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Case Number: T 1073/04 - 3.4.03

Application Number: 99307842.7

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IPC: G03F 7/20

Language of the proceedings: EN

Title of invention:
Projection exposure apparatus, and device manufacturing method

Applicant:
CANON KABUSHIKI KAISHA

Opponent:
-

Headword:
-

Relevant legal provisions:
EPC Art. 56

Keyword:
"Inventive step (no)"

Decisions cited:
-

Catchword:
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Case Number: T 1073/04 - 3.4.03

D E C I S I O N
of the Technical Board of Appeal 3.4.03
of 6 June 2007

Appellant: CANON KABUSHIKI KAISHA
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Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 19 February 2004 refusing European application No. 99307842.7 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: R. G. O'Connell
Members: G. Eliasson
J. Van Moer

Summary of Facts and Submissions

I. This is an appeal against the refusal of European patent application 99 307 842.7 for lack of inventive step (Article 56 EPC).

II. The following prior art documents were cited in the examination procedure:

D1: JP 8 255 748 A;
D1a: US 6 014 455 A;
D2: EP 0 742 492 A.

III. The appellant applicant requests that the decision under appeal be set aside and a patent granted on the basis of main or auxiliary claim requests as amended on appeal. Alternatively, remittal of the case to the examining division is requested.

IV. Claim 1 of the main claim request reads as follows (board's emphasis indicating correction of typographical errors):

"1. A projection exposure apparatus wherein projection magnification (β), symmetric distortion aberration (SD) and an optical characteristic (A) different from the projection magnification and the symmetric distortion aberration of a projection optical system (5) can be adjusted, said apparatus comprising:

first changing means (8) for changing a first optical parameter (S1) of the projection optical system;

second changing means (8) for changing a second optical parameter (S2) of the projection optical system;

and characterised by further comprising:
third changing means (9) for changing a third optical parameter (W) of the projection optical system;

wherein:
the exposure light is produced by an excimer laser which produces ultraviolet rays with a wavelength of one of 248 nm, 193 nm, and 157 nm as exposure light;

$\Delta\beta1$, $\Delta SD1$ and $\Delta A1$ are the change in the projection magnification, the change in the symmetric distortion aberration and the change in the optical characteristic produced when the first optical parameter is changed by unit amount (S1), respectively;

$\Delta\beta2$, $\Delta SD2$ and $\Delta A2$ are the change in the projection magnification, the change in the symmetric distortion aberration and the change in the optical characteristic produced when the second optical parameter is changed by unit amount (S2), respectively;

$\Delta\beta3$, $\Delta SD3$ and $\Delta A3$ are the change in the projection magnification, the change in the symmetric distortion aberration and the change in the optical characteristic produced when the third optical parameter is changed by unit amount (W), respectively;

the largest adjustments required to the projection magnification, the symmetric distortion aberration and the optical characteristic are respectively βmax, SDmax and Amax;

wherein the first, second and third changing means are configured such that the angles between any two of the three vectors ($\Delta\beta 1/\beta max$, $\Delta SD1/SDmax$, $\Delta A1/Amax$), ($\Delta\beta 2/\beta max$, $\Delta SD2/SDmax$, $\Delta A2/Amax$) and ($\Delta\beta 3/\beta max$, $\Delta SD3/SDmax$, $\Delta A3/Amax$) are not less than 30 degrees and not greater than 150 degrees; and wherein said first changing means (8) changes the position of a first optical element (G1) of the projection optical system (5) in a direction of an optical axis, said second changing means (8) changes the position of a second optical element (G2) of the projection optical system (5) in a direction of an optical axis, and said third changing means (9) changes a wavelength of exposure light to be incident on the projection optical system."

V. Claim 1 of the auxiliary claim request reads as follows:

"1. A method of adjusting projection magnification (β), symmetric distortion aberration (SD) and a further optical characteristic (A) different from the projection magnification and the symmetric distortion aberration of a projection optical system in a projection exposure method using an exposure apparatus comprising:

an excimer laser which produces ultraviolet rays of a wavelength of one of 248 nm, 193 nm, and 157 nm;

first changing means (8) for changing a first optical parameter (S1) of the projection optical system;

second changing means (8) for changing a second optical parameter (S2) of the projection optical system; and

third changing means (9) for changing a third optical parameter (W) of the projection optical system;

wherein:

$\Delta\beta1$, $\Delta SD1$ and $\Delta A1$ are the change in the projection magnification, the change in the symmetric distortion aberration and the change in said further optical characteristic to be produced when the first optical parameter (S1) is changed by unit amount, respectively;

$\Delta\beta2$, $\Delta SD2$ and $\Delta A2$ are the change in the projection magnification, the change in the symmetric distortion aberration and the change in said further optical characteristic to be produced when the second optical parameter (S2) is changed by unit amount, respectively;

$\Delta\beta3$, $\Delta SD3$ and $\Delta A3$ are the change in the projection magnification, the change in the symmetric distortion aberration and the change in said further optical characteristic to be produced when the third optical parameter (W) is changed by unit amount, respectively; and

the largest adjustments required to the projection magnification, the symmetric distortion aberration and the further optical characteristic are respectively βmax, SDmax and Amax;

characterised by the steps of:
configuring the first, second and third changing means such that the angles between any two of the three vectors ($\Delta\beta$1/βmax, ΔSD1/SDmax, ΔA1/Amax), ($\Delta\beta$2/βmax, ΔSD2/SDmax, ΔA2/Amax) and ($\Delta\beta$3/βmax, ΔSD3/SDmax, ΔA3/Amax) are not less than 30 degrees and not greater than 150 degrees;

calculating the adjustment amounts (S1, S2, W) required to produce a desired adjustment of projection magnification (β), symmetric distortion aberration (SD) and the optical characteristic (A) by solving three simultaneous equations (4-1, 4-2, 4-4) which relate the amount of change in each of projection magnification (β), symmetric distortion aberration (SD) and the optical characteristic (A) to the respective adjustment amounts (S1, S2, W);

and adjusting the first (8), second (8) and third changing means (9) by the calculated adjustment amounts (S1, S2, W);

wherein said first changing means (8) changes the position of a first optical element (G1) of the projection optical system (5) in a direction of an optical axis, said second changing means (8) changes the position of a second optical element (G2) of the projection optical system in a direction of an optical axis, and said third changing means (9) changes a wavelength of exposure light to be incident on the projection optical system (5)."

VI. The appellant applicant's arguments can be summarized as follows:

(a) Claim 1 of the main claim request as amended on appeal was distinguished from document Dl in that the apparatus comprised an excimer laser adapted to emit light of differing wavelengths, and a variation in the wavelength was used as the third optical parameter of the system, and furthermore in that the angle defined between the vectors was not less than 30° and not greater than 150°. Document D1 neither taught nor suggested these features.

(b) The Examining Division had acknowledged in the first instance oral proceedings (minutes point 3) that the angles between vectors derivable from document Dl were not comparable with the angles between vectors defined in the present case, and for this reason the angles as claimed could not be derived from document Dl. The invention as claimed brought the additional limitation in terms of the maximum amount of adjustment provided in the optical system, which was neither disclosed nor suggested in Dl.

Reasons for the Decision

1. The appeal is admissible.

2. The amendments to the claim requests on appeal are not such that a remittal to the examining division would be necessary or appropriate. Accordingly the board exercises its power pursuant to Article 111(1) EPC to examine the amended requests itself.

3. *Inventive step - Main request*

3.1 Document D1 discloses a projection exposure apparatus wherein projection magnification β and symmetric distortion aberration D can be adjusted (column 2, lines 8 to 12 and column 3, lines 44 to 46) (citations refer to document D1a, a postpublished member of the D1 family). The apparatus comprises a first and second changing means in terms of two movable lens groups for changing a first and a second optical parameter (projection magnification and symmetric distortion aberration), respectively, of the projection optical system. It is also envisaged in document D1 that a third changing means may be used for changing a third optical parameter (column 3, lines 51 to 57 and column 6, lines 18 to 21 and 66 to 67). An ultra-high pressure mercury discharge lamp is used as exposure light source (column 3, lines 29 to 30).

The two lens groups G forming the first and second changing means are chosen under the criterion that when the lens group is varied a unit amount (1 mm) to change the symmetrical distortion δD and projection magnification $\delta\beta$, this variation should produce as little change as possible in spherical aberration SA, coma CM and astigmatism AS (column 5, lines 23 to column 6, line 1). Furthermore, the two lens groups should have a large difference in absolute value of the ratio $|\delta D/\delta\beta|$ (column 6, lines 6 to 12). A system of two linear equations for the change in distortion δD and change in projection magnification $\delta\beta$ in terms of change in the two lens groups chosen (G1, G3) is formulated (column 6, equation (1)). Once the correction target values for the symmetrical distortion aberration δD and projection magnification $\delta\beta$ have been determined, the necessary adjustment ($\delta G1$, $\delta G2$) of the lens groups can be calculated by solving the linear equation system (column 6, equation (2)).

3.2 The subject matter of claim 1 of the main claim request differs from the apparatus of document D1 in that

(a) a third optical characteristic A in addition to the projection magnification β and the symmetric distortion aberration SD can be adjusted;

(b) the first, second and third changing means are configured such that the angles between any two of the three vectors ($\Delta\beta 1/\beta max$, $\Delta SD1/SDmax$, $\Delta A1/Amax$), ($\Delta\beta 2/\beta max$, $\Delta SD2/SDmax$, $\Delta A2/Amax$) and ($\Delta\beta 3/\beta max$, $\Delta SD3/SDmax$, $\Delta A3/Amax$) are not less than 30 degrees and not greater than 150 degrees, where βmax, SDmax and Amax represent the largest required adjustments of the respective optical characteristics;

(c) the exposure light is produced by an excimer laser which produces UV rays with a wavelength of one of 248 nm, 193 nm, and 157 nm as exposure light, whereas in document D1, a mercury lamp is used as light source; and

(d) the third changing means changes the wavelength of the exposure light to be incident on the projection optical system. In the apparatus of document D1, two lens groups with variable positions form first and second changing means.

3.3 Document D2 discloses a projection exposure apparatus having a KrF excimer laser 24 as exposure light source emitting light of a wavelength of 248 nm (see Figure 1; page 4, lines 52 to 56). In order to compensate for changes in optical characteristics such as focus position, projection magnification, spherical aberration, coma, astigmatism, the emission wavelength λ of the excimer laser is changed (page 6, lines 43 to 47; page 5, lines 10 to 24).

In contrast to the apparatus of claim 1, the apparatus of document D2 discloses only the variation of a single optical parameter (emission wavelength) for adjusting the optical characteristics of the apparatus.

3.4 In view of the above, document D1 is considered the closest prior art, since it relates to the adjustment of more than one optical characteristic by changing more than one optical parameter. The technical problem relative to document D1 and solved by features (a) to

(d) above relates to further improving the image quality of the optical system.

3.5 As illustrated in Table 2 of document D1, a change in the position of any lens group G inevitably induces changes in other optical properties such as the spherical aberration SA, coma CM and astigmatism AS. This effect is kept to a minimum by choosing the two lens groups G1 and G3 which induce small unwanted changes δSA, δCM and δAS (column 5, line 56 to column 6, line 12).

3.5.1 As document D1 already suggests varying three or more optical parameters (see column 6, lines 66 and 67), the skilled person seeking to improve the image quality of the apparatus of document D1 would consider varying a third optical parameter, since this would enable the correction of one of the remaining uncorrected aberrations, such as spherical aberration, coma and astigmatism. In the apparatus of document D1, the user has to be content when the above remaining uncorrected aberrations have not deteriorated further in the process of correcting projection magnification and symmetrical distortion.

3.5.2 As to the implementation of a third variable optical parameter, the skilled person would realise that this would entail the solution of a system of three linear equations in analogy with the linear equation system (1) of document D1 (feature (a)).

3.6 Regarding feature (b), document D1 discloses that the two variable lens systems have to be chosen such that the difference in the absolute value of the ratio

$|\delta D/\delta\beta|$ is large (column 6, lines 6 to 12). Using the notation of claim 1, document D1 teaches that the difference between $|\Delta\beta 1/\Delta SD1|$ and $|\Delta\beta 2/\Delta SD2|$ should be large. This condition ensures that only small movements of the two lens systems are necessary for arriving at the desired correction and that the determinant of the coefficient matrix for the equation system (1) is non-zero.

3.6.1 In analogy with the above, the skilled person introducing a third variable optical parameter and a third optical characteristic to be adjusted would understand that in order to be able to make substantially independent changes to the projection magnification, symmetric distortion aberration and the further optical characteristic, the determinant of the coefficient matrix of the system of three simultaneous linear equations must be non-zero, since it is a standard theorem from linear algebra and part of the mathematical toolkit of the skilled person that otherwise it would not be possible to find a solution to the problem of finding the desirable adjustment of the three optical characteristics.

3.6.2 Claim 1 specifies a range of angles between the three vectors forming the coefficient matrix of the three linear equations. In order to allow a meaningful definition of an angle between two vectors, all the components of each vector have to have the same dimension. For this purpose, claim 1 defines the vectors ($\Delta\beta i/\beta max$, $\Delta SDi/SDmax$, $\Delta Ai/Amax$), i = 1, 2, 3 so that all components have the dimension of reciprocal length. The quantities βmax, SDmax and Amax correspond to "the largest adjustments required" to the projection magnification, symmetric distortion aberration and the third optical characteristics, respectively.

3.6.3 The appellant applicant argued in this context that document D1 did not suggest the above angle-requirement on the coefficient-vectors (item VI(b) above). The board however agrees with the reasoning in the decision under appeal that the skilled person, although he might not express himself in the same way as in claim 1, would nevertheless arrive at an apparatus having such properties that it would fall within the terms of claim 1.

As mentioned above, it follows from elementary linear algebra that none of the above coefficient vectors can be parallel to another of the coefficient vectors. Otherwise it would not be possible to solve the system of three linear equations defined by the three vectors, as the determinant of the coefficient matrix in this case would be zero. Furthermore, it is undisputed common general knowledge in the art that the adjustment process is most efficient when the vectors formed from the coefficients of the three linear equations are as orthogonal as possible. Such an equation system would fall under the terms of feature (b).

3.6.4 It should also be pointed out that the quantities βmax, SDmax and Amax are defined to represent the "largest adjustments required" to projection magnification, symmetric distortion aberration and further optical characteristic. Such a definition is however not unambiguous, and therefore, for any non-parallel vectors, the angle between the vectors would depend on the chosen values for βmax, SDmax and Amax. The question whether or not a set of vectors would fall within the claimed range thus depends at least to a certain extent on the values chosen for βmax, SDmax and Amax, and consequently, the scope of claim 1 is not clearly defined. Nevertheless, as the skilled person for the reasons given above seeks to find variable optical parameters such that the vectors formed from the matrix of the linear equations would be as orthogonal as possible, such a system would have angles lying in the mid-region of the claimed range of 30 to 150 degrees and would therefore be within the claimed ranges of angles for at least some βmax, SDmax and Amax.

3.6.5 From the above the board judges that the skilled person without employing inventive skills would arrive at an apparatus having features which fall within the terms of feature (b).

3.7 Regarding features (c) and (d), the use of an excimer laser as a light source and choosing the wavelength as the third variable optical parameter, document D2 discloses the use of a KrF excimer laser having a wavelength of 248 nm where the wavelength can be adjusted in order to compensate for variations in the optical characteristics of the projection exposure apparatus. Since the use of an excimer laser was known in the art before the priority date as an exposure light source, eg from D2, the skilled person would have regarded it as an obvious alternative to the high-pressure mercury lamp used in the apparatus of document D1, given that a KrF excimer laser emits light of shorter wavelength (248 nm) than that of a mercury lamp (I-line of Hg: 365 nm).

3.7.1 As to the problem of finding a suitable third variable optical parameter, the skilled person would consider the teaching of document D2 in this respect. As argued by the examining division, in the light of the fact that the apparatus of document D1 already has changing means for independently changing two lens groups, it would be convenient to look for some other variable optical parameter than another lens group, as the latter would require modifications of the lens system resulting in a more complex lens system with three independently adjustable optical elements.

3.8 For the above reasons, in the board's judgement, the subject matter of claim 1 of the main request does not involve an inventive step within the meaning of Article 56 EPC.

4. *Inventive step - Auxiliary request*

The method of claim 1 of the auxiliary request differs from that of document D1 in the same three features (a) to (d) referred to under point 3.2 above. Therefore, the reasons for lack of inventive step within the meaning of Article 56 EPC given above for the main request apply *mutatis mutandis* for the subject matter of claim 1 of the auxiliary request as well.

Order

For these reasons it is decided that:

The appeal is dismissed.

Registrar	Chair
S. Sánchez Chiquero	R. G. O'Connell