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Lemmond

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[54] **LAMINATED MULTI-APERTURED ELECTRODE**

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[73] Assignee: **General Electric Company,** Schenectady, N.Y.

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[52] **U.S. Cl.** **313/458;** 313/402; 313/414

[51] **Int. Cl.²** **H01J 29/07;** H01J 29/02; H01J 29/62

[58] **Field of Search** ..... 313/69 R, 402, 411, 417, 313/444, 458, 460

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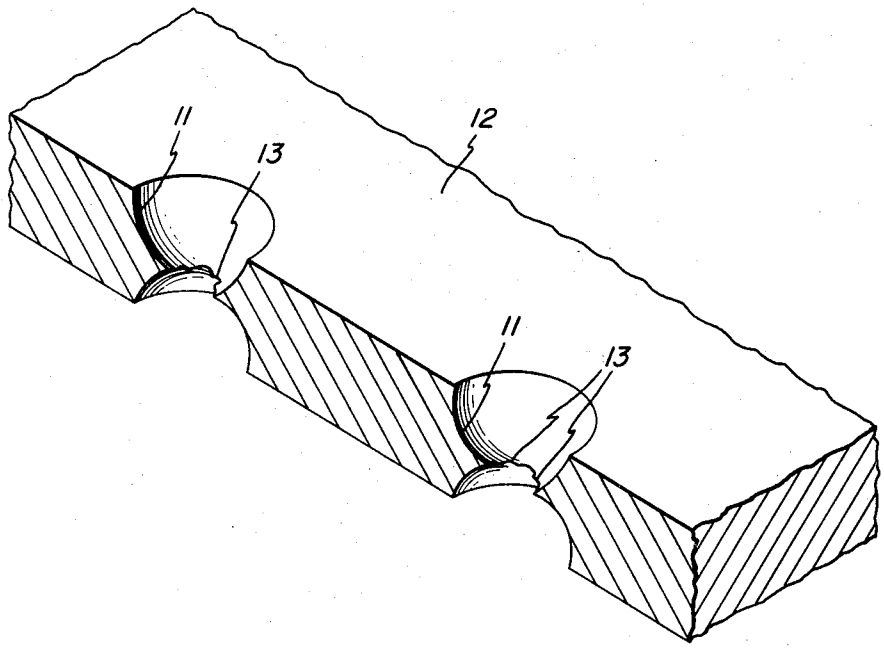
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[57] **ABSTRACT**

Electron optical lenses having an array of lenslets with each lenslet of substantially identical size and shape with precise spacing and alignment are described. Methods for making these lenses include forming lenslets in lens plates having a thickness substantially less than the diameter of the lenslets and then forming a laminated structure with a support plate bonded between two lens plates to provide mechanical rigidity to the electron optical lens.

5 Claims, 3 Drawing Figures



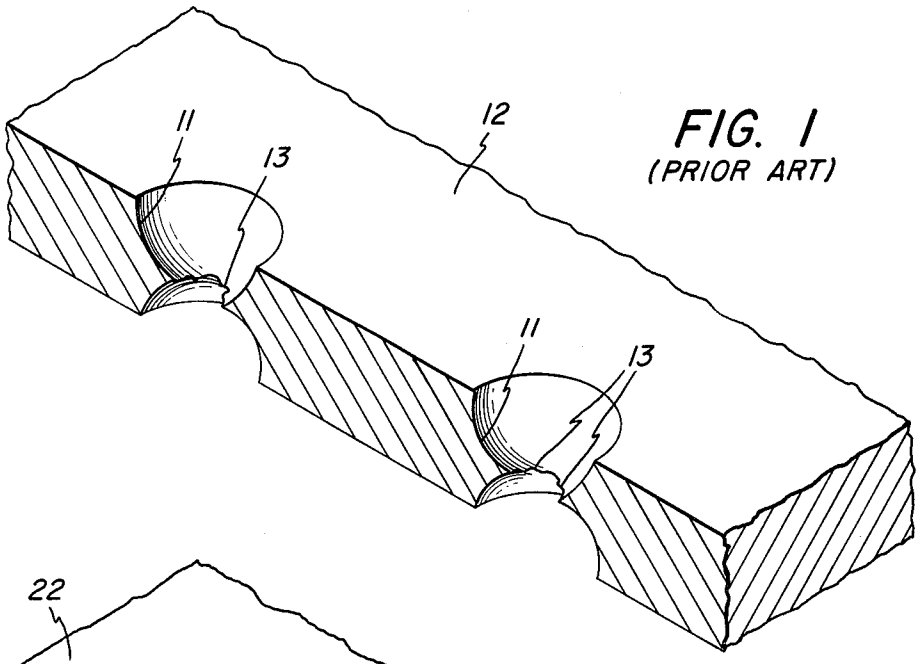


FIG. 1
(PRIOR ART)

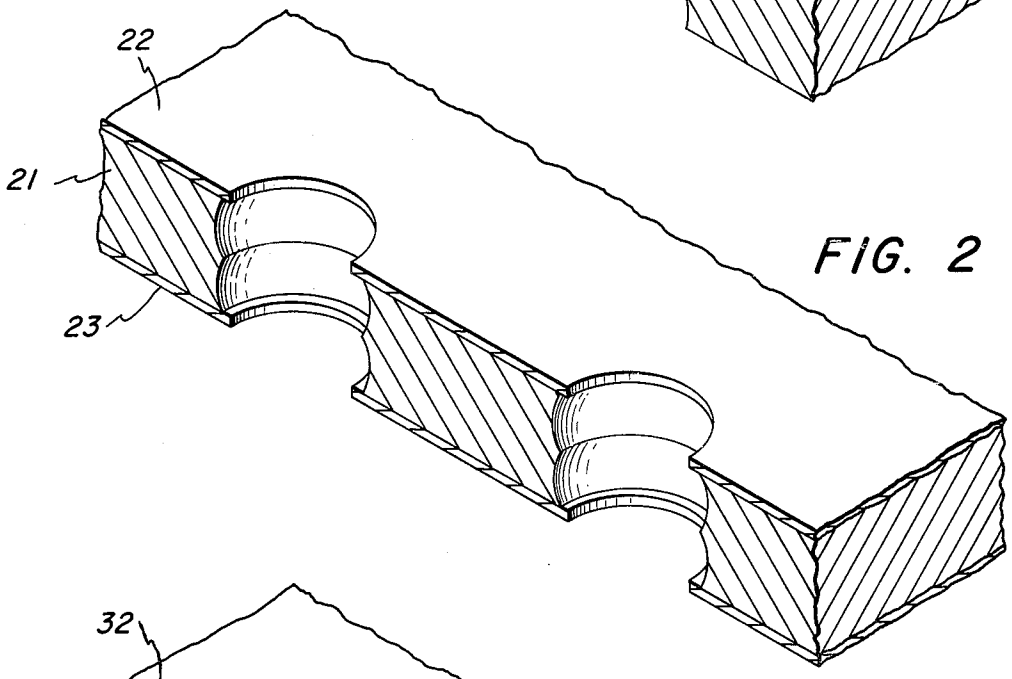


FIG. 2

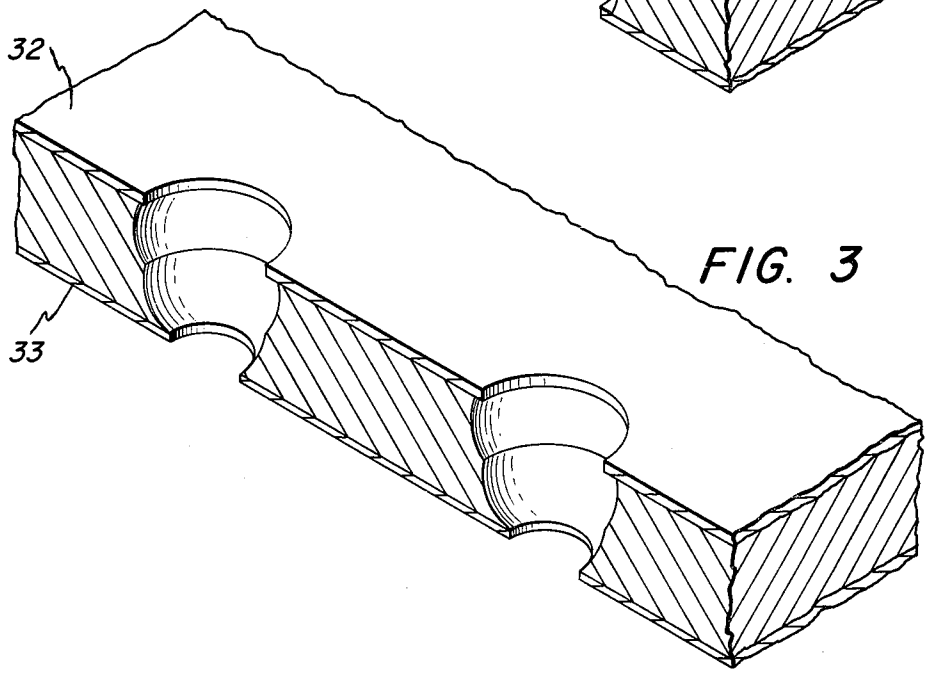


FIG. 3

LAMINATED MULTI-APERTURED ELECTRODE

The invention herein described was made in the course of or under a contract or subcontract thereunder with the Department of Army.

The present invention relates to electron optical lenses and more particularly to improved methods of making electron optical lenses having an array of lenslets of substantially identical size and shape.

Recent advances in storage density of electron beam addressable memory systems have improved very stringent requirements on the electron optical system. One optical system which has been very useful in high density electron beam addressable memory systems is described in U.S. Pat. No. 3,534,219 to S. P. Newberry. This patent describes an electron optical system referred to generally as a fly's eye lens because it is superficially similar in appearance to the compound eye of an ordinary housefly. In the fly's eye lens system, an electron beam is directed to a receiving surface by first coarsely deflecting the beam in the general direction of a desired point of impingement on the receiving surface and then finally deflecting the beam toward the desired point of impingement so as to correct the path of the beam and then further deflecting the beam to the precise point of impingement. Apparatus utilized for this purpose includes a deflection system and a matrix of electron lenses for directing the electron beam to the desired point of impingement. The foregoing patent to Newberry describes a matrix electron lens comprising three substantially parallel apertured plates. These apertured plates are biased so that the electron beam passing therethrough is focussed prior to passing through a fine deflection apparatus.

An improved electron lens comprising two substantially parallel plates having a plurality of aligned apertures with the spacing between the plates and the diameters of the apertures determining the electron optical characteristics of the lens is described in co-pending application Ser. No. 294,021, filed Oct 2, 1972, by H. G. Parks et al, and of common assignee as the instant application, the entire disclosure of which is incorporated herein by reference thereto. As described in the Parks et al application, the use of a two-aperture lens system provides a substantial improvement in the spherical aberration characteristics over the three-element Einzel lens described in the Newberry patent.

Electron beam addressable memories, such as those described by Newberry and Parks et al generally employ an electron optical lens system comprising a plurality of lenslets or apertures for focussing an electron beam on a target structure. To achieve uniform beam characteristics on the target, it is necessary to provide a lens system in which each lenslet is substantially identical in size and shape with each other lenslet in the array. This problem becomes paramount when an array of 256 or more lenslets of 0.030 inch diameter, for example, are required to exhibit substantially identical operating performance characteristics. In order to achieve this degree of performance, dimensional tolerances on lenslet size, shape, spacing and hole alignment must be in the order of ± 0.0001 inch, or approximately 2½ microns. This tolerance is placed not only on the individual lenslet, but also on the lenslet to lenslet spacing and as a cumulative error across the array of lenslets. These requirements are extremely difficult to achieve in accord with prior art techniques.

It is therefore an object of this invention to provide electron optical lenses which exhibit the aforementioned characteristics and methods for making the same.

It is another object of this invention to provide methods of making electron optical lenses having an array of lenslets with each lenslet having substantially identical size and shape.

It is still a further object of this invention to provide methods of making electron optical lenses in which dimensional tolerances on lenslet size, shape, spacing and hole alignment are within approximately a 0.0001 inch.

Briefly, these and other objects are achieved in accord with one embodiment of my invention wherein an array of lenslets is etched in a lens plate having a thickness substantially less than the diameter of the lenslets and then forming a laminated structure with a support plate bonded between two lens plates to provide the necessary mechanical rigidity required. The support plate also comprises a plurality of apertures equal to the number of lenslets but having a larger diameter so that the electron optical characteristics of each lenslet is determined by the diameter of the lenslet formed in the lens plate rather than by the diameter of the aperture in the support plate.

In accord with another embodiment of my invention, an electron optical lens plate is made in a laminated structure including a support plate sandwiched between two lens plates by photolithographically etching an array of optically aligned lenslets in the lens plates and then etching a similar array of lenslets in the support plate by using the lens plates as an etch resistant mask for etching the apertures in the support plate. A better understanding of my invention, as well as other objects and advantages thereof, will become more apparent to those skilled in the art from the following detailed description, taken in connection with the accompanying drawings in which:

FIG. 1 illustrates a partial perspective view of a lens plate made in accord with prior art techniques;

FIG. 2 is a partial perspective view of an electron optical lens constructed in accord with one embodiment of my invention; and

FIG. 3 is a partial perspective view of an electron optical lens constructed in accord with another embodiment of my invention.

Various methods of fabricating electron optical lenses have been employed to produce lenslets or apertures in a lens plate. For example, in addition to photolithographic masking and etching techniques, methods such as electro-chemical machining, precision drilling, ultrasonic drilling and even laser drilling have been proposed. While some of these methods can produce an aperture in a lens plate of the proper diameter with a high degree of circularity, these methods are unsuitable for producing a large array of substantially identical apertures having the same size, shape, spacing and alignment in the order of 0.0001 inch.

One of the requirements which an electron optical lens must satisfy is a high degree of tolerance to deformation of the lens plate, such as buckling or bending, which results from electrostatic forces created by a potential difference between adjacent electron optical elements. Accordingly, the electron optical lens plates must be relatively thick to meet this requirement. However, this requirement makes the formation of an array of apertures of uniform size, shape, spacing and align-

ment exceedingly difficult, if not impossible, with the prior art methods.

FIG. 1 illustrates, by way of example, the results of photolithographically masking and etching a lenslet **11** in a lens plate **12.** The lens plate **12,** for example, may be molybdenum, titanium, tungsten, or other suitable materials, having a thickness of approximately 15 to 20 mils. If the lenslet **11** is to have a diameter of approximately 30 mils, the results of photolithographically masking and etching simultaneously from both sides of the lens plate produces a profile substantially similar to that illustrated in FIG. **1.** This lenslet includes necked-down cusps of metal **13** which vary in size and shape from lenslet to lenslet, thereby producing lenslets of different sizes and shapes. These differences in lenslet size and shape undesirably affect the electron beam characteristics, such as altering the focus thereof and introducing variable spherical aberration effects.

In accord with one embodiment of my invention, an electron optical lens having an array of lenslets of substantially identical size, shape, spacing and alignment is fabricated in a laminated structure comprising a thick support plate sandwiched between two thin lens plates. Precision lenslets are formed in the thin lens plates to the size, shape, spacing and dimensional tolerances required by selecting a lens plate thickness of less than approximately 25 percent of the lenslet diameter. Also, larger apertures are formed in the support plate than in the lens plates so that the electron lens fields are established by the edges of the apertures in the thin lens plates and not the support plate.

FIG. 2 illustrates a typical electron optical lens constructed in accord with one embodiment of my invention wherein a relatively thick (e.g., 0.015 to 0.020 inch) support plate **21** is sandwiched between lens plates **22** and **23** of between approximately 2.0 and 5.0 mils thickness, for example. Utilizing standard photomasking and etching techniques, the desired size and shape apertures are etched in the lens plates **22** and **23.** For example, if 30.0 mil apertures on 60 mil centers are to be formed in the lens plates, then a suitable mask is made, and by standard photomasking and etching techniques, the apertures are etched through the lens plates. Due to the high aperture diameter to lens plate thickness, apertures of the desired size, shape and spacing are readily achieved with high dimensional tolerances, e.g., a 0.0001 inch.

The support plate is similarly etched, but due to the increased thickness of the support plate relative to the diameter of the apertures, the size and shape of the apertures are not precisely defined. However, in accord with one of the advantages of my invention, it is not necessary to provide high precision apertures in the support plate. In fact, it is preferable to produce apertures of a slightly larger diameter to insure that the apertures in the lens plates determine the electron optical characteristics of the lens.

After forming the apertures in the support plate, the laminated structure is formed by bonding the lens plates to the support plate. Typically, this is achieved by evaporating films of nickel and gold on the mating surfaces of each plate and then after aligning the apertures in the lens plates with the support plate, the plates are held together firmly and placed in a vacuum furnace to form a vacuum brazed, laminated structure.

Another method of making electron optical lenses in accord with my invention includes the use of a pre-laminated structure, such as a molybdenum plate having a thickness of between 10 and 20 mils, for example, plated with a thin film of gold, for example, on both major surfaces of the molybdenum plate. The thickness of the gold film is typically between 0.2 and 1.0 mils. In accord with this method of making electron optical lenses, the surfaces of the thin gold film are covered with a photoresist and exposed through a mask having the desired lenslet pattern. The photoresist is then developed and apertures corresponding to the lenslets are etched in the gold film with a suitable etchant, such as aqua regia. The unetched portions of the gold film are then utilized as an etch-resistant mask for etching apertures in the molybdenum support plate. Typically, a suitable etching solution for this purpose is a 30 to 40 percent warm solution of nitric acid and water. The molybdenum is etched for a sufficient period of time so that undercutting of the molybdenum occurs and the diameter of the aperture is larger than that in the gold films. The resulting electron optical lens is substantially similar to that illustrated in FIG. **2.**

Still another method of making electron optical lenses in accord with my invention includes selecting a suitable support plate, such as a copper plate having a thickness of between approximately 10 and 30 mils thickness, for example, coating the support plate with a photoresist and exposing the photoresist to a negative of the desired lenslet pattern to be formed in the support plate. The photoresist is then developed and the support plate with the lenslet pattern, in the form of circular mounds of resist, for example, is then placed in an electroless nickel phosphate bath. After approximately 20 minutes in this bath, a 0.3 mil thickness of nickel is plated on those portions of the copper plate not covered by the photoresist.

The photoresist is then stripped from the support plate, leaving precisely defined openings in the thin nickel layer. If for some reason the openings are larger than desired, additional plating may be employed to reduce the diameter of the openings uniformly. The plate is then placed in an etching solution, such as chromic sulphuric acid which etches the copper support plate but not the nickel. The copper is etched for a sufficient period of time to produce undercutting so that the diameter of the apertures in the copper is larger than that in the nickel.

FIG. 3 illustrates a typical electron optical lens constructed in accord with the electroless plating method wherein the diameters of the lenslets formed in the thin nickel lens plates **32** and **33** are different. The different diameter lenslets provide an electron beam limiting aperture so that an electron beam exiting from the smaller aperture side of the lens has a smaller diameter than that entering the larger diameter side of the lens.

In summary, I have described various methods of fabricating electron optical lenses in which a large array of lenslets having substantially identical electron optical characteristics are required. In accord with the methods described herein, arrays of lenslets of substantially identical size, shape, spacing and hole alignment are provided with dimensional tolerances in the order of a 0.0001 inch.

Those skilled in the art can readily appreciate that many modifications and variations of my invention are possible. For example, in addition to the various materials described herein for use as the support plate and as the lens plates, various other materials may be em-

ployed. It is therefore to be understood that changes may be made in the particular embodiments of the invention described which fall within the full intended scope of the invention as defined by the appended claims.

What I claim as new and desire to secure by Letters Patent of the U.S. is:

1. An electron optical lens comprising:
a conductive support plate having an array of apertures therein;
a pair of lens plates, each having the same number of apertures therein as said support plate and in the same pattern;
said support plate positioned between said lens plates and bonded thereto with said apertures in substantial alignment;
the apertures in said support plate being larger than the apertures in said lens plates whereby the electron optical characteristics of said lens are determined solely by the size and shape of the apertures in said lens plates;
said apertures characterized by a generally circular shape, the apertures of said lens plates having a diameter of up to 30 mils and a center to center spacing of up to 60 mils.

2. The electron optical lens of claim 1 wherein the diameter of the apertures in one lens plate is greater than that in the other lens plate.

3. The electron optical lens as set forth in claim 2 wherein the lens plate having smaller apertures has apertures of up to 10 mils.

4. The electron optical lens of claim 1 wherein said lens plates have a thickness of between approximately 1 and 25 percent of the diameter of the apertures in said lens plates.

5. The electron optical lens of claim 4 wherein the thickness of said support plate is greater than that of said lens plates but less than one-half the diameter of said apertures.

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