Claims

1. Method for automated inline determination of the refractive power of an ophthalmic lens (5) in an automated manufacturing line for ophthalmic lenses, for example soft contact lenses, the method comprising the steps of:
- providing an inspection cuvette (2) comprising an optically transparent bottom (21) having a concave inner surface (210) and containing the ophthalmic lens (5) immersed in a liquid, and positioning the inspection cuvette at a first inspection location (800) of an inspection module (1) of the automated manufacturing line;
- providing a light source (42) and a wavefront sensor (6), the wavefront sensor (6) comprising a detector (602) for receiving light coming from the light source (42) and having passed the ophthalmic lens (5) contained in the inspection cuvette (2) and impinging on the detector (602), thus generating signals at the detector;
- comparing the signals generated at the detector (602) with predetermined signals representative of a reference refractive power thereby determining the refractive power of the ophthalmic lens (5).

2. Method according to claim 1, wherein the step of providing a wavefront sensor (6) comprises providing a wavefront sensor comprising an array of micro-lenses (501), for example a Shack-Hartmann-sensor (60).

3. Method according to claim 1 or claim 2, wherein the step of determining the refractive power of the ophthalmic lens (5) comprises
- providing the inspection cuvette (2) comprising the optically transparent bottom (21) and containing the liquid but not containing the ophthalmic lens (5) at the first inspection location (800) of the inspection module (1) of the automated manufacturing line;
- the wavefront sensor (6) receiving light coming from the light source (42) and having passed the optically transparent bottom (21) of the inspection cuvette (2) and the liquid and impinging on the detector (602), and from the signals thus

generated at the detector (602) determining the refractive power of the inspection cuvette (2) containing the liquid but not containing the ophthalmic lens;

- considering the refractive power of the inspection cuvette containing the liquid but not containing the ophthalmic lens when determining the refractive power of the ophthalmic lens.

4. Method according to claim 3, wherein the step of considering the refractive power of the inspection cuvette containing the liquid but not containing the ophthalmic lens when determining the refractive power of the ophthalmic lens comprises

- providing the inspection cuvette (2) containing the ophthalmic lens (5) immersed in the liquid at the first inspection location (800) of the inspection module (1) of the automated manufacturing line;

- generating at the detector (602) of the wavefront sensor (6) signals representative of the collective refractive power of the inspection cuvette (2) containing the ophthalmic lens (5) immersed in the liquid;

- subtracting the refractive power of the inspection cuvette (2) containing the liquid but not containing the ophthalmic lens from the collective refractive power of the inspection cuvette (2) containing the ophthalmic lens, thus obtaining the refractive power of the ophthalmic lens (5).

5. Method according to any one of the preceding claims, further comprising the steps of:

- comparing the determined refractive power of the ophthalmic lens (5) with a predetermined set refractive power of the ophthalmic lens (5); and

- identifying the ophthalmic lens (5) as having an unacceptable refractive power if the determined refractive power of the ophthalmic lens (5) is outside a predetermined range of tolerance around the predetermined set refractive power of the ophthalmic lens (5), or

- identifying the ophthalmic lens (5) as having an acceptable refractive power if the

determined refractive power of the ophthalmic lens (5) is within the predetermined range of tolerance around the predetermined set refractive power of the ophthalmic lens (5); and

- removing the ophthalmic lens (5) from the manufacturing line in case the ophthalmic lens (5) has been identified as having an unacceptable refractive power, but further processing the ophthalmic lens (5) in the manufacturing line in case the ophthalmic lens (5) has been identified as having an acceptable refractive power.

6. Method according to any one of the preceding claims, comprising the steps of:

- providing a plurality of inspection cuvettes (2), each inspection cuvette (2) comprising an optically transparent bottom (21) having a concave inner surface (210) and containing an ophthalmic lens (5) immersed in a liquid, and positioning the plurality of inspection cuvettes (2) at the first inspection location (800) of the inspection module;

- sequentially determining the refractive power of each of the ophthalmic lenses (5) contained in the plurality of inspection cuvettes (2).

7. Method according to any one of the preceding claims, further comprising the step of:

- after determination of the refractive power of the ophthalmic lens (5) or the ophthalmic lenses (5), moving the inspection cuvette (2) containing the ophthalmic lens or the plurality of inspection cuvettes containing the ophthalmic lenses from the first inspection location (800) to a second inspection location (900); and

- at the second inspection location (900) performing an inline optical inspection of the ophthalmic lens (5) contained in the inspection cuvette (2) or of the ophthalmic lenses contained in the inspection cuvettes for the presence of other deficiencies.

8. Method according to any one of claims 1 to 7, further comprising the steps of:

- positioning the inspection cuvette (2) at a third inspection location (700) of the

inspection module (1) for of the automated manufacturing line, for determination of the center thickness of the ophthalmic lens;

- providing an interferometer (3) comprising a light source and a focusing probe (30), the focusing probe focusing light coming from the light source to a set position (310) of the ophthalmic lens at the center of the concave inner surface of the optically transparent bottom of the inspection cuvette (2) and the focusing probe (30) further directing light reflected at the boundary (510) between the back surface (51) of the ophthalmic lens and the liquid on the one hand as well as light reflected at the boundary (500) between the front surface (50) of the ophthalmic lens and the liquid or light reflected at the boundary (502) between the front surface (50) of the ophthalmic lens (5) and the concave inner surface (210) of the optically transparent bottom (21) of the inspection cuvette (2) on the other hand to a detector of the interferometer (3);

- determining the center thickness (55) of the ophthalmic lens (5) from the signals generated at the detector of the interferometer by the light reflected at the respective boundary (510;500,502) at the back surface (51) and at the front surface (50) of the ophthalmic lens (5).

9. Method according to claim 8, wherein the step of determining the center thickness (55) of the ophthalmic lens (5) comprises

- in case the ophthalmic lens (5) rests on the concave inner surface (210) of the optically transparent bottom (21) of the inspection cuvette (2), selecting the signal generated by the light reflected at the boundary (502) between the front surface (50) of the ophthalmic lens and the concave inner surface (210) of the optically transparent bottom (21) of the inspection cuvette (2) as well as the signal generated by the light reflected at the boundary (510) between the back surface (51) of the ophthalmic lens (5) and the liquid;

- in case the ophthalmic lens (5) is floating at a distance above the concave inner surface (210) of the optically transparent bottom (21) of the inspection cuvette (2), selecting the signal generated by the light reflected at the boundary (500) between

the front surface (50) of the ophthalmic lens (5) and the liquid as well as the signal generated by the light reflected at the boundary (510) between the back surface (51) of the ophthalmic lens (5) and the liquid.

10. Method according to claim 8 or claim 9, wherein the step of determining the center thickness (55) of the ophthalmic lens (5) comprises
- counting a number of signals generated by the light reflected at the respective boundary (510;500,502) and
- for a counted number of two signals, selecting the two signals for determining the center thickness (55) of the ophthalmic lens (5),
- for a counted number of three signals, ignoring the signal corresponding to the light reflected at the boundary (200) between the concave inner surface (210) of the optically transparent bottom (21) of the inspection cuvette (2) and the liquid, and selecting the remaining two signals for determining the center thickness (55) of the ophthalmic lens (5).

11. Method according to any one of claims 8 to 10, further comprising the steps of:
- comparing the determined center thickness (55) of the ophthalmic lens (5) with a predetermined set value for the center thickness; and
- identifying the ophthalmic lens (5) as having an unacceptable center thickness if the determined center thickness (55) is outside a predetermined range of tolerance around the predetermined set value for the center thickness, or
- identifying the ophthalmic lens (5) as having an acceptable center thickness if the determined center thickness (55) is within the predetermined range of tolerance around the predetermined set value for the center thickness; and
- removing the ophthalmic lens (5) from the manufacturing line in case the ophthalmic lens has been identified as having an unacceptable center thickness (55), but further processing the ophthalmic lens (5) in the manufacturing line in case the ophthalmic lens (5) has been identified as having an acceptable center thickness (55).

12. Method according to claim 6 and any one of claims 8 to 11, comprising the steps of:

- providing the plurality of inspection cuvettes (2) at the third inspection location (700) of the inspection module (1);
- providing a plurality of focusing probes (30) corresponding to the plurality of inspection cuvettes (2), each of the focusing probes (30) focusing light to a set position (310) of the ophthalmic lens (5) at the center of the concave inner surface of the optically transparent bottom of a corresponding inspection cuvette (2), and each of the focusing probes (30) directing light reflected at the respective boundary (510;500,502) at the back surface (51) and at the front surface (50) of the respective ophthalmic lens (5) to the detector of the interferometer (3); and
- determining the center thickness (55) of each ophthalmic lens (5).

13. Method according to claim 12, wherein focusing light to the set position (310) of the ophthalmic lens (5) is performed sequentially for the plurality of inspection cuvettes (2) by directing light from the light source of the interferometer (3) via a first focusing probe (30) of the plurality of focusing probes to the set position (310) of the ophthalmic lens (5) contained in a first inspection cuvette (2) of the plurality of inspection cuvettes, subsequently directing light from the light source of the interferometer via a second focusing probe (30) to the set position of the ophthalmic lens (5) contained in a second inspection cuvette (2) of the plurality of inspection cuvettes, and so on, until light from the light source of the interferometer (1) is directed via a last focusing probe (30) of the plurality of focusing probes to the set position (310) of the ophthalmic lens (5) contained in a last inspection cuvette (2) of the plurality of inspection cuvettes.

14. Method according to claim 13, wherein sequentially focusing light to a set position (310) of the ophthalmic lens (5) for the plurality of inspection cuvettes (2) comprises

- providing a plurality of deflectors (41_1, 41_2, 41_3, ...,41_{n-1}, 41_n) corresponding to

the plurality of focusing probes (30), the individual deflectors of the plurality of deflectors (41_1, 41_2, 41_3, ...,41_{n-1}, 41_n) each being capable of being switched between an active state, in which the respective deflector (41_1, 41_2, 41_3, ...,41_{n-1}, 41_n) directs light coming from the light source of the interferometer to the corresponding focusing probe (30) and in which the respective deflector (41_1, 41_2, 41_3, ...,41_{n-1}, 41_n) directs light reflected at the respective boundary (510;500,502) to the detector of the interferometer (3), and a passive state, in which the respective deflector allows the light coming from the light source to pass to the next deflector which is in the active state and which is arranged in an optical path of the light; and

- sequentially switching a first deflector (41_1) of the plurality of deflectors (41_1, 41_2, 41_3, ...,41_{n-1}, 41_n) from the active state to the passive state after determining the center thickness (55) of the ophthalmic lens (5) contained in the first inspection cuvette (2), switching a second deflector (41_2) of the plurality of deflectors (41_1, 41_2, 41_3, ...,41_{n-1}, 41_n) from the active state to the passive state after determining the center thickness (55) of the ophthalmic lens (5) contained in the second inspection cuvette (2), and so on, until switching a second last deflector (41_{n-1}) of the plurality of deflectors (41_1, 41_2, 41_3, ...,41_{n-1}, 41_n) from the active state to the passive state after determining the center thickness (55) of the ophthalmic lens (5) contained in the second last inspection cuvette (2), and then determining the center thickness (55) of the ophthalmic lens contained in the last inspection cuvette (2) with the last deflector (41_n) being in the active state.

15. Method according to any one of claims 12 to 14, further comprising the step of individually adjusting each focusing probe (30) of the plurality of focusing probes so as to focus light coming from the light source of the interferometer (3) to the corresponding set position (310) of the ophthalmic lens (5) at the center of the concave inner surface (210) of the optically transparent bottom (21) of the respective inspection cuvette (2) of the plurality of inspection cuvettes (2).

16. An automated manufacturing line for manufacturing ophthalmic lenses (5), for example soft contact lenses, the manufacturing line comprising:
- a production module for manufacturing ophthalmic lenses (5);
- an inspection module (1) for inspecting the manufactured ophthalmic lenses (5),
the inspection module (1) comprising a wavefront sensor (6) comprising a detector (602), the wavefront sensor (6) being arranged at a first inspection location (800) and being capable of receiving light from a light source (42), for inspection of ophthalmic lenses (5) being contained in a plurality of inspection cuvettes (2), each inspection cuvette comprising an optically transparent bottom (21) and containing the ophthalmic lens (5) immersed in a liquid, wherein in operation the inspection module (1) performs the method according to any one of claims 6 to 15.

17. An automated manufacturing line according to claim 16, wherein the inspection module (1) further comprises an interferometer (3) and a plurality of focusing probes (30) being arranged at a third inspection location (700) and being capable of being optically connected to the interferometer (3), for inspection of ophthalmic lenses (5) being contained in a plurality of inspection cuvettes (2) corresponding to the plurality of focusing probes (30), each inspection cuvette (2) comprising an optically transparent bottom (21) having a concave inner surface (210) and containing the ophthalmic lens (5) immersed in a liquid,
wherein in operation the inspection module (1) performs the method according to any one of claims 12 to 15.

Claims

1. Method for automated inline determination of the refractive power of an ophthalmic lens (5) in an automated manufacturing line for ophthalmic lenses, for example soft contact lenses, the method comprising the steps of:

   - providing an inspection cuvette (2) comprising an optically transparent bottom (21) having a concave inner surface (210) and containing the ophthalmic lens (5) immersed in a liquid, and positioning the inspection cuvette at a first inspection location (800) of an inspection module (1) of the automated manufacturing line;

   - providing a light source (42) and a wavefront sensor (6), the wavefront sensor (6) comprising a detector (602) for receiving light coming from the light source (42) and having passed the ophthalmic lens (5) contained in the inspection cuvette (2) and impinging on the detector (602), thus generating signals at the detector;

   - comparing the signals generated at the detector (602) with predetermined signals representative of a reference refractive power thereby determining the refractive power of the ophthalmic lens (5), wherein the step of providing a wavefront sensor (6) comprises providing a wavefront sensor comprising an array of micro-lenses (501), for example a Shack-Hartmann-sensor (60).