Jan. 19, 1971 J. A. ROBERTS ET AL 3,556,636

COLLIMATED HOLE STRUCTURE WITH MASK FOR PRODUCING HIGH RESOLUTION IMAGES

Filed Jan. 30, 1968

Fig. 1.

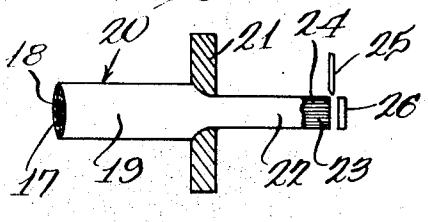



Fig. 2.

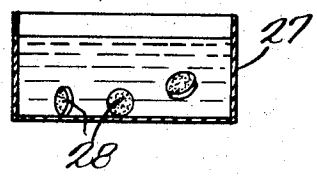



Fig. 3.

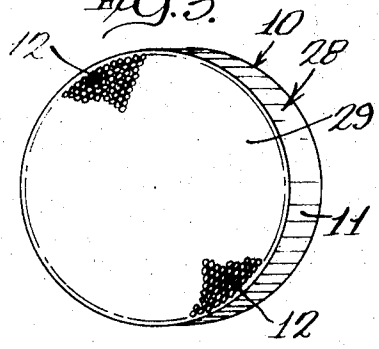



Fig. 4.

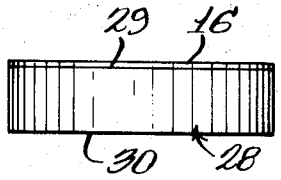



Fig. 5.

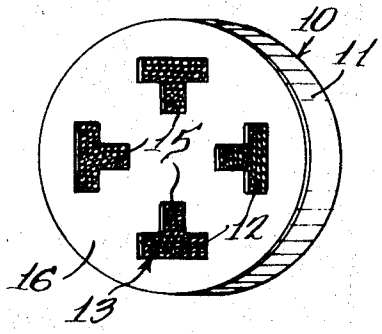



Fig. 6.

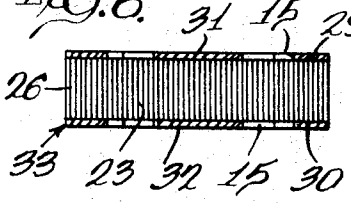



Fig. 8.

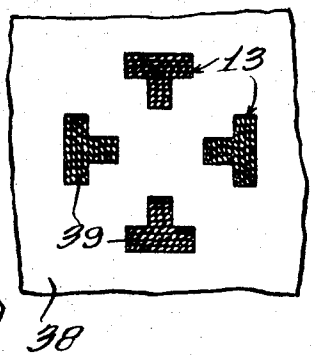
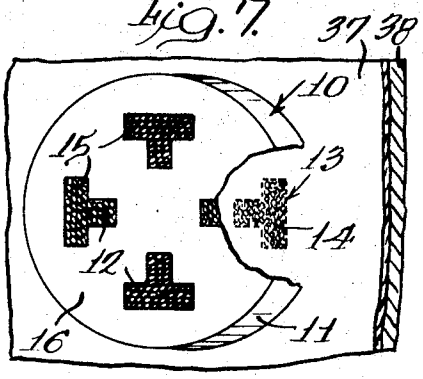



Fig. 7.



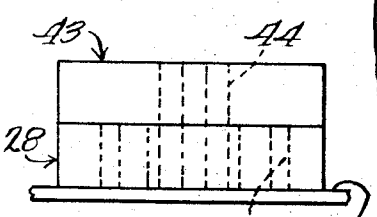




Fig. 9.

Fig. 10.

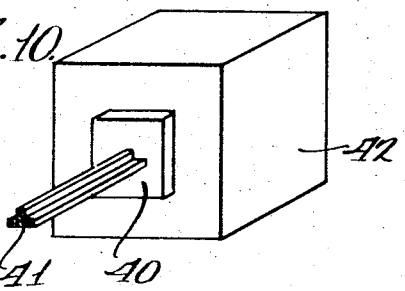
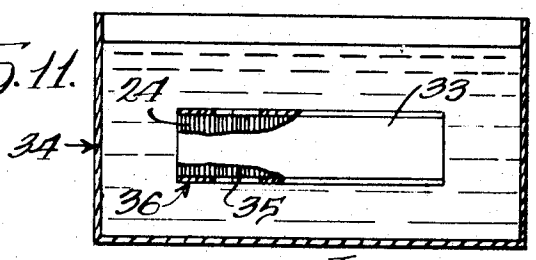



Fig. 11.

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Attys

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# 3,556,636
# COLLIMATED HOLE STRUCTURE WITH MASK FOR PRODUCING HIGH RESOLUTION IMAGES

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U.S. Cl. 350—96 1 Claim

## ABSTRACT OF THE DISCLOSURE

A method of producing high resolution images formed of a plurality of small images produced by passing radiation through a collimated hole structure having substantially rectilinear small cross section passages. The collimated hole structure is provided with a high aspect ratio of passage length to passage cross section to provide a high resolution in the individual images produced thereby. A mask may be formed on one surface of the collimated hole structure having an opening exposing preselected ones of the collimated hole structure passages for producing a composite image defining a preselected pattern corresponding to the opening.

This invention relates to image producing devices and, in particular, to a method of producing high resolution images and means for use therein.

In connection with the disclosure of this application, reference may be had to copending Roberts and Roberts application Ser. No. 471,123, filed July 12, 1965, for a "Passage Structure," owned by the assignee hereof and now abandoned.

In applications such as micro-circuitry, it is desirable to provide images having a high resolution for subsequent etching. In the known structures, the resolution characteristics of the image producing means has been primarily controlled by the size of the openings of the screen utilized. The present invention comprehends an improved method and means for producing high resolution images wherein both opening size and aspect ratio of the openings are controlled to produce an improved image producing means.

Thus, a principal feature of the present invention is the provision of a new and improved method of producing high resolution images.

Another feature of the invention is the provision of such a method of producing high resolution images comprising the steps of forming a collimated hole structure defined by a body having a plurality of substantially rectilinear, parallel through passages opening through a spaced surface of said body, the passages having a maximum transverse dimension of under approximately 500 microns and having a preselected high aspect ratio of at least approximately 5 to 1, providing on one of the surfaces a mask defining an opening having a preselected shape, the opening exposing a plurality of the passages, and passing radiation through the exposed passages to define a plurality of radiation images corresponding accurately to the cross sections of the exposed passages.

Still another feature of the invention is the provision of such a method of producing high resolution images comprising the steps of forming a composite defined by a metal matrix having a plurality of substantially rectilinear, parallel filaments formed of a different metal adapted to be leached from the matrix and extending to spaced surfaces of the matrix, the filaments having a maximum transverse dimension of under approximately 500 microns and a length between the surfaces of at least five times the maximum transverse dimension, providing on one of the

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surfaces a mask defining an opening having a preselected shape, the opening exposing the end of a plurality of the filaments, and leaching the filaments through the opening to define a plurality of passages defining an array corresponding to the shape of the opening, and passing radiation through the passages to define a plurality of radiation images corresponding accurately to the cross section of the passages.

Yet another feature of the invention is the provision of such a method of producing high resolution images wherein the mask comprises a plating layer.

A further feature of the invention is the provision of such a method of producing high resolution images wherein the mask comprises a developed radiation-resist layer.

A still further feature of the invention is the provision of such a method of producing high resolution images wherein the image is utilized in etching a sheet.

A yet further feature of the invention is the provision of such a method of producing high resolution images further including the step of providing on the other of the spaced surfaces a second mask corresponding to the first named mask having its opening aligned with the opening of the first named mask.

Another feature of the invention is the provision of such a method of producing high resolution images wherein the mask comprises a collimated hole structure having a relative large passage therein defining the opening.

Still another feature of the invention is the provision of such a method of producing high resolution images wherein the passages have a maximum transverse cross section of under approximately 10 microns.

Yet another feature of the invention is the provision of a new and improved high resolution image producing device comprising a collimated hole structure defined by a body having a plurality of substantially rectilinear, parallel through passages opening through spaced surfaces of the body, the passages having a maximum transverse dimension of under approximately 500 microns and having a preselected high aspect ratio of at least approximately 5 to 1, and a mask fixed to one of the surfaces and defining an opening having a preselected shape, the opening exposing a preselected plurality of the passages for radiation transmission therethrough.

Other features and advantages of the invention will be apparent from the following description taken in connection with the accompanying drawing wherein:

FIG. 1 is a side elevation illustrating the first step in the forming of a collimated hole structure for use in an image producing device embodying the invention;

FIG. 2 is a vertical section illustrating a second step therein;

FIG. 3 is an enlarged isometric view of an element as formed by the process illustrated in FIG. 1;

FIG. 4 is a side elevation thereof with a mask layer provided on one end surface thereof;

FIG. 5 is an isometric view thereof illustrating a pattern of openings in the mask;

FIG. 6 is a diametric section illustrating a modified form of masked element wherein corresponding masks are provided on each of the opposite end surfaces;

FIG. 7 is an isometric view of a formed image producing device embodying the invention utilized for producing an image on a subjacent sheet;

FIG. 8 is a plan view of the sheet upon completion of the forming of holes therein in accordance with the pattern of FIG. 7;

FIG. 9 is a side elevation illustrating the use of a pair of collimated hole structures embodying the invention for cooperatively defining the image producing means;

FIG. 10 is an isometric view illustrating the use of a portion of the structure of FIG. 8 as a spinnerette; and

FIG. 11 is a view similar to that of FIG. 2 illustrating the formation of selected through passages in the element by means of a double masked structure as shown in FIG. 6.

In the exemplary embodiment of the invention as disclosed in the drawing, an image producing device, generally designated **10**, is shown to comprise a matrix body **11** provided with a plurality of substantially rectilinear through passages **12**. The image producing device **10** effectively defines a high resolution image producing device wherein patterns **13** are provided made up of a plurality of small images **14** of the passages **12**, the patterns **13** corresponding to openings **15** in a mask **16** provided on the image producing device. As the passages **12** may have extremely small cross section and a relatively high aspect ratio, i.e. the ratio of the length of the passages to the maximum cross sectional dimension thereof, the images produced thereby may be extremely high resolution images.

The method of forming the image producing device **10** includes a first step, as illustrated in FIG. 1, wherein a plurality of rods **17** are sheathed in tubular sheaths **18** and bundled in an outer sheath, or can, **19** to define an assembly **20**. The assembly **20** is constricted by suitable constricting means and herein, illustratively, is constricted by being drawn through a suitable die **21**. The constricting process may be carried out in a plurality of steps to define a final reduced composite **22** wherein the rods **17** define very fine filaments **23** embedded in a matrix **24** comprising the original sheaths **18** diffusion bonded together by the constricting forces to define a substantially monolithic body **11**. The composite **22** may be transversely cut as by a suitable knife **25** to define a plurality of disc-like elements **26**.

The rods **17** are preferably formed of a material differing from that of the sheaths **18** and can **19** to permit subsequent separation of the filaments **23** from the matrix **24** as by leaching. Illustratively, the rods **17** may be formed of Monel metal, and the sheaths **18** and can **19** may be formed of stainless steel. Thus, the filaments **23** may be removed by treating the elements in a conventional nitric acid bath, generally designated **27**, to dissolve the filament material leaving the stainless steel body **11** with a plurality of very small passages **12**.

As the sheaths **18** become fusion bonded together and to the can **19**, a substantially rigid monolithic body **11** is formed having high strength. By accurately controlling the rod and sheath sizes and the constricting steps, very high accuracy in the size disposition and configuration of the passages **12** may be obtained. Illustratively, the filaments, and thus the passages **12**, may have a maximum cross sectional dimension of under 500 microns. As the filaments may be made as small as desired by the novel forming method, the passages may have extremely small maximum cross section, such as below 10 microns down to submicron sizes. Further, as the filaments **23** support the matrix **24** in the cutting operation, the elements **26** may be made extremely small. The elements **26** may be cut by knife **25** to be relatively thin. However, the invention comprehends providing the image producing device **10** with passages having a relatively high aspect ratio, such as at least approximately 5 to 1 for improved resolution of the images **14**.

The collimated hole structure **28** resulting from the leaching of the filaments from the elements **26** is illustrated in greater detail in FIG. 3. As shown therein, the passages **12** extend through the collimated hole structure to open through a front surface **29** and a rear surface **30** (FIG. 4). The mask **16** is provided on the surface **29** to define the openings **15** corresponding to the image patterns **13**. Illustratively, the mask may comprise a layer of material, such as metal, plated onto the surface **29** with suitable plating-resist material applied to the surface portion defining the openings **15**. Thus, when radiation such as light is directed against one surface **29**, or **30**, of the image producing device **10**, only those passages **12** exposed by the openings **15** will transmit light therethrough. As the passages have a relatively high aspect ratio and small cross section, the light passing therethrough may be used to produce dot-like images of extremely high resolution.



An alternative method of forming such an image producing device is illustrated in FIGS. 6 and 11 wherein the element **26** is provided with a first mask **31** on surface **29** and a similar mask **32** on surface **30**. By indexing the respective masks to expose the opposite ends of the fine filaments **23** and removing the exposed filaments as by placing the plated element **33** in a suitable nitric acid leaching bath **34**, passages **35** will be selectively leached with the unexposed filaments remaining in the matrix **24** to define an image producing device, generally designated **36**, effectively similar to image producing device **10**.

The masks **31** and **32** may be formed by other suitable methods such as by exposing and developing a photoresist material to define the desired openings **15**. Other methods of providing the desired masks will be obvious to those skilled in the art.

The image producing device **10** (**36**) may be utilized to provide high resolution images as for use in applications such as micro-circuitry, spinnerette, etc., applications. As shown in FIG. 7, the image producing device **10** may be utilized to provide images **14** on a photoresist layer **37** on a base such as metal plate **38**. Upon development of the latent images **14** and subsequent leaching of the plate through the holes defined by the developed images, passages **39** may be provided in the plate **38** arranged in the patterns **13** corresponding to the openings **15**.

Thus, as shown in FIGS. 7 and 8, where the openings **15** are T-shaped the patterns **13** of the openings **39** in plate **38** will be similarly T-shaped, with the individual passages therein accurately conforming to the accurately controlled cross sections of the passages **12** of the image producing device. Illustratively, such a pattern of holes **39** may be utilized in forming a spinnerette **40** to provide a T-shaped multi-strand plastic filament **41** as by extrusion in a conventional plastic extruder **42**.

The invention further comprehends the use of a collimated hole structure to define the mask for selectively exposing preselected ones of the passages **12**, such as in collimated hole structure **28**. Thus, as illustrated in FIG. 9 a collimated hole structure, generally designated **43**, having a preselected arrangement of relatively large passages **44**, may be superimposed on collimated hole structure **28** to expose the desired passages **12** whereby the pattern defined by the passages **44** will be reproduced on the subjacent surface **45** by passage of radiation through the superposed collimated hole structures.

Thus, it may be seen that the collimated hole structure **28** provides means for defining high resolution images. The pattern of the images may be controlled by providing a mask on the collimated hole structure, or by superposing any one of a plurality of different masks thereon, including masks defined by other collimated hole structures. Any desirable pattern arrangement may be employed to expose different passages **12** so that an infinite variety of patterns may be obtained.

Accurate control of the resolution of the images **14** provided by the improved image producing device hereof permits the use thereof in forming extremely small images, such as used in micro-circuitry. The rigid strong characteristics of the collimated hole structures permits substantial reuse of the image producing devices while assuring maintained accuracy and control of the images produced thereby. As the masks may be formed integrally with the collimated hole structures, accurate reproduction of the images may be effected to provide a high degree of mask production accuracy.

While we have shown and described certain embodiments of our invention, it is to be understood that it is capable of many modifications. Changes, therefore, in

the construction and arrangement may be made without departing from the spirit and scope of the invention as defined in the appended claim.

We claim:

1. A high resolution image producing device comprising:

a rigid monolithic wrought metal body formed of a plurality of individually sheathed fine filaments, the filaments and sheaths being formed of different metals and the sheaths being diffusion bonded to each other, said sheathed filaments extending rectilineally and in parallel relationship between opposed end surfaces of the body, an opaque mask element fixed to one of said end surfaces and defining an image opening of preselected shape, and only those filaments aligned with the mask opening being leached out of their respective sheaths to define a collimated hole structure formed by the sheaths in the outline shape of the mask opening, the individual holes having a maximum cross-sectional dimension of less than 500 microns and the aspect ratio of hole



length to passage cross-sectional dimension being greater than 5 to 1, whereby a sharp edged image outline is formed by passing light radiation through the hole structure.


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