FABRICATION OF AN ELECTROSTATIC LENS ARRAY WITH SEPARATE ELECTRODES AND SHIELD MEMBRANES USING THE UV-LIGA PROCESS

Haruhito Ono*, Kenichi Nagae*, Yasuhiro Shimada*, Hiroshi Maehara*, Takayuki Yagi*, Masato Muraki** , and Masahiko Okunuki**
*Canon Research Center, Canon Inc., 5-1,Morinosato-Wakamiya, Atsugi-shi, Kanagawa 243-0193, Japan
phone : +81-46-247-2111 ext. 8626, fax: +81-46-248-0306, e-mail: ono.haruhito@canon.co.jp
** Nanotechnology & Advanced System Research Laboratories, Canon Inc.

SUMMARY

A lens array of 20×20 three element electrostatic lenses (einzel lenses) for multiple electron beam direct write (MEBDW) systems is presented.
It possesses shield membranes to prevent cross talk (or interferences between lenses) and the separate electrodes to provide the different lens powers. Each lens has a hole of 80 μm diameter and is separated from the neighbors by 200 μm. Three electrode substrates were mechanically assembled on a base substrate by using V-grooves and optical fibers. Lens action of the assembled lens array was confirmed in a preliminary setup.

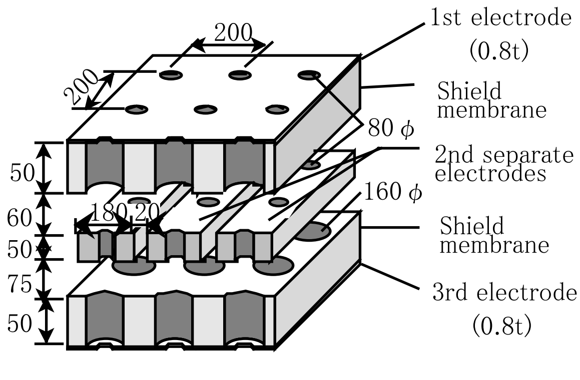
Keywords: einzel lens, electron beam, lithography

INTRODUCTION

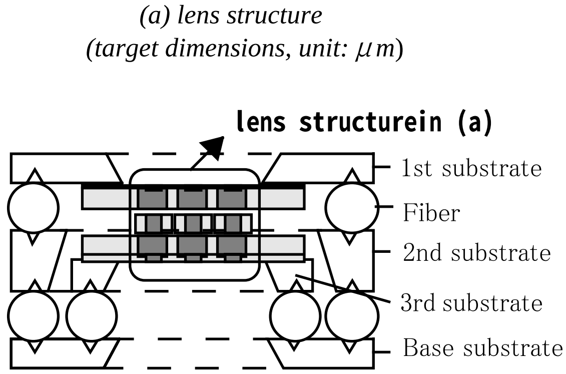
Various lithography systems — vacuum ultraviolet lithography (VUVL), proximity x-ray lithography (PXL), electron beam projection lithography (EPL) and extreme ultraviolet lithography (EUVL) — are considered as candidates for next generation lithography (NGL) at the International Technology Roadmap for Semiconductors (ITRS) 70nm node. These candidates all use masks. In contrast, MEBDW systems are maskless and offer advantages in eliminating mask amortization costs and shortening chip development cycles.
Among MEBDW approaches [1,2,3,4,5], a novel concept to compensate field curvature and distortion of the reduction optics was proposed [6]. It uses a key device called correction lens array (CLA) which comprises of a aperture array, a deflector array and einzel lens arrays. We describe the structure, farbication process and experiment of the einzel lens array in this article.

STRUCTURE

The einzel lens array has to produce different lens powers without cross talk. It comprises of the first electrode, second separate electrodes, and third electrode as shown in Fig.1(a).
The first and third electrodes possess shield membranes that prevent cross talk. The second electrodes are separated in lines to get the different lens powers by applying different voltages. Substrates, on which the above electrodes were formed, were mechanically



(a) lens structure
(target dimensions, unit: μm)



(b) crosssection of the lens array

Fig.1 Schematic of the einzel lens array assembled by using V-grooves and optical fibers [7] on a base substrate as shown in Fig.1(b). In addition, the third substrate, on which the third electrode and membrane are formed, is inside the second substrate to get a narrow gap between the second electrode and the membrane on the third electrode.

In a practical MEBDW system, two of the einzel lens arrays should be utilized. One is the array shown in Fig.1 and the other is the array whose 2nd separate electrodes are rotated 90 degrees horizontally.

FABRICATION PROCESS

Electrodes

The fabrication process for these electrodes and the base substrate are described below. The UV-LIGA process sequence of the first electrode with the shield membrane is shown in Fig.2. V-grooves are formed on a 400 μm-thick Si (100) substrate with a Si_3N_4 layer by anisotropic etching which uses a KOH solution (Fig.2(a)). Following this, a 5nm-thick Cr and a 0.8 μm-thick Au layer are subsequently deposited and patterned to form the first electrode (Fig.2(b)). A 0.5 μm-thick photoresist (OMR-83) as an adhesive layer and 70 μm-thick photoresist (SU-8) are both deposited and patterned by photolithography. The adhesive layer is necessary to increase the adhesion of the SU-8 to the substrate. Next, a 50 μm-thick Cu layer is electroplated as the membrane (Fig.2(c)). Thereafter, SU-8 and the adhesive layer are removed. The Si substrate is anisotropically etched from the back using the KOH solution and the Si_3N_4 and Cr layers are etched from the back to form both V-grooves on the back and an opening for the electron beams (Fig.2(d)).

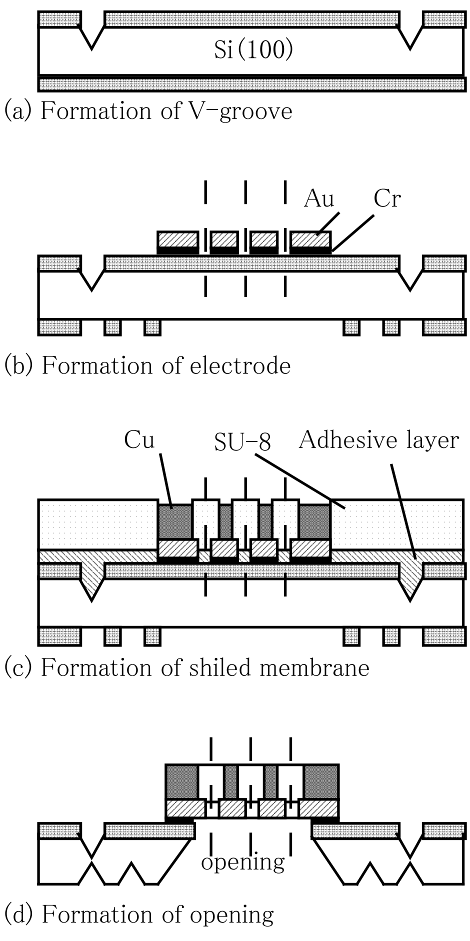


Fig.2 Process sequence of the first electrode with the shield membrane

Fig. 3 shows the magnified SEM view of the first electorde with the membrane. The first electrode has 20 ×20 holes of 80 μm diameter at intervals of 200 μm.

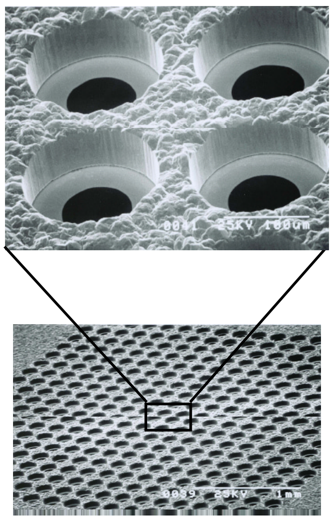


Fig.3 SEM of the first electrode with the shield membrane

The third electrode is obtained following the same procedure as in Fig.2. The differences between the first and the third electrodes are only the external dimensions. Similarly, the second electrodes are formed on a 525 μm-thick Si (100) substrate following the procedure as shown in Fig.4. V-grooves are formed (Fig.4(a)) followed by a 5nm-thick Cr and 100 nm-thick Au layer formation as the seed layer for electroplating (Fig.4(b)). A 50 μm-thick Cu layer is electroplated for the second electrodes by using SU-8 with the adhesive layer (Fig.4(c)). After removing the SU-8 and adhesive layer, the Au and Cr layers are etched to isolate the second electrodes electrically from the front (Fig.4(d)). Next, the substrate is anisotropically etched from the back.

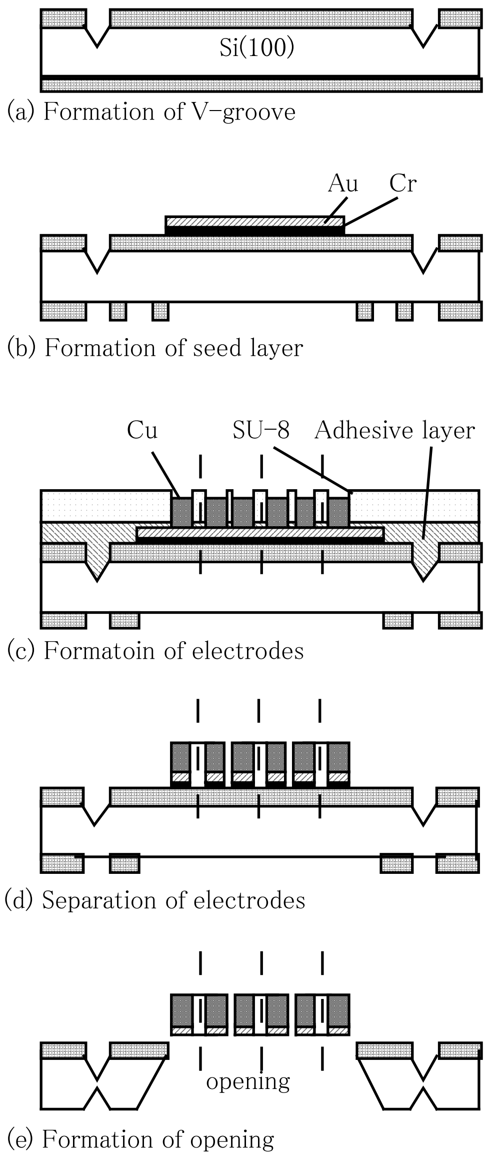


Fig.4 Process sequence of the second electrodes

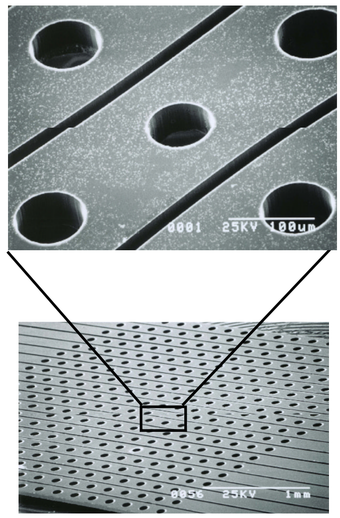


Fig.5 SEM of the second electrodes

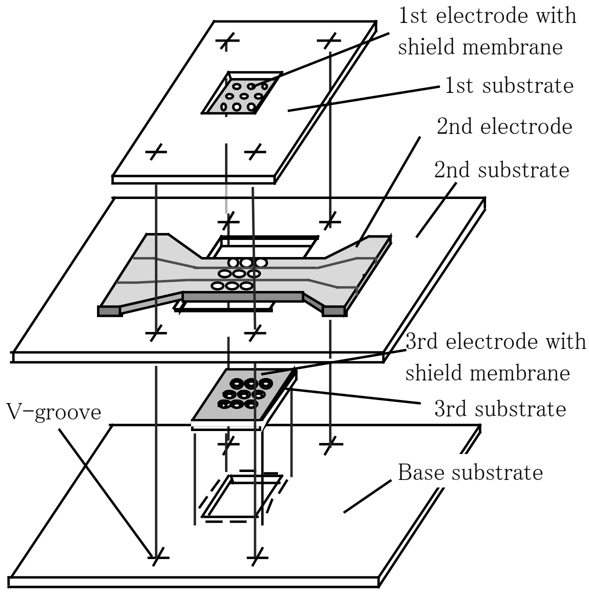


Fig.6 Assembly of the lens array

Finally, the Si_3N_4 and Cr layers are etched from the back (Fig.4(e)).

Fig. 5 shows the magnified SEM view of the second electordes. The second electrodes comprise of 20 separate line electrodes at intervals of 200 μm. One of the line electrodes has 20 holes at intervals of 200 μm.

The base substrate is obtained following a similar procedure as shown in Fig.2 except the formation of the electrode and membrane.

The back sides of the first and third substrates and the front side of the base substrate are covered by 9 nm-thick Pt layers to get electrical contact when the substrates are assembled.

Assembly

Fig.6 shows how to assemble the lens array. Four fiber pieces, not shown in the figure, are put into four V-grooves on the base substrate. Following this, the third

substrate is put onto the fibers and bonded with a conductive adhesive. Similarly, the second substrate is put on the base substrate, and the first substrate on the second substrate by using V-grooves and fiber pieces. These substrates are bonded to each other with a nonconducting adhesive. Finally, each electrode is wired to a pin on the lens holder. Fig.7 shows the assembled lens array on the lens holder.
The alignment accuracy of the electrodes in horizontal direction was estimated to be ±5 μm or better.

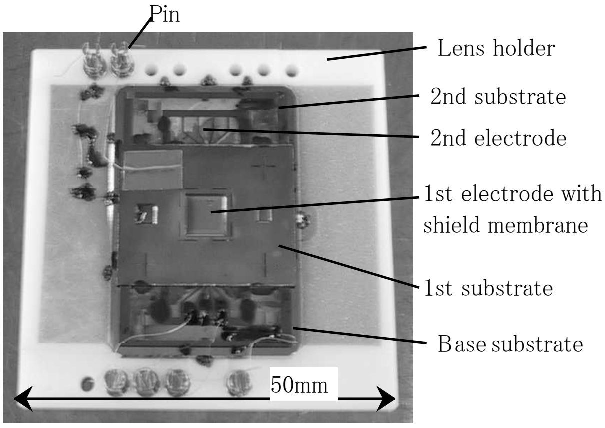


Fig.7 Photo of the lens array

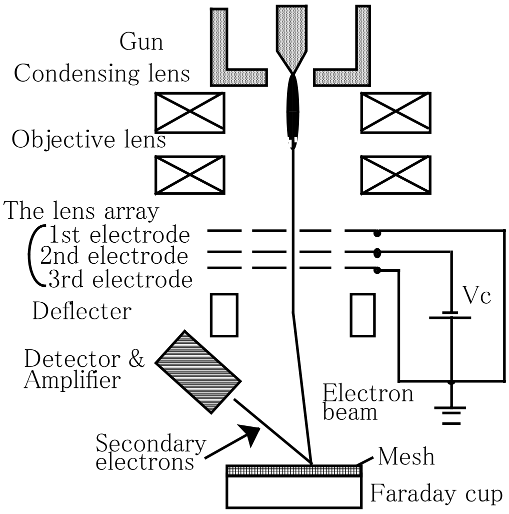


Fig.8 Eexperimental setup for the lens action (test machine)

EXPERIMENT

We confirmed the lens action of the assembled lens array in an electron beam test machine shown in Fig.8. The SEM micrographs of a Faraday cup in the machine were taken under the condition of 10kV acceleration voltage. They showed a focused and a defocused image corresponding to second electrode voltages Vc (in Fig.8) of 0 and -450V respectively. The defocused image was adjusted to the focused image by lowering the objective lens power of the test machine. This indicates the lens action of the lens array.

CONCLUSIONS

We have presented an einzel lens array which is available for MEBDW systems. The lens array fabricated using the UV-LIGA process has shield membranes to prevent cross talk and separate electrodes to provide separately controlled lens power. The electrode substrates were mechanically assembled by using V-grooves and optical fibers on a base substrate. The alignment accuracy of the electrodes was estimated to be ±5 μm or better. Lens action of the assembled lens array was confirmed in a preliminary experiment.

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