

Method and Device for Producing a Lens Wafer

This invention relates to a method and a device for producing, especially stamping, a lens wafer which has a plurality of microlenses according to Claims 1 and 8. Furthermore as claimed in the invention a lens wafer according to Claim 11 and microlenses which have been produced from the lens wafer according to Claim 12 are provided.

Microlenses are used primarily for devices which require an optical focusing means, such as for example cameras of cell phones. As a result of miniaturization pressure, functional regions will become smaller and smaller. The more the microlenses are to be miniaturized, the more difficult their optically correct production becomes, because at the same time the cost pressure for the microlenses which are ideally to be produced in mass production is enormous. In the prior art microlenses are produced on a carrier substrate by different production methods, such as for example as shown 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 fundamentally a certain thickness is necessary and the light which passes through the microlens must pass not only through the lens, but the carrier substrate. As a result of 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 along the beam path, further optimization of the microlenses according to the prior art is desirable.

The greatest problem for these microlenses with carriers is the correct alignment of the

stamping die relative to the carrier. Faults in the alignment are often exacerbated by the microlenses which have been produced with carriers generally being stacked.

The elimination of a wedge fault of the die relative to the carrier is especially important for a correct optical axis of the microlenses, since in the presence of a wedge fault during stamping the optical axis cannot be stamped exactly perpendicular to the carrier.

The object of this invention is to devise a device and a method with which, especially in mass production, microlenses with carriers can be produced which have high production accuracy, especially an exactly aligned optical axis.

This object is achieved with the features of Claims 1 and 8 as well as 10 and 11. Advantageous developments of the invention are given in the dependent claims. All combinations of at least two of the features given in the specification, the claims and/or the figures also fall within the framework of the invention. At the given value ranges, values which lie within the indicated limits will also be considered disclosed as boundary values and will be claimed in any combination.

The invention is based on the idea of aligning the carrier, especially the wafer, during stamping, especially during shaping of the curable fluid relative to the stamping die. In this way in-situ alignment is enabled. This furthermore has the positive consequence that the distance D between the die and the carrier, especially towards the end of shaping of the microlens field, is as small as possible. In this way the alignment can be done much more precisely than in the prior art.

The following method steps are provided as claimed in the invention, especially in the sequence cited below:

- application of the lens material, especially of a curable fluid, preferably a polymer, in fluid form to one stamping side of the wafer and/or to one stamping side of a die, which side has

- lens molds for stamping of the microlenses,
- movement of the die which is located essentially parallel, specifically in an X-Y plane, and oppositely to the wafer, together, in a Z-direction which runs perpendicular to the X-Y plane,
 - stamping of the lens wafer by shaping and subsequent curing of the lens material, the shaping taking place by moving the dies together.

The invention is characterized in that wedge faults are equalized by wedge fault equalization means for parallel alignment of the stamping sides and/or an X-Y alignment of the die with the wafer during shaping. The X-Y alignment means an alignment in the X-Y plane, therefore includes especially rotation in the X-Y plane.

The wedge fault equalization is especially important for the quality of the microlenses produced by the method as claimed in the invention since wedge fault equalization according to this invention enables a much more exact and reproducible, exactly vertical position of the optical axis of the microlenses.

According to one advantageous embodiment of the invention, it is provided that the wedge fault equalization or the X-Y alignment takes place especially continuously after a certain value of a distance D of the stamping side of the wafer and the stamping side of the die is no longer reached. This is because as claimed in the invention it is especially advantageous to carry out alignment briefly before the stamping or curing of the lens wafer since at this instant the distance D between the stamping sides is the minimum possible so that especially with a position detection means which is rigid to the stamping sides extremely accurate detection of the position of the stamping sides and thus the position of the wafer and the die is enabled. Detecting the position of the wafer

and of the die or of the respective stamping sides to one another enables exact control of the wedge fault equalization means and of the X-Y alignment by X-Y alignment means.

Accordingly it is especially advantageous when shaping according to one embodiment of the invention takes place position-controlled.

To the extent for wedge fault equalization and/or for X-Y alignment in the die, especially on its stamping side, preferably at least on one peripheral edge of the die, and in the wafer, especially on its stamping side, preferably at least on one peripheral edge of the wafer, there are corresponding alignment marks, still more exact detection of the position of the stamping sides can be accomplished, and integrated into the stamping sides, especially flush, by the arrangement of the position marks on the stamping sides, the distance between the position marks is as small as possible. In this way the accuracy of the position detection is distinctly increased.

According to another advantageous embodiment of the invention it is provided that the wedge fault equalization and/or X-Y alignment take place since both the stamping side of the die and also the stamping side of the wafer are at least partially, preferably predominantly, covered by the fluid. It is especially advantageous if the fluid is transparent to electromagnetic rays, especially to light, that during alignment the position detection takes place through the fluid. This is hereinafter called in-liquid alignment and this measure yields a depth of field region of the position detections means provided as claimed in the invention, especially optics for detecting the position of the position marks or of the stamping sides of the wafer and of the die, which depth of field region is enlarged by the index of refraction of the fluid as multiplier.

As a consequence it is especially advantageous when there are optical position detection means, especially optics, for wedge fault equalization and/or for X-Y alignment, during the wedge

fault equalization and/or the X-Y alignment both the stamping side of the die or its alignment marks and also the stamping side of the wafer or its alignment marks being located, especially at the same time, in the depth of field region of the optical position detection means which are rigid especially to the wafer. Therefore according to the invention it is no longer necessary to shift the position detection means during position detection or during the alignment and the shaping, so that the position detection means themselves do not have any effect on the relative position of the die to the wafer and therefore an additional fault source is precluded. In the prior art the problem was that either a rigid position detection means with a larger depth of field region or a movable position detection means with a smaller depth of field region had to be used. This dilemma is resolved by this measure as claimed in the invention.

The detection precision is improved or increased by the distance D between the stamping side of the die and the stamping side of the wafer in the Z direction being greater than 0 and at the same time smaller than the depth of field region in the Z-direction during the position detection.

A device as claimed in the invention for producing a lens wafer which has a plurality of microlenses has the following features:

- a die with one stamping side with a stamping structure which has lens molds,
- a first receiving means for accommodating the die on one receiving side which faces away from the stamping side,
- a second receiving means for accommodating a wafer on its receiving side which faces away from its stamping side,
- application means for application of a curable fluid, especially a polymer, in fluid form to the stamping side or the stamping side,

- wedge fault equalization means and/or X-Y alignment means,
- stamping means for stamping of a lens wafer by shaping and curing of the curable fluid.

The device as claimed in the invention is characterized in that during shaping the wafer can be aligned relative to the die by the wedge fault equalization means and/or the X-Y alignment means. In the past, alignment of the wafer relative to the die, therefore wedge fault equalization or X-Y alignment, had not been possible during shaping of the lens wafer.

The device as claimed in the invention is improved in that for wedge fault equalization and/or for X-Y alignment in the die, especially on the stamping side, preferably at least on one peripheral edge of the die, there are alignment marks which are arranged corresponding to alignment marks of the wafer.

The invention is further improved in that for wedge fault equalization and/or for X-Y alignment there are optical position detection means, especially optics, during the wedge fault equalization and/or the X-Y alignment both the stamping side of the die or its alignment marks and also the stamping side or its alignment marks, can be arranged, especially at the same time, in the depth of field region of the optical position detection means which are rigid especially to the wafer.

As an independent invention there is moreover a lens wafer which consists of the following features:

- a wafer with alignment marks which are designed for wedge fault equalization and/or for X-Y alignment in the wafer especially on the stamping side, preferably at least on one peripheral edge of the wafer and
- a microlens field which has been applied to the wafer, which has been aligned with the wafer by the wedge fault equalization and/or X-Y alignment, and which has been cured on

the wafer.

Moreover one or more microlenses which have been produced from the lens wafer by separation can be regarded as an independent invention.

A lens wafer which is produced by the device described as claimed in the invention and/or the method described as claimed in the invention can be regarded as an independent invention.

As another independent inventive idea it is conceivable as claimed in the invention to provide instead of the wafer a second die for shaping of the curable fluid with which the curable fluid is shaped on its second side. The result would be a monolithic lens wafer which is formed exclusively from the curable fluid.

Other advantages, features and details of the invention will become apparent from the following description of preferred exemplary embodiments and using the drawings:

Figure 1 shows a schematic cutaway side view of a device as claimed in the invention for producing a lens wafer which has a plurality of microlenses,

Figures 2a to 2c show a schematic of a method sequence as claimed in the invention for producing a lens wafer,

Figures 3a to 3c show a schematic of a method sequence as claimed in the invention in another embodiment of the method as claimed in the invention and

Figures 4a to 4c show a schematic of the method sequence according to Figures 2a to 2c with another embodiment of the device as claimed in the invention, specifically a modified die.

In the figures the advantages and features of the invention are identified with reference numbers which identify them according to embodiments of the invention, components and features with the same or equivalent function being identified with identical reference numbers.

Figure 1 shows a device as claimed in the invention for producing a lens matrix 25 which has a plurality of microlenses 24 (see Figures 2c, 3c and 4c).

For stamping of the lens matrix 25 onto an especially planar wafer 2, a die 1 with one stamping side 1o with a stamping structure 21 which has lens molds 8 can be held in a first receiving means. The first receiving means consists of a holding device 9 which is ring-shaped especially on the inside, on whose peripheral shoulder 9u which is pointed toward the interior of the ring a receiver 11 which is provided with suction paths 10 can be inserted and fixed. In turn the die 1 on its receiving side 1a facing away from the stamping side 1o can be fixed on the receiver 11 via the suction paths 10. In addition the die 1 on its peripheral edge 1u is supported by an inner ring wall 9i of the holding device 9.

The first receiving means is rigidly located in the device, especially on a rack which is not shown, and above the receiving means there are optical position detection means in the form of microscopes 22, 23 which are fixed or can be fixed relative to the receiving means or the die 1 at least in one Z-direction which corresponds to one stamping direction. The Z-direction or stamping direction is orthogonal to an X-Y plane or to an X-direction and Y-direction which spans the X-Y plane. Exactly orthogonally to the Z-direction and thus parallel to the stamping side 1o of the die 1, therefore to the X-Y plane, as claimed in the invention there can be a wafer 2 with its stamping side 2o opposite the stamping side 1o, at the instant of stamping of the lens matrix 25 onto the wafer 2. The lens matrix 25 and the wafer 2 jointly form a lens wafer 12.

The wafer 2 can be fixed on a movable second receiving means. The movable receiving means consists of actuators 19 which are aligned to act in the Z-direction. Actuators 19 can be for example spindles. The actuators 19 can be each individually controlled by one control means. There

are one X-drive 18 and one Y-drive 17 on the actuators 19. With the X-drive 18 a movement of the wafer 2 in the X-direction which is controlled by the control means is possible, while the Y-drive 17 can cause a movement of the wafer 2 in the Y-direction.

Furthermore there is a rotation means 16 between the actuators 19 and the wafer 2 with which a rotational movement which rotates around an axis of rotation which runs in the Z-direction can be executed by the control means.

Between the X-drive 18, the Y-drive 17 and the rotation means 16 and the wafer 2 a receiver 14 is fixed which in turn has suction paths 13. On the suction paths 13 the wafer 2 can be fixed on its receiving side 2a which is opposite the stamping side 2o.

The die 1 in the region of the peripheral edge 1u has outer alignment marks 4 which can be aligned with reference to outer corresponding alignment marks 6 of the wafer 2. The outer alignment marks 4, 6 are located especially laterally outside the stamping structures 21 or the lens molds 8, preferably at no instant of the stamping process, especially of shaping, covered by a lens material which forms the lens matrix 25 in the form of a curable fluid 3. The outer alignment marks 4, 6 can be used for example for rough alignment of the die 1 relative to the wafer 2.

Furthermore the die 1 has inner alignment marks 5 which can be aligned to corresponding inner alignment marks 7 of the wafer 2. The inner alignment marks 5, 7 are located outside or between the lens molds 8, especially translationally symmetrically on the die 1 or the wafer 2. During the stamping process or during shaping, the alignment marks 5, 7 are covered with the lens material or the curable fluid 3 at least towards the end of the stamping process or shaping.

The device moreover has application means for application of the curable fluid 3, especially a polymer, in fluid form to the stamping side 1o and/or the stamping side 2o which are not shown.

The application means can consist for example of a metering line which can be placed in the intermediate space between the die 1 and the wafer 2.

The individually controllable actuators 19 can execute wedge fault equalization by the relative position of the alignment marks 4, 5, 6, 7 to one another being detectable by the position detection means 22, 23 and by a possible wedge fault being corrected accordingly.

Likewise X-Y alignment takes place by the X-drive 18 and the Y-drive 17 as well as the rotation means 16.

The die 1 and the wafer 2 are moved together by the actuators 19 which can be moved in the Z-direction and the curable fluid is shaped during the movement together.

The stamping means furthermore comprise, in addition to the features provided for shaping, curing means for curing of the curable fluid 3 which are triggered by the control means as soon as the shaping of the lens wafer 25 is completed.

The position detection means 22, 23 are located on the side of the receiver 11 facing away from the stamping side 10 and the position is detected through the receiver and die 1 which are transparent to electromagnetic radiation, especially visible or UV light. As claimed in the invention it is especially advantageous if position detection means with a depth of field less than 100 μm , especially less than 50 μm , preferably less than 25 μm , can be used.

The wafer 2 is generally transparent to corresponding electromagnetic radiation. The wafer 2 can be non-transparent when the final product is not transmission lenses, but only reflection lenses.

In the method step shown in Figure 2a, curable fluid 3 is centrally applied to the wafer 2 by the above described application means which are not shown for application of the curable fluid 3 to

the wafer 2.

Subsequently, according to Figure 2b and by means of the actuators 19, the wafer 2 is moved onto the rigid die 1 and during the movement together the curable fluid 3 is shaped by the curable fluid 3 moving from the center of the wafer 2 in the direction of the peripheral edge 1u or peripheral edge 2u.

As soon as shaping according to Figure 2c is completed, the movement in the Z-direction is stopped by the control means. The control quantity is for example a distance D between the stamping side 1o and the stamping side 2o.

Until the preset distance D is reached and within the depth of field region of the position detection means, during the movement together, therefore during shaping of the curable fluid 3, wedge fault equalization can take place continually by the wedge fault equalization means and/or an X-Y alignment can take place by the X-Y alignment means so that when the preset distance D is reached the die 1 is aligned exactly and without wedge faults relative to the wafer 2. The corresponding alignment marks 4, 5, 6, and 7 at this instant all have exactly the same distance and since the alignment marks 4, 5, 6, 7 are each arranged flush on the stamping side 1o or 2o, the distance of the alignment marks 4, 5, 6, 7 corresponds to the preset distance D.

According to one preferred version, alignment takes place only within the depth of field, preferably during or after reaching the preset distance D.

The wedge fault equalization and the X-Y alignment take place preferably at least while the distance D is less than 100 μm , especially less than 50 μm , preferably less than 25 μm .

In the embodiment of the method according to Figures 3a to 3c the device according to Figure 1 is more or less reversed so that the wafer 2 is located above the die 1 and in this

embodiment the die 1 is moved onto the wafer 2, while the wafer 2 remains rigid.

The position detection means are located underneath the die 1 in this case. The curable fluid 3 is applied into/onto the lens molds 8 by droplet deposition. In the case of concave lens molds 8 the curable fluid 3 is automatically held in a stable position by the force of gravity and the recess. In a convex lens mold the curable fluid has a relatively high viscosity in order to stabilize the polymer on the die or on the lens mold 8.

By moving the die 1 and the wafer 2 closer to one another the curable fluid 3 will come into contact with the stamping side 2o of the wafer 2. Depending on the amount of curable fluid 3, the distance of the lens molds 8 to one another and the ambient conditions, the inner alignment marks 5, 7 can be separated by the curable fluid 3, air, gas, especially inert gas, preferably nitrogen or vacuum.

According to one version of the embodiment according to Figures 3a to 3c the die 1 is located above and the wafer 2 below, and the curable fluid 3 in this case can also be applied to the die 1 since as a result of the adhesion forces between the curable fluid 3 and the die the curable fluid 3 can adhere to the die 1.

According to another embodiment of the invention shown in Figures 4a to 4c, in contrast to the embodiment according to Figures 2a to 2c it is provided that the die 1 has projections 26. The projections 26 extend above the stamping side 1o and in the projections 26 there are alignment marks 4, 5 so that the alignment marks 4, 5 can be located nearer the corresponding alignment marks 6, 7 when the lens wafer 25 is being molded. The result is even more accurate alignment at a given thickness or height of the microlenses 25.

Otherwise the method according to Figures 4a to 4c corresponds to the method according to

Figures 2a to 2c.

The curable fluid 3 is cured by irradiation means for producing electromagnetic radiation, especially in the form of at least one lamp 27, preferably a UV lamp, which means are located above or within the receiver 11.

Reference number list

1	die
1a	receiving side
1o	stamping side
1u	peripheral edge
2	wafer
2a	receiving side
2o	stamping side
2u	peripheral edge
3	curable fluid
4	alignment marks
5	alignment marks
6	alignment marks
7	alignment marks
8	lens molds
9	holding device
9u	peripheral shoulder
9i	ring wall
10	suction paths
11	receiver
12	lens wafer
13	suction paths

14	receiver
16	rotation means
17	Y-drive
18	X-drive
19	actuators
21	stamping structure
22	microscope
23	microscope
24	microlenses
25	lens matrix
26	projections
27	lamp
D	distance
Z	Z-direction
Y	Y-direction
X	X-direction

Claims

1. Method for producing a lens wafer (12) which has a plurality of microlenses and which consists of a lens material and a wafer (2), with the following steps, especially with the following sequence:

- application of the lens material, especially of a curable fluid (3), preferably a polymer, in fluid form to one stamping side (2o) of the wafer (2) and/or to one stamping side (1o) of a die (1), which side has lens molds (8) for stamping of the microlenses,
- movement of the die (1) which is located essentially parallel, specifically in an X-Y plane, and oppositely to the wafer (2), together in a Z-direction which runs perpendicular to the X-Y plane,
- stamping of the lens wafer (12) by shaping and subsequent curing of the lens material, the shaping taking place by moving the dies (1, 2) together,

characterized in that wedge faults equalization takes place by wedge fault equalization means (19) for parallel alignment of the stamping sides (1o, 2o) and/or an X-Y alignment of the die (1) with the wafer (2) during shaping.

2. Method as claimed in Claim 1, wherein the wedge fault equalization and/or the X-Y alignment takes place especially continuously after a distance D between the stamping side (1o) and the stamping side (2o) is no longer reached.

3. Method as claimed in Claim 1 or 2, wherein shaping takes place position-controlled.

4. Method as claimed in Claim 1 or 2, wherein there are corresponding alignment marks (4, 5, 6, 7) for wedge fault equalization and/or for X-Y alignment in the die (1), especially on the

stamping side (1o), preferably at least on one peripheral edge (1u) of the die (1), and in the wafer (2), especially on the stamping side (2o), preferably at least on one peripheral edge (2u) of the wafer (2).

5. Method as claimed in Claim 1 or 2, wherein the wedge fault equalization and/or X-Y alignment take place since both the stamping side (1o) and also the stamping side (2o) are at least partially, preferably predominantly, covered by the fluid (3).

6. Method as claimed in Claim 1 or 2, wherein there are optical position detection means, especially optics, for wedge fault equalization and/or for X-Y alignment, during the wedge fault equalization and/or the X-Y alignment both the stamping side (1o) or its alignment marks (4, 5) and also the stamping side (2o) or its alignment marks (6, 7) being located, especially at the same time, in the depth of field region of the optical position detection means () which are rigid especially to the wafer (2).

7. Method as claimed in Claim 6, wherein a distance D between the stamping side (1o) and the stamping side (2o) in the Z direction is greater than 0 and at the same time smaller than the depth of field region in the Z-direction.

8. Device for producing a lens wafer (25) which has a plurality of microlenses with:

- a die (1) with one stamping side (1o) with a stamping structure (21) which has lens molds (8),
- a first receiving means for accommodating the die (1) on one receiving side (1a) which faces away from the stamping side (1o),
- a second receiving means for accommodating a wafer (2) on its receiving side (2a) which faces away from its stamping side (2o),

- application means for application of a curable fluid (3), especially a polymer, in fluid form to the stamping side (1o) or the stamping side (2o),
 - wedge fault equalization means (19) and/or X-Y alignment means,
 - stamping means for stamping of a lens wafer by shaping and curing of the curable fluid (3),
- and

the wafer (2) during shaping can be aligned relative to the die (1) by the wedge fault equalization means and/or the X-Y alignment means.

9. Device as claimed in Claim 8, wherein for wedge fault equalization and/or for X-Y alignment in the die (1), especially on the stamping side (1o), preferably at least on one peripheral edge (1u) of the die (1), there are alignment marks (4, 5) which are arranged corresponding to alignment marks (6, 7) of the wafer (2).

10. Device as claimed in Claim 8 or 9, wherein there are optical position detection means, especially optics, for wedge fault equalization and/or for X-Y alignment, during the wedge fault equalization and/or the X-Y alignment both the stamping side (1o) or its alignment marks (4, 5) and also the stamping side (2o) or its alignment marks (6, 7) being located, especially at the same time, in the depth of field region of the optical position detection means which are rigid especially to the wafer (2).

11. Lens wafer consisting of the following:

- a wafer (2) with alignment marks (6, 7) which are designed for wedge fault equalization and/or for X-Y alignment in the wafer (2) especially on the stamping side (2o), preferably at least on one peripheral edge (2u) of the wafer (2) and
- a microlens field () which has been applied to the wafer (2), which has been aligned with

the wafer (2) by the wedge fault equalization and/or X-Y alignment, and which has been cured on the wafer (2).

12. Microlenses which have been produced from a lens wafer as claimed in Claim 11 by separation.