Method of Structuring a Photosensitive Material

A method of structuring a photosensitive material comprises the steps of: illuminating a first object structure and projecting a pattern of the first object structure onto the photosensitive material such that the projected pattern of the first object structure is focussed at a first focus position with respect to the photosensitive material, and illuminating a second object structure and projecting a pattern of the second object structure onto the photosensitive material such that the projected pattern of the second object structure is focussed at a second focus position with respect to the photosensitive material, wherein the respective patterns are projected in the same projection direction.
Method of structuring a photosensitive material

Background of the invention

The invention relates to a method of structuring a photosensitive material, a projection exposure system for structuring a photosensitive material and a mask for a projection exposure system.

Microlithography is a well known technique used to create two-dimensional structures. It involves transferring a structure from one surface to another. For example, a common type of lithography, known as photolithography, is the driving technology in manufacturing Integrated Circuits (ICs). In photolithography a permanent mask, for example, consists of an opaque material that is selectively located on a transparent substance in the desired structure. Light is incident on the mask and a shadow or pattern from the structured opaque regions is cast onto a substrate coated with a photosensitive material known as photo-resist. The photo-resist changes its chemical properties when light impinges upon it. The resist is then developed to remove the exposed (or unexposed) areas of the resist. In this process, the structure from the mask is transferred to the photo-resist. Further processing is usually performed by developing and other processing to create resistant structures.

Lithography has also been adapted to make three-dimensional objects. In US 2002/0061472 A1 a tomographic method is described in which a photosensitive material is exposed from a vertical and a horizontal direction in order to create a three-dimensional structure. However, the apparatus used for this method is rather elaborate and complex.

Summary of the invention
It is an object of the invention to provide a method and a projection exposure system for three-dimensional structuring of a photosensitive material, and therefore for generating three-dimensional structures or shapes in the photosensitive material, in a cost efficient manner.

The above object is solved according to the invention by a method of structuring a photosensitive material comprising the steps of: illuminating a first object structure and projecting a pattern of the first object structure onto the photosensitive material such that the projected pattern of the first object structure is focussed at a first focus position with respect to the photosensitive material; illuminating a second object structure and projecting a pattern of the second object structure onto the photosensitive material such that the projected pattern of the second object structure is focussed at a second focus position with respect to the photosensitive material, wherein the respective patterns are projected in the same projection direction.

The above object is further solved by a projection exposure system for structuring a photosensitive material, which projection exposure system comprises: illumination means for illuminating a first object structure and a second object structure; optical projection means for projecting a respective pattern of the first object structure and the second object structure onto the photosensitive material; and control means for controlling the operation of the projection exposure system such that the projected pattern of the first object structure is focussed at a first focus position with respect to the photosensitive material, that the projected pattern of the second object structure is focussed at a second focus position with respect to the photosensitive material and that the respective patterns are projected in the same projection direction.

The different focus positions at which the different object structures are focussed can cover extended areas in the projection direction in which the projected pattern is in focus. The photosensitive material structured by the inventive method can,
for example, be a photo-resist layer formed on a silicon substrate as typically used in microlithography.

In other words, according to the invention, the single patterns of the different object structures are focused at different focus positions with respect to the photosensitive material, therefore the focus points of the different projected patterns are shifted in the projection direction.

By focusing the projected patterns of the respective object structures at different focus positions according to the invention at least two structures are created in different levels of the photosensitive material, which can be two-dimensional in approximation. The created structures together form a three-dimensional structure or shape in the photosensitive material. The invention is based on the insight that three-dimensional structural information transferred into the photosensitive material can be decomposed into at least two sections which are independently exposed into the photosensitive material. As elaborated above, this is done by projecting the different object structures at different focus positions onto the photosensitive material. In order to yield a distinct focus-range of the projected patterns, the structures are advantageously illuminated appropriately.

As, according to the invention, the projection of both object structures is performed in the same direction, a projection exposure system for performing the inventive method can be developed on the basis of projection exposure systems generally used in microlithography. Therefore the cost and effort involved in manufacturing projection exposure system adapted for performing the method according to the invention remains limited. It is for example possible to manufacture the three-dimensional photonic crystal described in the patent application US 2007/01 721 90A1.

In an embodiment according to the invention the respective patterns are projected onto the same location of the photosensitive material in a plane perpendicular to the projection direction. The same location of the photosensitive material in a plane perpendicular to the projection direction in this context means that the
respective patterns at least overlap or are even centered on the same point of the plane. In other words, according to this embodiment of the invention, the patterns of the different object structures are projected onto the same location of the photosensitive material and therefore onto the same location in a plane perpendicular to the projection direction.

In a further embodiment according to the invention the first focus position and the second focus position are both located within the photosensitive material. This way the image patterns of the respective object structures are precisely defined in the respective focal planes defined by the different focus positions. This allows the formation of a precisely shaped three-dimensional structure.

In a further embodiment according to the invention the photosensitive material has a given thickness in the projection direction and a distance between the first focus position and the second focus position is at least 10%, preferably at least 50%, of the given thickness. This way it can be ensured that the irradiation profiles of the different image structures in the photosensitive material do not significantly interfere with each other. Therefore, the irradiation profiles generated in the different focal planes of the photosensitive material are distinct enough to allow the formation of a precisely shaped three-dimensional structure.

In a further embodiment according to the invention the photosensitive material has a given thickness in the projection direction, each of the object structures is illuminated by light rays having an angular distribution, which angular distribution is adapted to the shape of the illuminated object structure such that an irradiation profile of at least one of the projected patterns, in particular both of the projected patterns, extends in the projection direction inside the photosensitive material by less than 50% of the given thickness, in particular by less than 10% of the given thickness, of the photosensitive material. The angular distribution of the light illuminating the object structures is generally referred to as an "illumination setting". Such an illumination setting can include, for example, standard illumination of various partial coherence settings, annular illumination or
quadrupole illumination. According to an embodiment the illumination setting is chosen depending on the shape of the illuminated object such that the resulting irradiation profile of the projected pattern extends in a small layer within the photosensitive material. Ideally, the depth of focus of the image is adjusted such that exclusively the desired sectional plane within the photosensitive material is illuminated. The term "extending" of the irradiation profile within the photosensitive material in this context means that the intensity level of the irradiation profile is sufficient to change a characteristic property of the photosensitive material, for example is sufficient to expose photo-resist such that the resist material can be removed during subsequent development. In the area, which the irradiation profile does not "extend" to, the intensity level is so small that the characteristic property of the photosensitive material is not changed. According to this embodiment the image structures formed in the different focal planes do not overlap with each other and therefore a precisely shaped three-dimensional structure can be obtained.

In a further embodiment according to the invention the first object structure is illuminated by light rays having a first angular distribution and the second object structure is illuminated by light rays having a second angular distribution. Therefore the different object structures are exposed in different exposure steps, wherein between the exposure steps the illumination setting is changed.

In a further embodiment according to the invention at least one of the object structures is projected onto the photosensitive material as a dark field image. A dark field image is generated by object structures, which are transmissive to light, for example transmissive slits or holes, surrounded by an opaque or dark background. This is in contrast to bright field images, in which the object structures are opaque elements surrounded by a transmissive background. Therefore, according to the embodiment, the images of the object structures on the photosensitive material are illuminated elements. This way more complex three-dimensional structures can be formed in the photosensitive material, which photosensitive material is advantageously in the form of positive photo-resist.
In a further embodiment according to the invention at least one of the object structures is projected onto said photosensitive material as bright field image and the projected pattern extends in the direction of the projection direction by more than 80% of the thickness of the photosensitive material, preferably by more than 100% of the thickness of the photosensitive material.

In a further embodiment according to the invention spherical aberrations in a wave front of at least one of the projected patterns are caused by interaction of the light of the projected pattern with the photosensitive material and the spherical aberrations are corrected by optical projection means projecting the respective pattern onto the photosensitive material. A resist layer having a thickness of several microns can cause significant spherical aberrations. According to the embodiment these aberrations are e.g. corrected in the optical projection means by means of manipulators for adjusting the Zernike coefficient Z9 to be constant over the exposure field. The projection means advantageously correct the spherical aberrations depending on the focus setting and type of photosensitive material.

In a further embodiment according to the invention the object structures are located on separate masks and after projecting the pattern of the first object structure a mask change is performed. A first mask containing the first object structure is arranged in an exposure position of the projection exposure system for a first exposure step projecting the first object structure onto the photosensitive material. Subsequently, the first mask is removed from the exposure position and a second mask containing the second object structure is brought into the exposure position. Thereupon the second structure is projected onto the photosensitive material.

In a further embodiment according to the invention the patterns are projected onto the photosensitive material using optical projection means having a numerical aperture of NA, the patterns generate material structures in the photosensitive
material and the process of generating the material structures from the object structures is determined by the lithographic process constant \( k_1 \), wherein \( NA \) and \( k_1 \) satisfy the following relation: \( NA/k_1 > 0.5 \). The lithographic process constant \( k_1 \) of a lithographic imaging process is defined by the following equation:

\[
R = k_1 \lambda \frac{\lambda}{NA},
\]

wherein \( R \) is the maximum achievable resolution of an object structure imaged onto the photosensitive material and \( \lambda \) is the wavelength of monochromatic light used for projecting the object structure onto the photosensitive material. \( k_1 \) can be influenced by the shape of the object structure, the illumination setting and the properties of the photosensitive material itself. Choosing \( NA/k_1 > 0.5 \) results in well defined irradiation profiles in each of the focal planes and therefore allows a three-dimensional structure to be manufactured with a high precision.

In a further embodiment according to the invention, after projecting the object structures onto the photosensitive material the photosensitive material is chemically conditioned such that regions within the photosensitive material which were exposed to light change an optical and/or electrical characteristic. Chemical conditioning can include a development of the photosensitive material, as is typical after the exposure of photo-resist. The optical characteristic to be changed by the chemical conditioning in the regions, which were exposed to light, advantageously includes the refractive index or the transmission property of the photosensitive material to light. No material has to be extracted during the chemical conditioning. The structuring of the photosensitive material in this case is not achieved by removing material to achieve the three-dimensional structure but in that three-dimensional regions of different material characteristics are produced in the photosensitive material. An electrical characteristic varying between the different regions according to the embodiment can include, for example, the electrical resistance of the photosensitive material.
In a further embodiment according to the invention the pattern of the first object structure is projected onto the photosensitive material in a first exposure step and the pattern of the second object structure is projected onto the photosensitive material in a subsequent exposure step. The photosensitive material remains unchanged between both exposure steps.

In a further embodiment according to the invention the first object structure differs from said second object structure in its orientation, shape and/or size. This way three-dimensional objects having a complex shape can be produced.

In a further embodiment according to the invention the object structures are simultaneously illuminated by light having two different optical properties, the pattern of the first object structure is generated predominantly or completely from first light having the first of the optical properties and the pattern of the second object structure is generated predominantly or completely from second light having the second one of the optical properties. According to this embodiment both object structures can be projected onto the photosensitive material during a single exposure step as both patterns are generated separately.

In a further embodiment according to the invention the patterns are projected onto the photosensitive material by optical projection means, which are adapted to focus the first light at the first focus position and the second light at the second focus position. Therefore, the images of the object structures can be focussed at different focus positions at the same location of the photosensitive material in only one exposure step.

It is further advantageous, if different optical properties are different optical wavelengths of the light illuminating the object structures. In a further embodiment the different optical properties are different orthogonal polarisation states of the light. Both in the case, in which the first light and the second light have different wavelengths, and in the case, in which the first light and the second light have different orthogonal polarisation states, the first light and the second
light can be handled by the projection means separately. Therefore, the first light and the second light can be projected to different focus positions by the projection means without interfering with each other.

The above object is further solved according to the invention by a projection exposure system for structuring a photosensitive material, which projection exposure system comprises: a mask holder for holding a mask having a first object structure and a second object structure at different locations of the mask; a material holder for holding the photosensitive material; optical projection means for imaging the mask onto the photosensitive material; and control means for controlling the projection exposure system to automatically perform a double exposure of the mask in which, in a first exposure step the first object structure, and in a second exposure step the second object structure is imaged onto the photosensitive material, such that the first object structure and the second object structure are imaged onto the same location of the photosensitive material and the photosensitive material remains on the material holder during the double mask exposure.

In other words, the projection exposure system according to the invention is configured to perform a so called double mask exposure. In a first exposure step of the double mask exposure a first object structure on the mask is imaged onto a certain location of the photosensitive material. As also mentioned above, the location on the photosensitive material is defined as a location in a plane perpendicular to a projection direction of the optical projection means. Subsequently, a second object structure located on the mask is imaged onto the same location of the photosensitive material. The projection exposure system is configured to automatically perform this double mask exposure. Such a projection exposure system allows the method according to the invention described above to be performed efficiently.

In an embodiment of the projection exposure system according to the invention the control means are adapted to control the projection exposure system such
that in the first exposure step the first object structure is imaged onto the photosensitive material at a first focus setting of the optical projection means and in the second exposure step the second object structure is imaged onto the photosensitive material at a second focus setting of the optical projection means. The different focus settings can, for example, be adjusted by moving the material holder, holding the photosensitive material, in the direction of an optical axis of the optical projection means.

In a further embodiment according to the invention the mask comprises a first exposure region containing the first object structure and a second exposure region containing the second object structure, and the control means are configured to cause the projection exposure system to project the image of the first region in the first exposure step and the second region in the second exposure step onto the photosensitive material. The first and the second exposure regions can, for example, be the right and the left half of the mask, respectively. During the double mask exposure at least respective portions of the exposure regions are exposed in an overlapping manner onto the photosensitive material.

In a further embodiment according to the invention the control means are implemented by hardware and/or software.

The above object is further solved by a projection exposure system for structuring a photosensitive material, which projection exposure system comprises two projection objectives each having an optical axis wherein the optical axes are parallel and offset relative to each other and the projection objectives are adjusted to different focus positions.

This way a first object structure and a second object structure can be exposed onto the photosensitive material at different focus positions in a fast and efficient way. No adjustment of the focus position of the photosensitive material or any other adjustment for moving the focus is necessary. By means of this projection
exposure system the above-mentioned method according to the invention can be performed efficiently and a large throughput can be achieved. The projection objectives are advantageously small field objectives and the exposure is performed in a "step and flash" mode. In an embodiment according to the invention, the optical axes of the projection objectives are oriented parallel to each other.

In a further embodiment according to the invention the projection exposure system is adapted for projecting a pattern of a first object structure onto the photosensitive material using a first one of the projection objectives and projecting a pattern of a second object structure onto the photosensitive material using the second one of the projection objectives, such that both object structures are projected onto the same location of the photosensitive material. As already mentioned above, the same location of the photosensitive material is considered the same location in a plane perpendicular to the projection direction of the object structures which coincides with the optical axes of the projection objectives. The projection onto the same location of the photosensitive material can be achieved by appropriately moving a material holder stage or wafer stage holding the photosensitive material during the two exposure steps.

The above object is further solved according to the invention by a projection exposure system for structuring a photosensitive material, which projection exposure system comprises: optical projection means for projecting a pattern of an object structure onto the photosensitive material such that the projected pattern is focussed at a focus position within the photosensitive material, wherein the focus position can be altered by adjusting a focus adjustment parameter; input means for entering at least one characteristic parameter of the photosensitive material and for entering a desired distance between a first focus position and a second focus position within the photosensitive material; means for calculating an offset value of the focus adjustment parameter from the characteristic parameter and the desired distance, which offset value defines an offset in the focus adjustment parameter required for adjusting the focus position within the
photosensitive material from the first focus position to the second focus position; and means for automatically adjusting the focus adjustment parameter by the calculated offset value.

In other words, the projection exposure system according to the invention comprises input means for receiving a characteristic parameter or characteristic information of the photosensitive material. This characteristic parameter can, for example, be the refractive index of the photosensitive material. The optical projection means are adjusted to a first focus position within the photosensitive material. This can, for example, be done by means of a conventional focus sensor as contained in a typical projection exposure system for microlithography. The first focus position can be adjusted, as is typical in microlithography, by respective calibration of the focus sensor. The projection exposure system according to the invention further contains means for calculating a focus adjustment in order to move the focus from the first focus position to a second focus position within the photosensitive material. This is done by calculating an offset value for a focus adjustment parameter from the characteristic parameter and a desired focus offset between the first focus position and the second focus position. The characteristic parameter and the focus offset or desired distance between the two focus positions are used for calculating an offset value for the focus adjustment parameter, which offset value causes the focus to be moved from the first focus position to the second focus position. The offset value of the focus adjustment parameter can, for example, be a shift in the position of a material holder or wafer stage for holding the photosensitive material along an optical axis of the optical projection means or any other parameter for adjusting the focus of the projection exposure system.

The projection exposure system according to the invention allows quick and precise adjustment of the focus from the first focus position to the second focus position as no additional focus sensing is necessary. According to the invention the focus adjustment with respect to the photosensitive material using a focus sensor is typically done once to determine the first focus position. A second focus
position is then accessed by applying the calculated offset value of the focus adjustment parameter.

The above object is further solved according to the invention by a projection exposure system for structuring a photosensitive material, which projection exposure system comprises optical projection means for projecting a pattern of the object structure onto the photosensitive material; the optical projection means comprise an optical path for guiding light during the projection and a focus adjustment element, which is moveably mounted within the optical projection means such that it can be moved in and out of the optical path, wherein the focus adjustment element is adapted for causing a shift in a focus setting of the optical projection means if the focus adjustment element is moved into the beam path.

The focus adjustment element is advantageously configured such that the beam path of the optical beam projecting the pattern onto the photosensitive material is modified such that the focus of the optical projection means is shifted accordingly. This way the focus shift can be achieved in a quick and precise manner. The focus shift which occurs by inserting the focus adjustment element into the optical beam path is well defined and reproducible. Therefore, the focus shift between the focus positions with and without the focus adjustment element inserted into the optical path is well defined. This projection exposure system according to the invention allows the above-mentioned method according to the invention to be performed efficiently and with high precision.

In a further embodiment according to the invention the projection exposure system is a projection exposure system for microlithography. The projection exposure system can be configured as a stepper or a scanner known in the field of microlithography. The wavelengths used for exposing the photosensitive material can be in the visible and non-visible wavelength range. Examples for appropriate wavelengths are 365nm, 248nm, 193nm, 157nm or wavelengths in the extreme ultraviolet range, for example 13,5nm.
The above object is further solved by a mask for a projection exposure system which extends along a plane and comprises a first mask region and a second mask region, which are offset from each other in a direction perpendicular to the plane. The invention further provides a projection exposure system comprising the above-mentioned mask according to the invention.

In other words, the mask comprises a step between the different mask regions. The mask according to the invention allows the above-mentioned method according to the invention to be performed efficiently. The different mask regions being offset from each other allow structures in respective mask regions to be imaged onto the photosensitive material at different focus positions. In order to image object structures located in different mask regions onto the same location of the photosensitive material at different focus positions, the mask according to the invention simply can be moved in a mask plane between exposure steps.

The features specified above with respect to the method according to the invention can be transferred correspondingly to the projection exposure system according to the invention and vice versa. Advantageous embodiments of the projection exposure system and the method according to the invention resulting therefrom shall be covered by the disclosure of the invention.

_Brief description of the drawings_

The foregoing, as well as other advantageous features of the invention will be more apparent from the following detailed description of exemplary embodiments of the invention with reference to the following diagrammatic drawings, wherein:

Figure 1 illustrates a first embodiment of a projection exposure system for structuring a photosensitive material according to the invention;
Figure 2 shows a cross-section of the photosensitive material arranged on a silicon substrate shown in Figure 1;

Figure 3 shows a first embodiment of a first mask for use by the projection exposure system according to Figure 1;

Figure 4 shows a first embodiment of a second mask for use by the projection exposure system according to Figure 1;

Figure 5 shows a three-dimensional view of a photosensitive material three-dimensionally structured using the masks shown in Figures 3 and 4;

Figure 6 shows another three-dimensional view of the three-dimensionally structured photosensitive material of Figure 5;

Figure 7 illustrates a second embodiment of a projection exposure system for structuring a photosensitive material according to the invention;

Figure 8 shows an embodiment of a mask for use in the projection exposure system according to Figure 7;

Figure 9 shows a third embodiment of a projection exposure system for structuring a photosensitive material according to the invention;

Figure 10 shows a fourth embodiment of a projection exposure system for structuring a photosensitive material according to the invention;

Figure 11 shows a fifth embodiment of a projection exposure system for structuring a photosensitive material according to the invention;

Figure 12 shows a sixth embodiment of a projection exposure system for structuring a photosensitive material according to the invention;
Figure 13 shows a second embodiment of a first mask for use in the projection exposure system according to Figure 1;

Figure 14 shows a second embodiment of a second mask for use in the projection exposure system according to Figure 1;

Figure 15 is a three-dimensional view of a photosensitive material structured three-dimensionally using the masks shown in Figures 13 and 14;

Figure 16 shows a third embodiment of a first mask for use in the projection exposure system shown in Figure 1;

Figure 17 shows a third embodiment of a second mask for use in the projection exposure system shown in Figure 1;

Figure 18 shows an embodiment of a third mask for use in the projection exposure system according to Figure 1;

Figure 19 is a three-dimensional view of a photosensitive material structured three-dimensionally using the masks shown in Figures 16 to 18;

Figure 20 is a front view of the structured photosensitive material shown in Figure 19;

Figure 21 is a plan view of the structured photosensitive material shown in Figure 19;

Figure 22 is a fourth embodiment of a first mask for use in the projection exposure system according to Figure 1;
Figure 23 is a fourth embodiment of a second mask for use in the projection exposure system shown in Figure 1;

Figure 24 is another embodiment of a third mask for use in the projection exposure system shown in Figure 1;

Figure 25 is a three-dimensional view of a photosensitive material structured three-dimensionally using the masks of Figures 22 to 24;

Figure 26 is a plan view of the photosensitive material shown in Figure 25; and

Figure 27 is a front view of the photosensitive material shown in Figure 25.

**Detailed description of exemplary embodiments**

In the embodiments of the invention described below, components that are alike in function and structure are designated, as far as possible, with the same or alike reference numerals. Therefore, to understand the features of the individual components of a specific embodiment the description of other embodiments or the summary of the invention should be referred to.

Figure 1 is a schematic view of a first embodiment of a projection exposure system 10 according to the invention. The projection exposure system 10 is adapted for structuring a photosensitive material 12 in the form of a photo-resist layer on a silicon substrate 14. The photosensitive material 12 has a top surface 13 facing away from the silicon substrate 14 and a bottom surface 15 being attached to the silicon substrate 14. The photosensitive material 12 and the silicon substrate 14 together form a wafer 16. The wafer 16 is held by a material holder 18 in the form of a wafer chuck. The material holder 18 is held by a wafer stage 20 which is configured for moving the material holder 18 in x-, y- and z-directions according to the coordinate system of Figure 1.
The projection exposure system 10 comprises illumination means 22 for illuminating a mask 24a or 24b held by a mask holder 26. The mask holder is attached to a mask stage 28 which allows the respective mask 24a or 24b to be moved in the x-, y-, and z- directions. The illumination means 22 generate illumination radiation 30 having a suitable wavelength for lithographically exposing the masks 24a and 24b onto the wafer 16. Examples of the wavelengths of the illumination radiation 30 are: 365nm, 248nm, 193nm, 157nm or a wavelength in the EUV-region, for example 13.6nm.

The illumination means 22 can be configured with different illumination settings. An illumination setting defines the angular distribution of the illumination radiation 30 being incident on mask 24a or 24b. Examples of illumination settings are different partial coherence settings of standard illumination, annular illumination and quadruple illumination. The projection exposure system 10 further comprises optical projection means 32 in the form of a projection objective for projecting a pattern of an object structure 34 or 36 on the masks 24a and 24b, respectively, along an optical axis 38 of the optical projection means 32 onto the photosensitive material 12. The projection direction 40 along the optical axis 38 is graphically shown in Figure 1.

The projection exposure system 10 further comprises control means 42 for controlling the illumination means 22, the mask stage 28 and the wafer stage 20. The control means 42 are configured for controlling the projection exposure system 10 to perform the steps detailed in the following.

Firstly the first mask 24a is loaded into the mask holder 26. The first mask 24a contains at least one first object structure 34. An example of an embodiment of the first mask 24a is shown in Figure 3. The first object structure 34 comprises in this case two contact hole mask structures in a dark field environment. That means, the contact hole structures are configured as transmissive elements, wherein their surroundings are opaque, such that the light is blocked therefrom.
In a first exposure step a pattern of the first object structure 34 is projected by means of the optical projection means 32 onto the photosensitive material 12. Thereby the pattern of the first object structure 34 is projected in the projection direction 40 along the optical axis 38 of the optical projection means 32. During the first exposure the wafer 16 is located at a first position l. The photosensitive material 12 in position l is shown in Figure 1 by continuous lines. The wafer 16 of Figure 1 is also shown in Figure 2 for illustration purposes. The pattern of the first object structure 34 is focussed at an image location \((x_0, y_0)\) in the wafer plane which is perpendicular to the projection direction 40. The focus of the projected pattern is located at a first focus position \(Z_1\) close to the bottom surface 15 of the photosensitive material 12 which has a thickness \(d\) in the z-direction along the optical axis 38.

After the first exposure step the first mask 24a is removed from the mask stage 28 and a second mask 24b is loaded thereon. An example of a second mask 24b is shown in Figure 4. The second mask 24b comprises at least one second object structure 36 which is, in the case of Figure 4, a horizontal transmissive line in a dark field surrounding. The second mask 24b and the second object structure 36 are drawn in dotted lines in Figure 1.

Subsequently, a pattern of the second object structure 36 is projected onto the same location \((x_0, y_0)\) on the photosensitive material 12 as the pattern of the first object structure 34. However, during the second exposure step the wafer 16 is located at a different z-position. The position of the photosensitive material 12 during the second exposure step is designated by \(\Pi\) in Figure 1 and the photosensitive material 12 is drawn with dotted lines. The movement of the wafer 16 to a different z-position for the second exposure step has the effect that the focus position of the projected pattern of the second object structure 36 is focussed at a second focus position \(Z_2\) within the layer of photosensitive material 12. The second focus position \(Z_2\) is close to the top surface 13 of the photosensitive material 12 as can be seen from Figure 2. The three-dimensional
structure generated by the two exposure steps using the masks of Figures 3 and 4 is shown in Figures 5 and 6. The photosensitive material 12 comprises two vertical holes 44 in a lower section thereof which open up into a horizontally oriented groove 46 in the upper section of the photosensitive material 12.

The three-dimensional structures shown in Figures 5 and 6 of the photosensitive material 12 are obtained in a photo-resist having a thickness d of 1 μm. The first object structure 34 was exposed in the first exposure step at a defocus setting of 0.2 μm with respect to the upper surface 13 of the photosensitive material 12 and a so called standard illumination setting defined by a partial coherence of σ = 0.99 (σ_{inner} = 0, σ_{outer} = 0.99). The size of the holes of the first object structure 34 on the first mask 24a is 0.2 μm and the distance between the holes also 0.2 μm. The partial coherence σ of the illumination radiation 30 is defined by the quotient of the numerical aperture of the illumination means 22 generating the illumination radiation 30 and the numerical aperture of the optical projection means 32. The size of the line of the second object structure 36 shown in Figure 3 is 0.2 μm. The second exposure is performed at a defocus setting of 1 μm and a standard illumination setting defined by a partial coherence of σ = 0.99 (σ_{inner} = 0, σ_{outer} = 0.99). For DOpt exposures a wavelength of 248 nm is used and the optical projection means 32 have a numerical aperture (NA) of 0.8.

The projection exposure system 10 according to Figure 1 optionally further comprises input means 50 for entering a characteristic parameter of the photosensitive material 12 in form of the refractive index of the photosensitive material 12 and a desired distance Δz between the first focus position Z₁ and the second focus position Z₂ within the photosensitive material 12. Further, the projection exposure system 10 comprises calculation means 52 for calculating an offset value for an adjustment in the z-direction to be performed by the wafer stage 20. The offset value is calculated from the refractive index and the desired distance Δz. Before the first exposure step, the position of the wafer 16 is adjusted relative to the optical projection means 32 using focus sensors (not shown in the figure). Such focus sensors can be optical or capacitive sensors.
After the first exposure step the wafer 16 is moved by the calculated offset value in the z-direction. A further focus adjustment using focus sensors is not required.

Figure 7 shows a second embodiment of a projection exposure system 10 according to the invention. This embodiment differs from the embodiment shown in Figure 1 in that it is adapted for conducting the structuring method according to the invention using a single mask 24c which contains both object structures 34 and 36. An example of the mask 24c is shown in Figure 8. The first object structure 34 is located on the right half of the mask 24c and the second object structure 36 on the left half of the mask 24c.

During the first exposure step the left half of the mask is blocked from the illumination radiation 30 by a mask blade 48 such that only the first object structure 34 is imaged onto the photosensitive material 12. Subsequently, the right half of the mask is blocked from the illumination radiation 30 by the mask blade 48 and the second object structure 36 is imaged onto the same location of the photosensitive material 12 as the first object structure 34 in the second exposure step. This can be achieved, for example, by moving the mask 24c in the mask plane, as shown in Figure 7, such that the second object structure 36 is located during the second exposure step at the same location as is the first object structure 34 during the first exposure step. The projection of the structures 34 and 36 of the single mask 24c can also be achieved by appropriately moving the wafer stage 20 and/or the mask stage 28, as will be apparent to the person skilled in the art.

Figure 9 shows a third embodiment of a projection exposure system 10 according to the invention. This embodiment differs from the embodiment according to Figure 1 in that it is configured for exposing both object structures 34 and 36 using only a single mask 24d. The mask 24d is illuminated by illumination radiation 30 having two different monochromatic wavelengths. The first object structure 34 and the second object structure 36 are both located at the same location of the mask 24d. The first object structure 34 is configured such that its pattern is only
generated by first monochromatic light from the illumination radiation 30 having a first wavelength. The second object structure 36 is configured such that its pattern is only generated by second monochromatic light from the illumination radiation 30 having a second wavelength. The optical projection means 32 are configured such that the first light having the first wavelength is focussed onto the first focus position \( z_i \) and the second light having the second wavelength is focussed onto the second focus position \( z_2 \). The embodiment of the projection exposure system 10 according to Figure 9 therefore allows simultaneous imaging of the two object structures 34 and 36 onto different focus positions on the photosensitive material 12.

Figure 10 depicts a fourth embodiment of a projection exposure system 10 which is, like the projection exposure systems shown in Figures 7 and 9, also configured for exposing a single mask 24e containing both object structures 34 and 36. The mask 24e extends along a mask plane and comprises a first mask region 54 and a second mask region 56 which are offset from each other in the direction of the optical axis 38 of the optical projection means 32. The first mask region 54 contains the object structure 34 and the second mask region 56 contains the second object structure 36.

In a first exposure step the second mask region 56 is blocked from the illumination radiation 30 by a mask blade 48 such that only the first mask region 54 is imaged onto the photosensitive material 12 in a first focal plane at a first focus position \( Z_1 \). Thereby the first mask structure 34 is imaged onto the location \((x_0, y_0)\) of the photosensitive material 12. Subsequently, the second mask region 56 is exposed onto the same area of the photosensitive material 12 as was the first mask region 54. This is done such that the second object structure 36 is projected onto the same location \((x_0, y_0)\) on the photosensitive material 12 as the first mask structure 34.

In the embodiment illustrated in Figure 10 this is achieved by moving the mask 24e by the mask stage 28 along the x-direction of the coordinate system of Figure
10 such that the second object structure 36 is located at the same x-, y- position as is the first object structure 34 in the first exposure step. The position of the mask 24e in the first exposure step is designated in Figure 10 by I. During a second exposure step the mask 24e is depicted in Figure 10 by dotted lines and its position is indicated by II. Due to the fact, that the mask regions 54 and 56 are offset from each other in the z-direction, the images of the mask regions 54 and 56 are focussed in the different focal planes at the focus positions zi and z2, respectively.

Figure 11 depicts a fifth embodiment of a projection exposure system 10 according to the invention. This embodiment differs from the embodiment shown in Figure 1 in that the focus adjustment between the first focus position Σj and the second focus position Z2 in the two consecutive exposure steps is not achieved by moving the wafer 16 in the z-direction, but by inserting a focus adjustment element 60 into an optical path 58 of the optical projection means 32, which optical path 58 is guiding the light of the projected patterns through the projection means 32.

The focus adjustment element 60 is moveably mounted within the optical projection means 32 such that it can be moved in and out of the optical path 58. During the first exposure step, in which a first mask 24a is exposed, the focus adjustment element 60 is removed from the optical path 58 such that the first object structure 34 is focussed onto the first focus position Zi. Subsequently, the focus adjustment element 60 is moved into the optical path 58 which causes the focus of the optical projection means 32 to move to the second focus position Z2. Therefore, the second object structure 36 is focussed during the second exposure step at the second focus position Z2.

Figure 12 shows a sixth embodiment of the projection exposure system 10 according to the invention. This embodiment differs from the embodiment shown in Figure 7 in that the optical projection means 32 comprise two or more optical projection objectives 62 and 64. The projection objectives 62 and 64 each have
an optical axis 66 and 68, respectively, which are arranged parallel to each other at an offset. The projection objectives 62 and 64 are adjusted to different focus positions, namely the first projection objective 62 to a first focus position \(Z_1\) and the second projection objective 64 to the second focus position \(Z_2\).

A mask 24c is used having a first object structure 34 and a second object structure 36 arranged on different mask areas as, for example, shown in Figure 8. The first mask structure 34 is projected by the first projection objectives 62 onto the photosensitive material 12 in a first exposure step during which a mask region containing the second object structure 36 is blocked from the illumination radiation 30 by a mask blade 48. In a subsequent second exposure step the area of the mask 24c containing the first object structure 34 is blocked by the mask blade 48 and the second object structure 36 is projected by the second projection objective 64 onto the photosensitive material 12. Further embodiments of the projection exposure system 10 according to Figure 12 can also comprise three or more separate projection objectives for imaging a larger number of object structures at different focus positions onto the photosensitive material 12.

Figures 13 and 14 show two object structures 34 and 36, respectively, to be imaged onto the photosensitive material 12 using one of the projection exposure systems 10 described above. Figure 13 shows a first mask 24a having a first object structure 34 comprising three transmissive contact holes in a dark field surrounding. The contact holes each have a size of 0.2\(\mu\)m and are arranged at a distance of 0.2 microns. The first object structure 34 is exposed at a defocus setting of 0.8 microns with respect to the upper surface 13 of the photosensitive material 12 and a standard illumination having a partial coherence of \(\sigma_{outer} = 0.5\) (\(\sigma_{inner} = 0\)). Figure 14 shows a second mask 34b having an opaque line of a line width of 0.2 microns in a bright surrounding. The second object structure 36 is exposed at a defocus setting of 0.5 microns with respect to the upper surface 13 of the photosensitive material 12 and a standard illumination having a partial coherence of the illumination of \(\sigma_{inner} = 0.5\) (\(\sigma_{outer} = 0\)). Figure 15 shows a three-
dimensional view of the photosensitive material 12 having a layer thickness of 1 micron structured by exposure of the object structures 34 or 36 shown in Figures 13 and 14 at the above mentioned conditions. The structure shown in Figure 15 has a saddle-shaped base 70 and two bumps 12 on top thereof.

Figures 16, 17 and 18 show three different object structures 34, 36 and 74 exposed at different focus settings using any one of the projection exposure systems 12 described above. Figure 16 depicts a first mask 24a having a first object structure 34 in the form of a vertical transmissive line of a line width of 0.2 microns in a dark field surrounding. The first object structure 34 is exposed with annular illumination defined by $\sigma_{\text{mner}} = 0.8$ and $\sigma_{\text{OMer}} = 0.99$. The focus setting during the exposure of the first object structure 34 is 1 micron.

Figure 17 shows a second object structure 36 in the form of a horizontal transmissive line having a line width of 0.2 microns which is exposed at a defocus setting with respect to the upper surface 13 of the photosensitive material 12 of 0 microns with annular illumination defined by $\sigma_{\text{mner}} = 0.8$ and $\sigma_{\text{OMer}} = 0.99$. Figure 18 shows a third object structure 74 in the form of an opaque square pad having a side length of 0.6 microns. The third object structure 74d is exposed at a defocus setting of 0.5 microns with respect to the upper surface 13 of the photosensitive material 12. The photosensitive material has a layer thickness of 1 micron.

Figures 19, 20 and 21 show the resulting three-dimensionally shaped structure of the photosensitive material 12 obtained by exposing the object structures 34, 36 and 74 shown in Figures 16 to 18 at the conditions described above. The three-dimensionally shaped structure is characterised by a tunnel 76 and two bumps 72 on top of the structure.

Figures 22 to 24 show a further example of object structures 34, 36 and 74 exposed by any one of the inventive projection exposure systems 10 described above. Figure 22a first mask 24a containing a first object structure 34 in the form of a vertical line of a line width of 0.2 microns in a dark field surrounding. The first
object structure 34 is exposed at a defocus setting of 1 micron with respect to the upper surface 13 of the photosensitive material 12. The illumination setting used thereby is an annular illumination setting defined by $\sigma_{\text{inner}} = 0.8$ and $\sigma_{\text{outer}} = 0.99$.

Figure 23 shows a second object structure 36 in the form of crossed transmissive lines of different length, each having a line width of 0.2 microns. The defocus setting for exposing the second object structure 36 of this example is 0 microns with respect to the upper surface 13 of the photosensitive material 12. The illumination used for this exposure is also an annular illumination characterised by $\sigma_{\text{inner}} = 0.8$ and $\sigma_{\text{outer}} = 0.99$. Figure 24 shows a third object structure 74 in the form of an opaque square pad having a side length of 0.6 microns. The third object structure 74 according to Figure 24 is exposed at standard illumination defined by $\sigma_{\text{inner}} = 0$ and $\sigma_{\text{outer}} = 0.5$.

Figures 25 to 27 show a three-dimensionally shaped structure in the photosensitive material 12 obtained by exposing the object structures 34, 36 and 74 shown in Figures 22 to 24 using the exposure conditions described above. The structure shown in Figures 25 to 27 is characterised by four legs 78 and a plateau area 80 containing two holes 82. The structure has two bumps 72 on its top.

All exposure conditions used for producing the three-dimensionally shaped structures shown in the figures include a NA of 0.8 and a wavelength of 248nm. As photosensitive material 12 a resist model of so called UV 210 has been used.
List of reference numerals

10 projection exposure system
12 photosensitive material
13 top surface
14 silicon substrate
15 bottom surface
16 wafer
18 material holder
20 wafer stage
22 illumination means
24a first mask
24b second mask
24c single mask
24d single mask
24e single mask
26 mask holder
28 mask stage
30 illumination radiation
32 optical projection means
34 first object structure
36 second object structure
38 optical axis
40 projection direction
42 control means
44 hole
46 groove
48 mask blade
50 input means
52 calculation means
54 first mask region
56 second mask region
optical path
focus adjustment element
first projection objective
second projection objective
optical axis
optical axis
saddle-shaped base
bump
third object structure
tunnel
leg
plateau
hole
Claims

1. A method of structuring a photosensitive material comprising the steps of:
   - illuminating a first object structure and projecting a pattern of said first object structure onto said photosensitive material such that said projected pattern of said first object structure is focussed at a first focus position with respect to said photosensitive material, and
   - illuminating a second object structure and projecting a pattern of said second object structure onto said photosensitive material such that said projected pattern of said second object structure is focussed at a second focus position with respect to said photosensitive material, wherein the respective patterns are projected in the same projection direction.

2. The method according to claim 1,
   wherein said respective patterns are projected onto the same location of said photosensitive material in a plane perpendicular to said projection direction.

3. The method according to claim 1 or 2,
   wherein said first focus position and said second focus position are both located within said photosensitive material.

4. The method according to any one of the preceding claims,
   wherein said photosensitive material has a given thickness in said projection direction and a distance between said first focus position and said second focus position is at least 10%, preferably at least 50%, of said thickness.

5. The method according to any one of the preceding claims,
   wherein said photosensitive material has a given thickness in said projection direction, each of said object structures is illuminated by light rays having an angular distribution, which angular distribution is adapted to the shape of the illuminated object structure such that an irradiation profile of at least one of said
projected patterns extends in the direction of said projection direction inside the photosensitive material by less than 50% of said thickness, in particular by less than 10% of said thickness, of said photosensitive material.

6. The method according to any one of the preceding claims, wherein said first object structure is illuminated by light rays having a first angular distribution and said second object structure is illuminated by light rays having a second angular distribution.

7. The method according to any one of the preceding claims, wherein at least one of said object structures is projected onto said photosensitive material as a dark field image.

8. The method according to any one of claims 1 to 6, wherein at least one of said object structures is projected onto said photosensitive material as a bright field image and the projected pattern extends in the direction of said projection direction by more than 80% of the thickness of the photosensitive material, preferably by more than 100% of the thickness of the photosensitive material.

9. The method according to any one of the preceding claims, wherein spherical aberrations in a wave front of at least one of said projected patterns are caused by interaction of the light of said projected pattern with said photosensitive material and said spherical aberrations are corrected by optical projection means projecting the respective pattern onto said photosensitive material.

10. The method according to any one of the preceding claims, wherein said object structures are located on separate masks and after projecting said pattern of said first object structure a mask change is performed.

11. The method according to any one of the preceding claims,
wherein said patterns are projected onto said photosensitive material using optical projection means having a numerical aperture of $NA$, said patterns generate material structures in said photosensitive material, and the process of generating said material structures from said object structures is determined by the lithographic process constant $k_1$, wherein $NA$ and $k_1$ satisfy the following relation: $NA/k_1 > 0.5$.

12. The method according to any one of the preceding claims, wherein after projecting said object structures onto said photosensitive material said photosensitive material is chemically conditioned such that regions within said photosensitive material, which were exposed to light, change an optical and/or an electrical characteristic.

13. The method according to any one of the preceding claims, wherein said pattern of said first object structure is projected onto said photosensitive material in a first exposure step and said pattern of said second object structure is projected onto said photosensitive material in a subsequent second exposure step.

14. The method according to any one of the preceding claims, wherein said first object structure differs from said second object structure in its orientation, shape and/or size.

15. The method according to any one of the preceding claims, wherein said object structures are simultaneously illuminated by light having two different optical properties, said pattern of said first object structure is generated predominantly or completely from first light having a first one of said optical properties and said pattern of said second object structure is generated predominantly or completely from second light having the second one of said optical properties.

16. The method according to claim 15,
wherein said patterns are projected onto said photosensitive material by optical projection means, which optical projection means are adapted to focus said first light at said first focus position and said second light at said second focus position.

17. The method according to claim 15 or 16, wherein said different optical properties are different optical wavelengths of said light.

18. The method according to any one of claims 15 to 17, wherein said different optical properties are different orthogonal polarisation states of said light.

19. A projection exposure system for structuring a photosensitive material, in particular being adapted for performing the method according to any one of claims 1 to 18, said projection exposure system comprising:
- illumination means for illuminating a first object structure and a second object structure;
- optical projection means for projecting a respective pattern of said first object structure and said second object structure onto said photosensitive material; and
- control means for controlling the operation of said projection exposure system such that said projected pattern of said first object structure is focussed at a first focus position with respect to said photosensitive material, said projected pattern of said second object structure is focussed at a second focus position with respect to said photosensitive material and said respective patterns are projected in the same projection direction.

20. A projection exposure system for structuring a photosensitive material, in particular according to claim 19, which projection exposure system comprises:
- a mask holder for holding a mask having a first object structure and a second object structure at different locations of said mask;
- a material holder for holding said photosensitive material;
- optical projection means for imaging said mask onto said photosensitive material; and
- control means for controlling said projection exposure system to automatically perform a double exposure of said mask, in which in a first exposure step said first object structure and in a second exposure step said second object structure is imaged onto said photosensitive material, such that said first object structure and said second object structure are imaged onto the same location of said photosensitive material and said photosensitive material remains on said material holder during said double mask exposure.

21. The projection exposure system according to claim 20, wherein said control means are adapted to control said projection exposure system such that in said first exposure step said first object structure is imaged onto said photosensitive material at a first focus setting of said optical projection means and in said second exposure step said second object structure is imaged onto said photosensitive material at a second focus setting of said optical projection means.

22. The projection exposure system according to claim 20 or 21, wherein said mask comprises a first exposure region containing said first object structure and a second exposure region containing said second object structure, and said control means are configured to cause said projection exposure system image said first region in said first exposure step and said second region in said second exposure step onto said photosensitive material.

23. The projection exposure system according to any one of claims 19 to 22, wherein said control means are implemented by hardware and/or software.

24. A projection exposure system for structuring a photosensitive material, in particular according to any one of claims 19 to 23, which projection exposure system comprises two projection objectives each having an optical axis, wherein
said optical axes are parallel and offset relative to each other and said projection objectives are adjusted to different focus positions.

25. The projection exposure system according to claim 24, wherein said projection exposure system is adapted for projecting a pattern of a first object structure onto said photosensitive material using a first one of said projection objectives and projecting a pattern of a second object structure onto said photosensitive material using the second one of said projection objectives such that both object structures are projected onto the same location of said photosensitive material.

26. A projection exposure system for structuring a photosensitive material, in particular according to any one of claims 19 to 25, which projection exposure system comprises:

optical projection means for projecting a pattern of an object structure onto said photosensitive material such that said projected pattern is focussed at a focus position within said photosensitive material, wherein said focus position can be altered by adjusting a focus adjustment parameter;

input means for entering at least one characteristic parameter of said photosensitive material and for entering a desired distance between a first focus position and a second focus position within said photosensitive material;

means for calculating an offset value of said focus adjustment parameter from said characteristic parameter and said desired distance, which offset value defines an offset in said focus adjustment parameter required for adjusting said focus position within said photosensitive material from said first focus position to said second focus position; and

means for automatically adjusting the focus adjustment parameter by said calculated offset value.

27. A projection exposure system for structuring a photosensitive material, in particular according to any one of claims 19 to 26, which projection exposure system comprises optical projection means for projecting a pattern of said object
structure onto said photosensitive material, which optical projection means comprise an optical path for guiding light during said projection and a focus adjustment element, which focus adjustment element is moveably mounted within said optical projection means such that it can moved in and out of said optical path, wherein said focus adjustment element is adapted for causing a shift in a focus setting of said optical projection means if said focus adjustment element is moved into said beam path.

28. The projection exposure system according to any one of claims 19 to 27, wherein said projection exposure system is a projection exposure system for microlithography.

29. A mask for a projection exposure system, which mask extends along a plane and comprises a first mask region and a second mask region, which mask regions are offset from each other in a direction perpendicular to said plane.

30. The mask according to claim 29, wherein said mask regions are offset from each other such that images of said mask regions generated by said projection exposure system are focussed in different focal planes.

31. The projection exposure system according to any one of claims 19 to 28, comprising a mask according to claim 29 or 30.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G03F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>DE 42 32 844 A1 (SIEMENS AG [DE]) 31 March 1994 (1994-03-31) column 2, line 60 - column 5, line 11; claim 8; figure 1</td>
<td>1,6-11, 29-31</td>
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<td>US 2006/051979 A1 (YOSHINAGA JUNICHI [JP]) 9 March 2006 (2006-03-09) paragraphs [0025], [0026]; figures 3-5</td>
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<td>US 2006/177778 A1 (YEN YUNG-SUNG [TW] ET AL) 10 August 2006 (2006-08-10) paragraphs [0024], [0025], [0041]; figures 2b, 3a, 4a, 6</td>
<td>1,4,5, 13,14</td>
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Further documents are listed in the continuation of Box C

See patent family annex

Date of the actual completion of the international search
18 June 2008

Date of mailing of the international search report
01/07/2008

Name and mailing address of the ISA:
European Patent Office, P B 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel (+31-70) 340-2040, Tx 31 651 epo nl Fax (+31-70) 340-3016

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This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos. because they relate to subject matter not required to be searched by this Authority, namely:

2. Claims Nos. because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be earned out, specifically:

3. Claims Nos. because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 64(a)

This International Searching Authority found multiple inventions in this international application as follows:

see additional sheet

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. X As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees

3. I As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- The additional search fees were accompanied by the applicant’s protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant’s protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.
This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-25

Closest prior art (DE 42 32 844 Al):
method and projection exposure system for structuring a photosensitive material. A first object structure is focussed at a first focus position with respect to the photosensitive material. A second object structure is focussed at a second focus position with respect to the photosensitive material.

Special technical feature:
First and second focus position are both located within the photosensitive material.

Problem solved by this special technical feature:
method and projection exposure system for three-dimensional structuring of a photosensitive material.

2. claims: 27, 28 (as far as referred to claim 27), 31 (as far as referred to claim 27)

Special technical features, taking due account of the description and drawings:
particular focus adjustment element which can be moved in and out of the optical path of the optical projection means,

Problem solved by this special technical features:
focus of the optical projection means can be shifted in a quick and precise manner
# INTERNATIONAL SEARCH REPORT

**Information on patent family members**

**International application No**

PCT/EP2007/007061

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Form PC17ISA/21O (patent family a-inex) (April 2005)