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FABRICATION TECHNIQUE OF EINZEL LENS ARRAY WITH RIE PROCESS

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1. Introduction

Recently, photolithography technologies for LSI have been well developed and enable us to fabricate below 60-nm-feature sizes. However, the minimum pattern sizes are limited by its wavelength. Its mask costs increase with decreasing the dimension of the LSI, which makes the small-lot production of LSI difficult.

As an alternative technology of the current photolithography, direct electron beam lithography has been studied. No masks are needed for the direct electron beam lithography, but generally the production throughputs of electron beam lithography are limited [1]. In order to solve this problem, multi-electron beam lithography is proposed [2-5]. In this technology, many electron beams are used to increase the throughput. The multi-electron beam systems can be classified into two kinds of systems. One of them is a single-column system, in which an electron beam emitted from a single electron source is divided into multibeam using an aperture array [3]. However, in this system, electron-electron interaction reduces the resolution, and the total current of the electron beam from the single electron source is limited. In order to avoid this problem, multi-electron beam lithography systems using multi-electron sources have been proposed [5].

Fig. 1 shows the example of the multi-electron beam emitter array with electrostatic lenses. In this device, electron beams are created by field emission from the gated field emitter array. On-off operation of each electron beam can be performed by the voltage to the gate voltage. Each electron beam is focused on a wafer surface using an electron lens array.

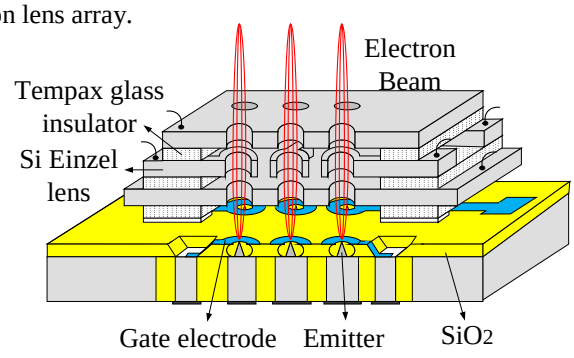

Fig .1 Schematic of Multi electron beam lithography system.

Electron lens is a kind of electron optics to focus or collimate the beam. Electromagnetic and electrostatic types of the electron lens are known. Electrostatic type of electron lens is easy to integrate, and compatible with microfabrication process. Einzel lens, which consists of three electrodes, is one of electrostatic lens. Einzel lens is well known electron or ion optics to focus or collimate the beam. The schematic structure and the principle of the Einzel lens are shown in Figs. 2 and 3. In Fig. 2, three silicon substrates with through-holes are aligned and stacked using insulative glass substrates by an anodic bonding technique. However, an error of each electrode position from center axis causes the aberration. In order to reduce the aberration, the center of each electrode must be exactly aligned on the center axis. However, few μm of misalignment are caused in the cases using the conventional bonding process. In order to solve this problem, we have employed fabrication process to make stacked Si structure using deep reactive ion etching [6]. Using this process, fabrication of Einzel lens is demonstrated. Using this process, alignment is not necessary, and Einzel structures can be batch-fabricated using only one mask.

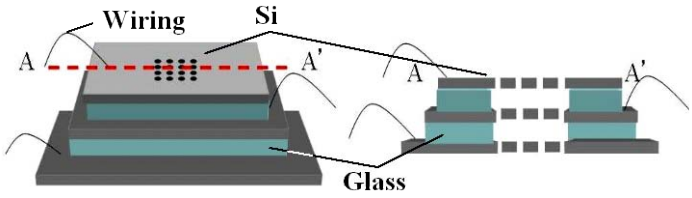

Fig.2 Einzel lens (a) Top side view (b) Cross-sectional view.

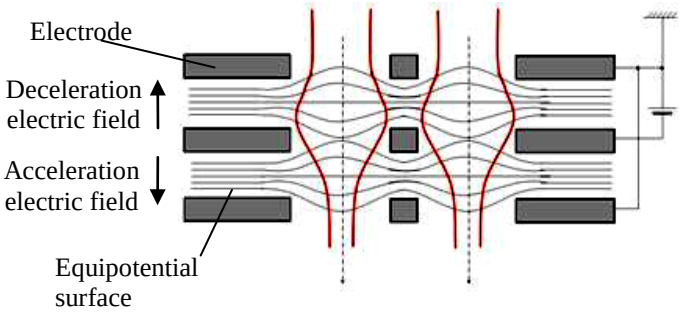

Fig. 3 Working principle of Einzel lens.

2. Fabrication

Fig.4 shows the fabrication process of the micro-Einzel lens array. At first, holes and grooves are formed on 200-μm-thick Tempax glass substrates by sand blast. Three 120-μm-thick Si substrates are anodically bonded using two glass substrates as an intermediate layer. An Al thin film is deposited on the backside to prevent built-in charge during etching using reactive ion etching (RIE) using Bosch process, and photolithography is conducted to make the

electrode pattern. The three Si substrates are etched, and electron optics structure is formed. The stacked substrate is diced to make electrode, and electrical wiring are conducted. In this fabrication, through-holes of the three Si layer are formed by RIE using one-mask resist pattern. Therefore, bonding process with precise alignment is not necessary.

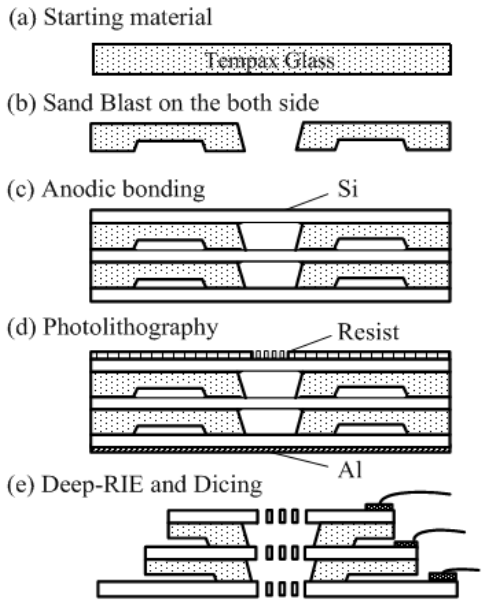

Fig .4 Fabrication process of Einzel lens array.

Fig. 5 Fabricated Micro-lens array.

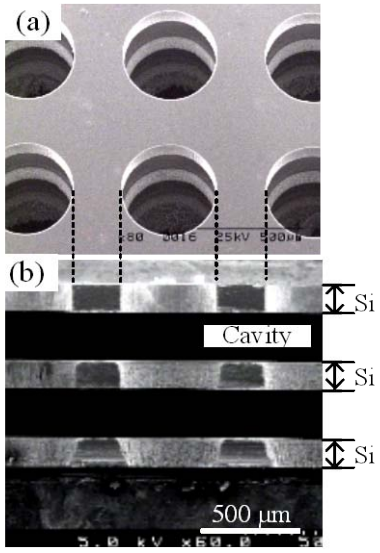

Fig.6 SEM images of typical micro-Einzel lens array.
(a) Top view. (b) Cross sectional view

3. Fabrication results

Fig. 5 is the example of the completed structure of Einzel lens array. Figs. 6 (a) and 6 (b) show the top view and cross section of the fabricated micro-lens array. It can be seen that the through-holes are well aligned. The side wall of the etched holes is almost vertical on first and second layers. However, the etched side walls are slightly tapered and become rough for the third Si layers. This may be due to the lens effect to the incident ions during the RIE process. It is demonstrated that the 25W platen power for RIE process suppress the tapering, as shown in Fig. 7.

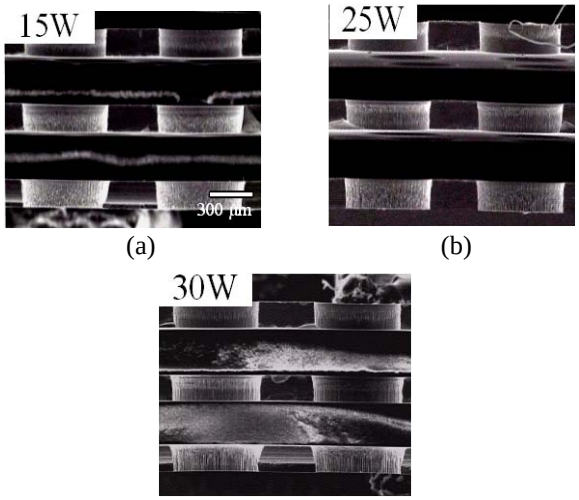

Fig. 7 Platen power dependence on the etching profile.

4. Conclusions

In summary, the fabrication technology of electron micro lens (Einzel lens) has been developed. Using deep-RIE, three 120-μm-thick Si layers with cavities are etched for making Einzel lens array. The taper angles were decreased at the bottom layers. Fabricated through-holes are well aligned within measurement error. It is expected that this fabrication technology of electron lens can be applied to making electron optics for multi-electron beam devices.

Acknowledgment

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