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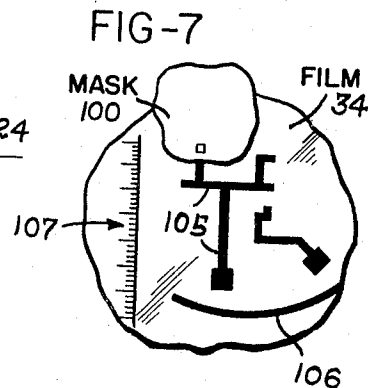
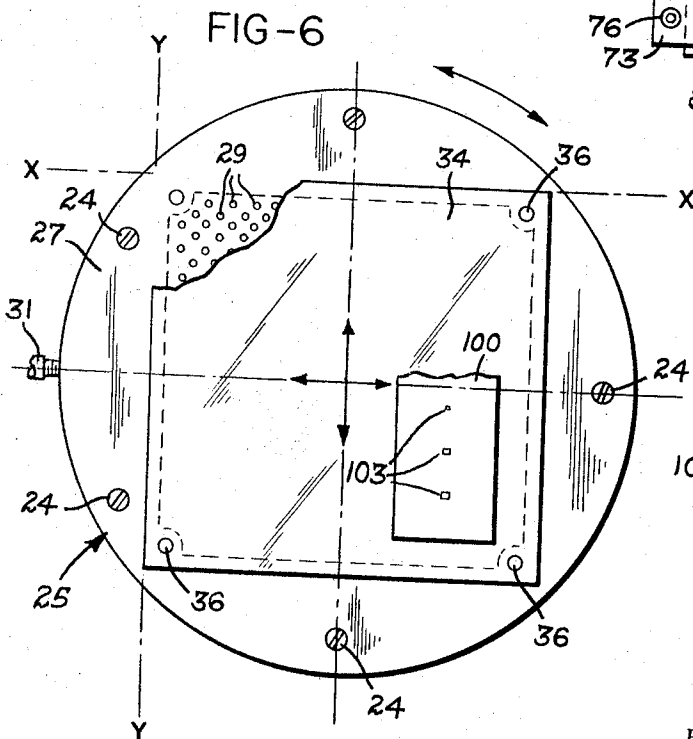
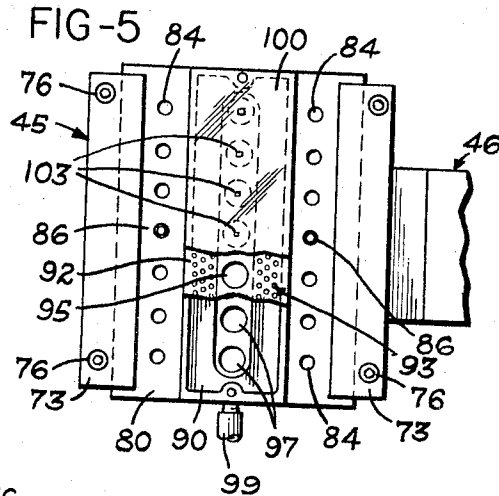
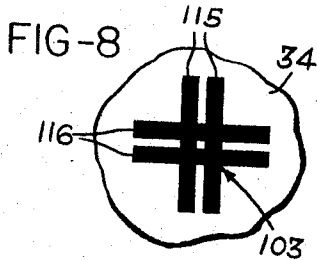
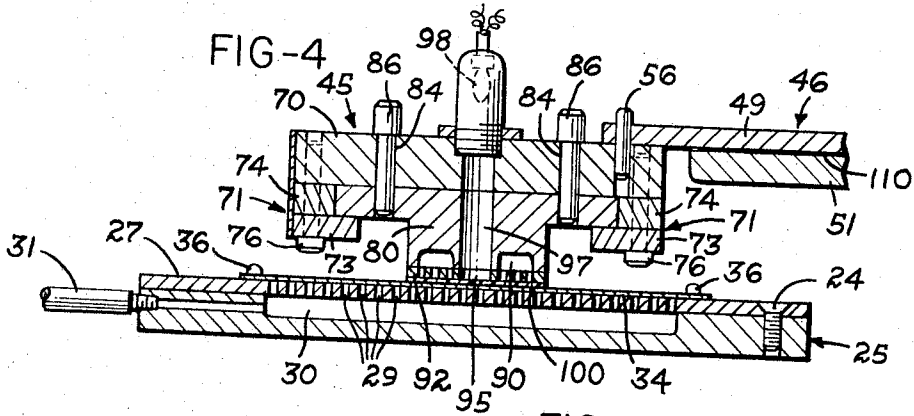
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METHOD AND APPARATUS FOR MAKING PRECISION ART WORK

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2 Sheets-Sheet 2



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METHOD AND APPARATUS FOR MAKING PRECISION ART WORK

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This invention relates to the making of original art work, and more particularly, to a method and apparatus for constructing by contact photographic means a precision line having such characteristics as uniform density and width as well as smooth and distinct edges, and which characteristics are especially apparent when viewed with the aid of a microscopic lens.

As a result of increasing emphasis on microminiaturized electronic circuitry and high density data storage as well as precision indicators, it has become increasingly important to prepare the original layout or art work with extreme precision so that when reduced through a microphotographic camera, the art work is within allowable tolerances. For example, in the preparation of a mask having 0.0001 inch line for an integrated circuit it is not uncommon to prepare the original art work at an enlargement of 1,000 times or a 0.100 inch line. Thus, when the art work is reduced photographically, errors in line width and edge roughness in the original are work are proportionately reduced.

Commonly, the original art work is prepared by the use of ink pens, diamond needles, ground knives or a projected light beam, and as a result, the edges of the lines when viewed under a microscope will not be distinct and will show roughness, burrs and/or a deposit of foreign matter. While the reduction of art work by several hundred times does proportionately reduce the roughness, on the other hand, this degree of reduction results in losing the sharpness, contrast and clarity of the lines. For example, when a line on the original art work forms a right angle, the inside and outside corners of the line become rounded when reduced by this magnitude to such an extent that it has been found necessary to distort the line intentionally at the corner by adding serifs or ears according to a predetermined formula, so that after reduction the roundness of the corners will be minimized.

In order to perform the extent of microphotography which is necessary for reducing the original art work by several hundred times, commonly the reduction must be accomplished in two or more steps through a precision microphotographic camera which is quite expensive since the lens system and the support members must be extremely accurate to minimize aberration and distortion through the lens. Furthermore, microphotographic cameras necessary for this magnitude of reduction are large and require considerable floor space. For example, a camera which reduces 200 times in one step with a lens having a four inch focal length would require a lens to subject distance of nearly 67 feet.

While the drawings of the apparatus according to the present invention are directed to an apparatus for use in making masks for the rapidly developing industry of microminiaturized electric circuits, it is to be understood that the process and the apparatus according to the invention are usable in many other industries where there is a requirement for precision original art work and especially for precision miniaturized art work. For example, the process is useful in the tool industry for making masters for optical gaging machines, and masks for chemical milling, for making precision optical scales, or in the data storage industry for making optical memory disks.

With the use of the process according to the present invention, it is no longer necessary to prepare the original art work at several hundred times the final desired size

in order to reduce proportionately the inaccuracies and errors within the original art work. Instead the present invention enables the original art work to be constructed on a substantially smaller scale and with extreme precision. In fact, by the use of the contact process and apparatus of the invention, it is simple to construct precision lines having a 0.001 inch width within tolerances of ± 0.0001 inch. Also, the lines have uniform density in addition to smooth and definite edges and the corners are perfectly sharp, clear and distinct.

Furthermore, it is possible to construct lines in an infinitely different number of patterns wherein the lines may be of different uniform widths. Then, by reducing the original lines constructed in accordance with the process and apparatus of the invention, for example by only a factor of 10 in a microphotography camera, it has been found that precision lines as fine as 0.0001 inch in width can be produced within tolerances of ± 1.00001 inch with no loss of sharpness and clarity. It is this degree of line precision that is necessary to meet the increasing demands for more compact miniaturized devices such as extremely complete integrated circuits or ultra high density data storage devices.

Presently known methods of using a projected light source do not offer this degree of precision which results from the contact process according to the present invention. One problem with projected light is that due to the inherent aberration in the lens, the line does not have uniform density and the edges are not sharp and distinct, but tend to fade, and this is especially noticeable when viewed under a high powered microscope.

Accordingly, it is a primary object of the present invention to provide a novel photographic process for constructing a precision line having an exact uniform width of predetermined dimension, and which line is characterized by uniform density and smooth and distinct edges which are particularly apparent when observed with the aid of a microscopic lens.

As another object, the present invention provides a novel photographic process for constructing a precision line having an exact uniform width of predetermined dimension and which line is of uniform density and has smooth and distinct edges which are particularly apparent when observed with the aid of a microscopic lens.

As another object, the present invention provides a novel photographic process for constructing precision lines as outlined above and an apparatus for carrying out the process whereby a photo-sensitive material is placed in tight contact with an opaque mask having a transparent aperture of predetermined configuration formed therein, and whereby the photo-sensitive material is moved relative to the aperture while remaining in tight contact with the mask so that a light source placed above the aperture will expose the photo-sensitive material in a progressive manner to define the line path of the aperture.

Still another object of the present invention is to provide novel apparatus for photographically constructing a precision line having a precise uniform width, smooth definite edges and uniform density and which apparatus includes a means for holding a photo-sensitive material in tight contact with an opaque mask having an aperture formed therein and also includes a means for sliding the photo-sensitive material in any direction transversely of the aperture so that a light source directed through the aperture can be used to expose any desired geometric configuration on the photo-sensitive material according to a predetermined pattern.

It is also an object of the present invention to provide a novel photographic apparatus as outlined above for constructing precision lines wherein the apparatus in-

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cludes a means for quickly and simply changing the aperture for lines of different widths whenever necessary for constructing a predetermined geometric pattern.

As a further object, the present invention provides a novel photographic process and apparatus as outlined above for constructing precision lines and which apparatus is ideally suited for use in the fabrication of integrated circuits and other microminiaturized devices since the reduction by microphotography is either eliminated or reduced substantially as a result of the capability of the process to form microminiature lines having smoothness and distinctness heretofore unobtainable.

As another object, the present invention provides a novel photographic process and apparatus for constructing precision lines as outlined above and is ideally suited for making original art work in miniature form wherein the precision width of each line must be considered when operating the apparatus so that the relationship or spacing of the lines is precise.

Still another object of the present invention is to provide an apparatus for photographically constructing precision line as outlined above wherein means are provided for controlling the tight contact pressure of the mask against the surface of the photo-sensitive material, but to reduce friction and prevent scratching or marring of the material.

It is also an object of the present invention to provide a novel photographic apparatus as outlined above wherein a photo-sensitive material is held in flat contact with a mask defining an aperture and wherein means are provided for relative movement of the photo-sensitive material along both an X axis and a Y axis in addition to rotary movement while the mask is held in firm contact with the photo-sensitive material.

As another object, the present invention provides a process for photographically constructing a precision line as outlined above, wherein the intensity of the light source is controlled depending upon the speed of relative movement between the mask and the photo-sensitive material.

Other objects and advantages of the invention will be apparent from the following description, the accompanying drawings and the appended claims.

In the drawings—

FIG. 1 is a perspective view of an apparatus showing the assembled relationship of the components for performing the process according to the invention;

FIG. 2 is a schematic diagram illustrating the different directions of movement for the circular table of the apparatus shown in FIG. 1;

FIG. 3 is a sectional view of a counter-balancing means for controlling the pressure between the pivotally mounted head and the table of the apparatus shown in FIG. 1;

FIG. 4 is an elevation section view of the vacuum system which holds the photo-sensitive material and the head which holds the mask in tight contact with the photo-sensitive material, in accordance with the invention;

FIG. 5 is a normal view of the mask retaining head with a portion of the surface plate cut away to show the vacuum chamber for holding the mask;

FIG. 6 is a top plan view of the movable table showing the positioning of a square sheet of photo-sensitive material and a portion of a mask in contact with the material;

FIG. 7 is a view showing a portion of the mask in contact with the photo-sensitive material illustrating typical variety of line exposures and relative spacing of the lines which are constructed by the process and apparatus according to the invention; and

FIG. 8 is a fragmentary view of a photo-sensitive film showing the exposure of two sets of parallel lines which are spaced apart and arranged at 90° to each other to define a precision transparent square aperture for use as a mask on the apparatus.

Referring to the drawings, which illustrate a preferred embodiment of the apparatus according to the invention,

and which is used for performing the process of the invention, FIG. 1 shows a generally L-shaped base member 10 having mounted on the longest leg thereof, by a series of screws 12, a combined rotary and linear movable table unit, generally referred to as 15, which is adapted to rotate by energizing the electric motor 17, move linearly along an X axis by energizing the motor 18 and move linearly along a Y axis by energizing the motor 19. It is highly desirable for the table unit 15 to have extreme accuracy in its movement so when lines are constructed by the apparatus, they will have extreme accuracy and can be precisely spaced in relation to one another. Thus, it is to be understood that while the table shown typifies a precision table, the degree in movement of the table along both the X and Y axis as well as a rotary direction depends solely upon the accuracy employed in constructing the table. For example, in order to obtain extreme precision movement of the table, it may be desirable to construct the table with X and Y guide ways from granite which is known to be stable and unaffected by reasonable changes in temperature or humidity.

While the electric motors 17, 18 and 19 are shown for controlling the different movements of the table 15, it is to be understood that either mechanical or hydraulic means may be employed for accurately controlling the rotary and linear movements of the table. In use with the electric motors, however, are the counters 21 which visually indicate in thousands the linear movement of the table along the X and Y axis. Another control over the precise linear movement of the table is by accurately timing the period of energizing the motors 18 and 19. Similarly, the fine scale 22 and pointers 23 may be used for indicating the degree of rotation of the table.

Rigidly connected by the screws 24 to the top portion of the table unit 15 is a vacuum table 25 having a surface plate 27 containing a plurality of openings 29 through which a partial vacuum is introduced from the vacuum chamber 30 connected to a suitable vacuum source by the line 31. The vacuum table 25 serves to hold a photo-sensitive material such as film 34 tightly to the top of the surface plate. Four equally spaced precision pins 36 project slightly upward from the surface plate 27 and are employed to engage corresponding precision holes formed in the film 34 for positioning the film with precision on top of the surface plate 27.

Preferably, the photo-sensitive film 34 is a chronar or estar base film which has a substantially hard emulsion surface which is positioned upward when the film 34 is fixtured on the surface plate 27. It is to be understood, however, that instead of using the film 34, other photo-sensitive materials having chemically treated surfaces or emulsion coated surfaces may be used. For example, material such as metal or glass to which has been applied a light sensitive chemical, is commonly known as a photo-resist. Whichever type of photo-sensitive material is used, however, it is desirable that the material have a tough and abrasive photo-sensitive surface and is dimensionally stable where exposed to moderate changes in temperature and humidity.

Extending from the shorter leg of the L-shaped base 10 are a pair of projections 42 between which the mask retaining head, generally referred to as 45, is pivotally mounted by a two-piece arm 46 and a pin 47. As shown in FIG. 1, the upper arm section 49 is attached adjustably on one end to the lower arm section 51 by the screws 53 and the opposite end of the upper section 49 is attached rigidly to the head 45 by the screws 55 and locating pin 56. Extending downwardly from the lower arm section 51 is a lever 58 through which is threaded a thumb screw 60 adapted to engage a plate 62 for exerting a force against the compression spring 64. As shown in FIG. 3, the compression spring 64 is retained within a housing 66 suitably mounted to the base member 10. The purpose of the thumb screws 60 and spring 64 is to

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counter-balance the weight of the head 45 and the arm 46. Thus, by adjusting the thumb screws 60 the pressure of the head 45 resting on the photo-sensitive material or film 34 can be varied.

As shown in the detailed view of FIG. 4, the mask retaining head 45 includes a top mounting plate 70 rigidly mounted to the upper arm section 49 by the screws 55 and the locating pin 56. Fastened to the underneath side of the plate 70 are a pair of parallel spaced guide ways 71 which are formed by the guide plates 73 and spacers 74. A mask retaining member 80 is mounted to slide within the guide ways 71 on top of the plates 73 and includes two rows of parallel spaced holes 84 which are adapted to receive a pair of locating pins 86 extending through the mounting plate 70.

As shown in FIG. 5, by releasing the pins 86 the mask retaining member 80 can be moved and positioned in one of several different locations according to the spacing of the holes 84. The lower portion of the mask retaining member defines a vacuum chamber 90 which is covered by the lower surface plate 92 having a plurality of suction openings 93 and a row of centrally spaced openings 95. As shown in FIG. 4, the openings 95 correspond to a series of chambers 97 formed within the member 80 so that each chamber 97 can be aligned with a light source 98 centrally mounted on the plate 70. The light source 98 may be a neon tube energized by a 110 volt D.C. source. This provides the advantage of instant start and stop. A direct current is employed for operating the neon light to eliminate any pulsing of the light source. Also, a suitable filter may be used according to the type of photo-sensitive material which is to be exposed.

By introducing a partial vacuum within the chamber 90 through the vacuum line 99, an opaque mask 100 is positively retained on the lower surface plate 92, and is positioned by the locating pins 86 so that the mask 100 is in tight uniform contact with the photo-sensitive film 34. Preferably, the emulsion surface of the mask is placed in tight contact with the emulsion surface of the film to eliminate parallax due to the thickness of the film or mask. By providing the mask 100 with a series of different size transparent apertures 103, FIG. 5, it can be seen that one of the apertures can be placed directly under the light source 98 so that the light source can expose the photo-sensitive film 34 through the desired aperture 103 and exactly according to the predetermined configuration of the aperture. Typical apertures formed within the mask 100 might include a series of perfectly square transparent openings ranging, for example, from .001 inch to .100 inch. By simply lifting the pins 86, an aperture of a different size can be quickly positioned directly under the light source 98.

It thus becomes apparent that by accurately controlling the rotational and the linear movement of the table 25, the photo-sensitive film 34 can be moved in a sliding manner relative to the mask 100 and by energizing the light source 98 the path of the aperture is progressively exposed on the film which, in turn, constructs a line having a precise uniform width exactly the same as the width of the aperture. It is further apparent that lines of different uniform width can be arranged in an infinite number of geometric patterns. A typical collection of such lines are illustrated in FIG. 7, such as the relative wide straight lines 105, curved lines 106 or fine scale lines 107. It is to be understood, however, that rather than moving the photo-sensitive material and holding the mask fixed, the mask may be moved relative to the fixed photo-sensitive material or an apparatus can be constructed where both the mask and the material move.

Depending upon the thickness of the photo-sensitive material employed and the thickness of the mask 100, it may be necessary to add or remove one or more of the fine shims 110 which are placed between the upper arm section 49 and the lower arm section 51. These shims or other suitable adjusting means are desired to

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provide uniform contact between the mask 100 and the photo-sensitive film 34. As mentioned above, it is desirable to control the pressure of the mask upon the film or other photo-sensitive material and this can be controlled on the apparatus shown by adjusting the thumb screw 60, although other control means are obvious. For example, it has been found that a force of approximately 6 ounces exerted by the head 45 on the table 25 results in a pressure which maintains tight contact between a film and mask and in addition, permit easy relative movement between the mask and the film without scratching or marring the emulsion surface of either the mask or the film. To obtain an exact exposure through the aperture of the photo-sensitive material placed on the top surface plate 27, it has been found desirable to control the intensity of the light source 98 depending upon the speed of relative movement between the mask and the photo-sensitive material. For this control, a suitable potentiometer can be connected in series with the light source 98. It has also been found desirable to dwell a fraction of a second with the light source at the beginning and end of each line while the table is not in motion so that the ends of the line receive the same uniform exposure as the rest of the line. Furthermore, it has been found desirable to use square aperture with the mask 100 rather than a circular aperture so that the edge of the line receives the same uniform exposure as the center portion of the line when the mask is moving over the photo-sensitive material. The square aperture is also preferred in constructing a curved line as well as a straight line for the same reason, that is, uniform exposure of the line.

In the same sense that a milling machine can make its own cutter, the apparatus according to the present invention can make its own mask. For example, in order to construct a square transparent precision aperture of 0.001 inch across the flats, a film is exposed by using a mask having a considerably larger aperture of known width, for example, 0.125 inch. Then, two sets of parallel lines are constructed as shown in FIG. 8. That is, one of the lines 115 is exposed on the film by moving the table along the X axis and then the table is spaced so that the other parallel line 115 is constructed allowing a space of 0.001 inch between the two lines 115. The process is then repeated by moving the table along the Y axis to construct the two parallel lines 116 spaced precisely at 0.001 inch apart and at 90° to the parallel lines 115. When the film is developed, a negative is made which defines a precision square of 0.001 inch between the lines and which negative can be easily converted into an opaque mask with a 0.001 inch square transparent aperture by simply blocking out the remaining unexposed portion of the mask. By using the process and apparatus of the invention to construct the mask, a microscope will show that the edges of the aperture are perfectly straight and smooth without any burrs or roughness and the corners are distinct. It is also to be understood, however, that the mask may be made from other materials in addition to film, as for example, metal or opaque glass having a transparent aperture which is intended to include an actual opening.

It thus becomes apparent that the process and apparatus according to the present invention provide a method of precise dimension according to a predetermined pattern. The lines are made with such accuracy that when viewed under a microscope, the edges of each line are clear and distinct in addition to being perfectly smooth. Furthermore, lines of extremely small uniform width can be constructed and can be precisely arranged and spaced with one another according to predetermined distances to such an extent that the width of each line must be considered to result in precision spacing of the lines. It is to be further understood that while the electric motors 17, 18 and 19 may be controlled by a timer to determine the rotary and linear movements of the table 25, it is possible to control the movements of the table through an

automatic system, for example, a programmed computer tape which controls the motors.

An important feature of the present invention results from the fact that the original art work may be constructed at an extremely small scale whereby photographic reduction is not necessary, or at most, only a small reduction is necessary, as for example, in the nature of 10 or below, to convert the art work into microminiature patterns or masks. These resulting sharp and distinct masks are ideally suited for making integrated circuits and other microminiature devices. Furthermore, by eliminating the necessity for making the original art work at several hundred times enlargement of the final product, expensive microphotography cameras are eliminated.

The precision of the lines constructed according to the photographic contact process of the present invention is increased by the fact that the intensity of the light source is controlled in relation to the speed of relative movement between the photo-sensitive material and the mask. Of course, after a speed is once determined, the intensity of the light source may be set and it is not necessary to adjust the intensity until the speed is altered or a different photo-sensitive material is used. The intensity of the light source, however, must be set according to the particular photo-sensitive material used. For example, if the intensity is too high, the exposure might spread within the emulsion resulting in a non-uniform line width. If the intensity is too low, the density of the line will not be uniform.

Another factor which contributes to the precision lines obtainable from the process and apparatus of the invention is the pressure by which the masks are held against the photo-sensitive material. If the pressure is too great, the photo-sensitive material will not withstand the friction and scratching or marring of the surface will result as well as a breakdown of the emulsion. On the other hand if the pressure is too light the mask may not be in firm contact with the photo-sensitive material and results in a non-uniform line width.

While the method herein described, and the form of apparatus for carrying this method into effect, constitute preferred embodiments of the invention, it is to be understood that the invention is not limited to this precise method and form of apparatus, and that changes may be made in either without departing from the scope of the invention which is defined in the appended claims.

What is claimed is:

1. A photographic process for making precision art work, comprising the steps of placing a photo-sensitive material in pressure contact with an opaque mask having a transparent aperture of precise configuration formed therein, placing a light source on the opposite side of said mask for exposing said material exactly to the precise geometric configuration of said aperture, and producing predetermined relative movement between said photo-sensitive material and said mask while retaining said material in pressure contact with said mask to expose in a progressive manner the path of said aperture on said material and thereby define a precision line having a width precisely the same as said aperture.

2. A process as defined by claim 1 wherein the photo-sensitive material is placed in pressure contact with an opaque mask having a square transparent aperture formed therein so that the edges of the line constructed by the process receive the same time exposure as the center of the line.

3. A photographic apparatus adapted for constructing a precision line having exact uniform width and density as well as smooth and distinct edges which are apparent when viewed with the aid of a microscopic lens, comprising means for supporting a material having a photosensitive surface, means for placing an opaque mask having a predetermined transparent aperture formed therein in pressure contact with said photo-sensitive sur-

face, a light source for exposing said surface on said material through said aperture, means for producing predetermined relative movement between said material and said mask while said mask remains in pressure contact with said surface for constructing a line by exposing in a progressive manner the path of said aperture on said surface, and means for controlling the magnitude of pressure contact between said mask and said material to prevent scratching or marring of said surface during the relative movement between said mask and said surface.

4. A photographic apparatus adapted for constructing without the use of a lens, a precision line having exact uniform width and density as well as smooth and distinct edges which are apparent when viewed with the aid of a microscopic lens, comprising flat table means for supporting a material having a photo-sensitive surface, head means for retaining an opaque mask having a predetermined transparent aperture formed therein in tight flat contact with said photo-sensitive surface, means for moving said head means away from said table means for attaching and removing said mask, a light source for exposing said surface on said material through said aperture, power operated means for producing predetermined relative movement between said material and said mask while said mask remains in tight contact with said surface for constructing a line by exposing in a progressive manner the path of said aperture on said surface, means for controlling the contact pressure between said mask and said material to prevent scratching or marring of said surface during the relative movement between said mask and said surface, and means for controlling the intensity of said light source according to the speed of relative movement between said material and said mask to expose a precision line having a width exactly the same as said aperture.

5. A photographic apparatus adapted for constructing a precision line having exact uniform width and density as well as smooth and distinct edges which are apparent when viewed with the aid of a microscopic lens, comprising flat table means for retaining a material having a photo-sensitive surface, head means for retaining an opaque mask having a predetermined transparent aperture formed therein, said head means disposed for placing said mask in pressure contact with said photo-sensitive surface, a light source for exposing said surface on said material through said aperture, means for mounting said table and said material for movement along an X axis and a Y axis as well as in rotary direction while said mask remains in pressure contact with said surface for constructing a line by exposing in a progressive manner the path of said aperture on said surface, and adjustable means for controlling the magnitude of pressure contact between said mask and said material to prevent scratching or marring of said surface during the relative movement between said mask and said surface.

6. A photographic process for making precision art work, comprising the steps of placing a photo-sensitive material, pressure contact with an opaque mask having a transparent aperture of precise configuration formed therein, placing a non-pulsating light source on the opposite side of said mask for uniformly exposing said material exactly to the precise geometric configuration of said aperture, producing predetermined relative movement between said photo-sensitive material and said mask while retaining said material in pressure contact with said mask to expose in a progressive manner the path of said aperture on said material, and controlling the intensity of said light source according to the speed of relative movement between said material and said work for constructing a precision line of uniform density and having a uniform width precisely the same as said aperture.

7. A photographic apparatus adapted for constructing a precision line having exact uniform width and density as well as smooth and distinct edges which are apparent when viewed with the aid of a microscopic lens, com-

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prising vacuum table means for supporting a film having a photo-sensitive emulsion surface, vacuum means for supporting an opaque mask having a predetermined transparent aperture formed therein, said mask supporting means disposed for placing said mask in pressure contact with the emulsion surface of said film, a light source for exposing said surface on said film through said aperture, means for producing predetermined relative movement between said film and said mask while said mask remains in pressure contact with said surface for constructing a line by exposing in a progressive manner the path of said aperture on said surface, and means for controlling the magnitude of pressure contact between said mask and said film to prevent scratching or marring of said surface during the relative movement between said mask and said surface.

8. Photographic apparatus for constructing precision art work, comprising means for supporting a material having a photo-sensitive surface, means for retaining an opaque mask having a precise transparent aperture formed therein, said mask retaining means disposed for placing said mask in pressure with said photo-sensitive surface, a light source for exposing said surface of said material through said aperture, means for producing predetermined relative movement between said material supporting means and said mask retaining means while said photo-sensitive surface and said mask remain in pressure contact, and means for controlling the magnitude of pressure contact between said mask and said material during relative sliding movement between said mask and said surface.

9. Apparatus as defined in claim 8 wherein said mask retaining means includes a member adapted to retain a mask having a plurality of spaced apertures, and means

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for selectively positioning said member for presenting each of said apertures to said light source.

10. Apparatus as defined in claim 8 wherein said material supporting means include a substantially horizontal table, said mask retaining means including a head member, and means supporting said head member for generally vertical movement for positioning said head member so that at least a portion of the weight of said head member is supported by said table.

11. A photographic process for constructing precision art work, comprising the steps of placing a photo-sensitive surface of a material in pressure contact with an opaque mask having a transparent aperture of precise configuration formed therein, placing a light source on the side of said mask opposite said surface for exposing on said surface the precise geometric configuration of said aperture, and producing predetermined relative sliding movement between said material and said mask while retaining said surface in pressure contact with said mask.

12. A process as defined in claim 11 including the step of controlling the magnitude of pressure contact between said mask and said surface during said relative sliding movement.

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