away from its embossing side,
- application means for application of the lens material which is intended for embossing of the microlenses, especially a curable fluid, preferably polymer, in fluid form to the first lens molds,
- embossing means for embossing of the microlenses by shaping and curing the lens material, the shaping taking place by movement of the first die and of the second die on top of one another, especially to a thickness D_I of the lens material in the Z-direction, especially by means for position control of the first and second die relative to one another, there being measurement means for measuring an embossing force during embossing, by means of which the embossing, especially at least during the curing, can be influenced, especially by force control, preferably in addition to the position control.

In the entire document a die is defined as an element which comes into contact with the fluid which is to be cured and shapes it accordingly. In particular therefore also a simple planar wafer of Si, glass or another other material, even if it is not structured, can be regarded as a die.

An embodiment of the invention is characterized both according to the device and also the method especially in that the lens material of each microlens at least during curing is separate from the lens material of each microlens which is adjacent in the X-Y plane. The X-Y plane is especially defined by the first embossing side, one X-direction of the X-Y plane being perpendicular to one Y direction of the X-Y plane.

The control of the features described as per embodiments of the invention takes place especially by a control apparatus which is assigned to the device, preferably which is integrated into it. The apparatus acquires signals from sensors or detection means which are provided according to the device and delivers corresponding control or adjustment signals to the elements of the device which carry out the method as per embodiments of the invention.

The integrated control apparatus preferably consists of position controllers which can move at least one of the two diees so that movement of the two diees on top of one another, therefore a relative movement, is enabled. Furthermore there are at least three force transducers which have been installed in the device such that the determination of the surface pressure and thus the surface force on the X-Y plane between the two diees is enabled.

The force is controlled especially such that at least during the curing a force control, especially in addition to the position control, takes place, the embossing force being made to compensate for a shrinkage of the lens material during curing. This is preferably effected by force control such that the embossing force remains the same during curing or increases according to an especially position-dependent and/or time-dependent control.

The shape of the microlenses is determined on the one hand by the first lens molds and on the other hand by the second die which as per embodiments of the invention can have especially second lens

molds. The first lens molds are especially convexly or concavely curved, while the second die has in particular a planar embossing surface. The lens molds or diees thus form the negatives of the microlenses.

The lens material of the microlenses is arranged separately as per embodiments of the invention for each microlens especially from the application to the curing, preferably during the entire method as per embodiments of the invention. In other words, the lens material of the microlenses has in particular no direct connection among one another as per embodiments of the invention.

According to one advantageous embodiment of the invention, it is provided both according to the device and also according to the method that during curing, force-controlled and position-controlled approach of the two diees toward one another takes place so that possible shrinkages of the microlenses are compensated by recompressed material.

Alternatively or jointly with the preceding embodiment, one preferred approach consists in that during the curing and/or during the embossing an X-Y alignment of the first embossing side relative to the second embossing side takes place in the X-Y plane. For this purpose the device has in particular a receiving apparatus with a calibration table which is made to execute a translational and especially in addition a rotational movement of the diees toward one another.

Alternatively or jointly with the preceding embodiments, one preferred approach consists in that prior to curing and/or prior to embossing a wedge fault compensation by wedge fault compensation means for parallel alignment of the embossing sides takes place. The wedge fault compensation means cause an exact and reproducible, exactly vertical position of the optical axis of each microlens of the plurality of microlenses.

In particular, the wedge fault compensation or the X-Y alignment or the Z-correction can

take place especially continually after falling short of certain value of a distance between the first embossing side and the second embossing side of the die. This is because it is especially advantageous as per embodiments of the invention to carry out the alignment, correction and/or wedge fault compensation shortly before the embossing or curing of the lens wafer and during the curing since at this instant a minimum possible distance between the two opposite embossing sides is present so that especially with a position detection apparatus which is rigid to the embossing sides an extremely accurate detection of the position of the embossing sides and thus of the position of the wafer and the die is enabled. By detecting the position of the diees and the respective embossing sides to one another exact control of the wedge fault compensation means and of the X-Y alignment means is possible. Accordingly it is especially advantageous if the shaping takes place position-controlled and/or force-controlled according to one advantageous embodiment of the invention. As per embodiments of the invention, position detection by means of capacitive and/or inductive distance meters and/or optical devices such as interferometers could take place.

To the extent the diees have corresponding alignment marks for wedge fault compensation and/or for X-Y alignment, especially on their embossing side, preferably at least on one peripheral edge of the diees, a still more exact detection of the position of the embossing sides can be implemented and by the arrangement of the alignment marks on the embossing sides, especially integrated flush into the embossing sides, the distance between the alignment marks is as small as possible. In this way the accuracy of position detection by detection means as per embodiments of the invention, especially in the form of optics, preferably microscopes, is substantially increased.

It is especially advantageous here if the lens material is transparent to electromagnetic rays, especially to light, so that during the alignment the position detection takes place through the lens

material, there being markings under the lenses. Hereinafter this is called in-liquid alignment and this measure yields a range of the depth of focus of position detection means provided as per embodiments of the invention, especially optics for detecting the position of the alignment marks and of the embossing sides of the diees, which range is enlarged especially by the index of refraction of the fluid as a multiplier.

As a consequence, it is especially advantageous if there are optical position detection means, especially optics, for wedge fault compensation and/or for X-Y alignment and/or for Z-correction, during the wedge fault compensation and/or the X-Y alignment and/or Z-correction both the embossing side of the first die or its alignment marks and also the embossing side of the second die or its alignment marks being located especially at the same time in the range of the depth of focus of the optical position detection means which are rigid especially to the die. As per embodiments of the invention it is therefore no longer necessary to shift the position detection means during the position detection or during the alignment and shaping so that the position detection means themselves have no effect on the relative position of the first die to the second die and thus an additional fault source is precluded. In the prior art the problem arose that either a rigid position detection means with a larger range of the depth of focus or a movable position detection means with a smaller range of the depth of focus had to be used. This dilemma is resolved by this measure as per embodiments of the invention.

By the distance between the embossing side (or the alignment marks) of the first die and the embossing side (or the alignment marks) of the second die in the Z-direction being greater than 0 and at the same time smaller than the range of the depth of focus in the Z-direction during position detection, the detection accuracy is improved and increased.

According to another embodiment of the invention, it is advantageously provided according to the device and/or method that the application of the lens material takes place by application of droplets. For this purpose according to the device there are droplet application means, especially a droplet dispenser. With these droplet application means exact metering of the respective amount of the lens material for each microlens can be controlled. The control takes place especially via the control apparatus.

The separation of the lens material of each microlens of the microlens field takes place according to another advantageous embodiment of the invention by free spaces which at least partially, especially completely surround the first lens molds being provided for separation of the lens material of adjacent microlenses during curing. Thus the lens material of the microlenses is separated at least predominantly, preferably completely from one another in space.

To the extent as per embodiments of the invention a shrinkage of the microlenses during curing is compensated especially by the wedge fault compensation means and/or the X-Y alignment means and/or by Z-correction and/or the position detection means, the accuracy of the microlenses is again distinctly increased.

As another embodiment of the invention there is moreover a microlens field which is produced by the device as per embodiments of the invention and/or the method as per embodiments of the invention and which consists of the following features:

- a second die which is made especially as a flat substrate, preferably a wafer, with a plurality of microlenses which have been cured and embossed from the second die and which are located separate from one another on the second die.

  In particular the second die, especially on the embossing side, preferably at least on one

Claims

1. A method for producing a plurality of microlenses (10) from a lens material with the following steps, especially with the following sequence:

- application of the lens material which is intended for the embossing of the microlenses (10) in fluid form, to a plurality of first lens molds (5) distributed on a first embossing side (3o) of a first die (3) for embossing of the microlenses (10),
- turning the first die (3) by 180°,
- moving the first die (3) and a second die (4) located essentially parallel, specifically in an X-Y plane, and opposite the first die (3), towards one another in a Z-direction which runs essentially perpendicular to the X-Y plane, especially by position control,
- embossing the microlenses (10) by shaping and curing the lens material, the shaping taking place by moving the first and second embossing sides (3o, 4o) towards one another,

wherein an embossing force is measured during embossing, by means of which the embossing, especially at least during the curing, can be influenced, especially by force control, preferably in addition to the position control.

2. The method as claimed in Claim 1, wherein the lens material of each microlens (10) at least during curing is separate from the lens material of each microlens (10) which is adjacent in the X-Y plane.

3. The method as claimed in Claim 1 or 2, wherein during the curing and/or during the embossing an X-Y alignment of the first embossing side (3o) relative to the second embossing side (4o) takes place in the X-Y plane.

4. The method as claimed in one of the preceding claims, wherein the first die (3) and the second die (4), especially on their embossing sides (3o, 4o), preferably at least on their peripheral edges (3u, 4u), have alignment marks (6, 6', 7, 7') corresponding to one another for wedge fault compensation and/or for X-Y alignment.

5. The method as claimed in one of the preceding claims, wherein the lens material is applied by application of droplets.

6. The method as claimed in one of the preceding claims, wherein there are free spaces (11) which at least partially, especially completely surround the first lens molds (5) for separation of the lens material of adjacent microlenses (10) during curing.

7. The method as claimed in one of the preceding claims, wherein shrinkage of the microlenses (10) is compensated during curing.

8. A device for producing a plurality of microlenses (10) from a lens material with the following:

- a first die (3) with first lens molds (5) distributed on one embossing side (3o) of the first die (3),
- a first receiving apparatus for accommodating the first die (3) on one receiving side (3a) which faces away from the embossing side (3o), wherein the first die (3) can be turned by 180° by means of the first receiving apparatus,
- a second receiving apparatus for accommodating a second die (4) on its receiving side (4a) which faces away from its embossing side (4o),
- application means for application of the lens material which is intended for embossing of the microlenses (10), especially a curable fluid (3), preferably polymer, in fluid form to first lens molds (5),
- embossing means for embossing of the microlenses by shaping and curing the lens

material, the shaping taking place by movement of the first die (3) and of the second die (4) towards one another in the Z-direction, especially by means for position control of the first (3) and second die (4) relative to one another,

wherein there are measurement means for measuring an embossing force during embossing, by means of which the embossing, especially at least during the curing, can be influenced, especially by force control, preferably in addition to the position control.

9. The device as claimed in Claim 8 which is made such that the lens material of each microlens (10) can be applied by application means such that at least during curing it is separate from the lens material of each microlens (10) which is adjacent in the X-Y plane.

10. The device as claimed in Claim 8 or 9 which is made such that by X-Y alignment of the device during curing and/or during embossing an X-Y alignment of the first embossing side (3o) relative to the second embossing side (4o) can be carried out in one X-Y plane.

11. The device as claimed in at least one of Claims 8 to 10 which is made such that for wedge fault compensation and/or for X-Y alignment in the first die (3), especially on the first embossing side (3o), preferably at least on one peripheral edge (3u) of the first die (3), there are first alignment marks (6, 6') which are arranged corresponding to the second alignment marks (7, 7') of the second die (4).

12. The device as claimed in at least one of Claims 8 to 11, wherein the application means are made as droplet application means, in particular a droplet dispenser (1).

13. The device as claimed in at least one of Claims 8 to 12, wherein the device has free spaces (11) which at least partially, especially completely surround the first lens molds (5) for separation of the lens material of adjacent microlenses (10) during curing.

14. The device as claimed in at least one of Claims 8 to 13, wherein the device has compensation means for compensation of a shrinkage of the microlenses (10) during curing.