

FABRICATION OF 50nm LEVEL MASTER WITH A SPIRAL PATTERN FOR OPTICAL STORAGE MEMORY USING E-BEAM LITHOGRAPHY

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INSTRUCTIONS

In order to satisfy the demand for increasing data capability, the further research will be focused on reducing the size pattern down to 50nm level. Recent optical storage memory pattern is fabricated using optical lithography, but it is very difficult to manufacture patterns fewer than 50nm scale because of limit of optical diffraction[1]. Therefore, electron beam lithography is required for the optical storage memory pattern with 50nm level. General patterning researches for storage memory with 50nm level using e-beam lithography were contents of orthogonal arrangement and continual circle arrangement. But, spiral pattern with repeated line will be required for optical storage memory such as DVD. However, existing study for this pattern is very rare.

We manufacture the software program to generate a discontinuous spiral pattern. Based on this program, we design the spiral pattern with line lengths of 50nm, 100nm, 150nm, 200nm and width of 100nm. And to fabricate the designed pattern using e-beam lithography, we consider the scattering effect of e-beam and the condition of development. Firstly, we perform the experiments with several parameters such as accelerating, aperture size and dose to optimize the exposure condition and minimize the scattering of e-beam and writing time. Also we find the optimum development process condition with development time and temperature to solve the swelling and bridging problems.

Through the several experiments, we acquire spiral patterns on HSQ resist for optical storage memory having small difference below 3% precision compared to the designed pattern. The fabricated ER master can be used as template for electroforming.

THE SPIRAL PATTERN DESIGN FOR OPTICAL STORAGE MEMORY

We devise the self-made program which can design the spiral patterns for original master fabrication with 50nm level. The design of a spiral pattern is stored in ASCII format and this ASCII file can be compatible with commercial program such as RAITH 150[2]. All unit lines in nanometer scale on a spiral curve are designed as the straight lines for short processing time and convenience of design.

The unit line consisting Point 1(x1, y2) and Point 2(x1, y2) is decoded as shown in Fig. 1(b). Fig. 1(c) displays the meaning of Fig. 1(b). Here, The form of "L 100 1 0" corresponds to Line, Dose percent, Layer number, Line thickness

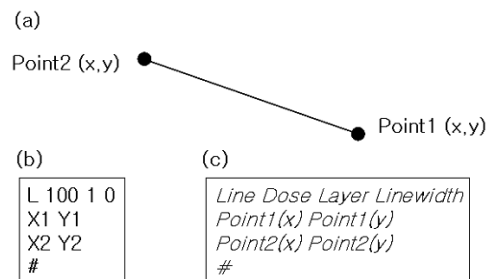


FIGURE 1. Defining a unit line for E-beam writing, (a) a unit line and (b) the corresponding codes in RAITH program and (c) the meaning.

The whole region of patterns is obtained by repeating a respective line design. Using the angle for 50nm line as unit angle for one cycle and the finely increased inner radius related with track pitch, we calculate the pattern length, pitch, starting point and ending points. Through this method, we make the spiral pattern to be made up of four discrete lines with a pitch of 100nm

and a length of 50nm, 100nm, 150nm, 200nm respectively.

Fig. 2 shows the window panel of the program to define the exposure area for a spiral pattern with the period of 4 lines. The input parameters are the inner radius and the number of cycles. The designated patterns can be created as an ASCII format by pressing the button of “create”

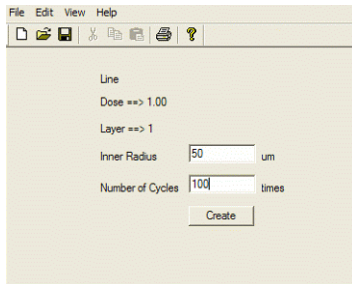
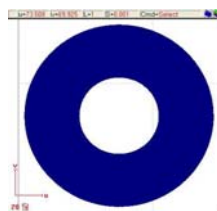
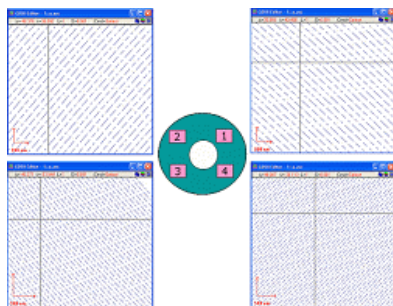


FIGURE 2. The window input panel for a spiral pattern design.

Fig.3 shows the results that display designed pattern to windows using RAITH program. There is no problem to compose the spiral pattern with designed 50nm~200nm straight lines.



(a) the whole area.



(b) the four different sections of the digitized spiral patterns.

FIGURE 3. The pattern array displayed from an ASCII design file.

EXPERIMENT

We use the commercial form of HSQ(Flowable Oxide resist-12 from Dow Coring) to fabricate

positive patterns. Firstly, the HSQ layer on the silicon substrate is coated in a very thin layer of 50nm for the high contrast and the short exposure time(4000rpm/s, 45sec). Then it is pre-baked on a hotplate at 200°C in order to eliminate the solvent excess and compact the resist. The e-beam lithography is performed using Raith 150. The working distance between resist and objective lens is 7mm and the step size is 3.2nm. After the exposure, HSQ resist is developed by TMAH 25% for 45sec at 21°C. Then it is rinsed by the DI water.

As the design and the size become denser and smaller, the scattering effect of e-beam comes to a barrier for clear pattern resolution[3]. To overcome the scattering of e-beam, the design of pattern is modified and optimized by applying 10 to 20 % expansion compared with the original design[3]. But, this spiral pattern by proposed program is difficult to modify the feature size in design. So we need to optimize the condition of exposure and development for desirable designed pattern without blurring. The dose to affect the feature size and uniformity is depended on beam current, dwelling time and field size. Here, the beam current is decided by EHT and aperture size; and the dwelling time is related to the step size. Therefore, the condition of exposure is optimized by controlling important parameters such as EHT, aperture size to precisely fabricate the designed spiral pattern. In order to optimize the expose condition, we perform several experiments with several parameters such as accelerating, aperture size, dose. Also, to solve problems with scum, swelling and bridging between features for development, we try to search the optimum development condition by controlling time and temperature.

THE OPTIMIZATION OF EXPOSURE AND DEVELOPMENT CONDITION

To analyze the effect of EHT, aperture size and dose in designed pattern fabrication, we performed the e-beam lithography with the properties such as aperture size, EHT and dose set as 10 or 30, 20kV or 10kV and within a range of 1500μC/cm and 3100μC/cm respectively. The experimental results are shown in Fig. 4 and Fig. 5. When the EHT is 10kV, the variation of pattern shape and scale do not appear for aperture size. Whereas, in case of the 20kV EHT and the 10 μm aperture size, the exposed HSQ residual layer at the center is existed in undesirable area due to the

scattering of e beam. But, in the 30 μm aperture size at the 20kV, the same problem does not arise within a range between 2500 $\mu\text{C}/\text{cm}$ and 2900 $\mu\text{C}/\text{cm}$. Hence, we can produce an improved result in terms of uniformity and precision. The reason for the above is caused by the relationship among aperture size, the current and the dwelling time(As the aperture size increases, the current also increases and the dwelling decreases). When EHT is 10kV or 20kV and dose is 1500 $\mu\text{C}/\text{cm}$, we acquire the designed pattern with high precision. But, this process condition has the limit of throughput due to long exposure time and low beam speed.

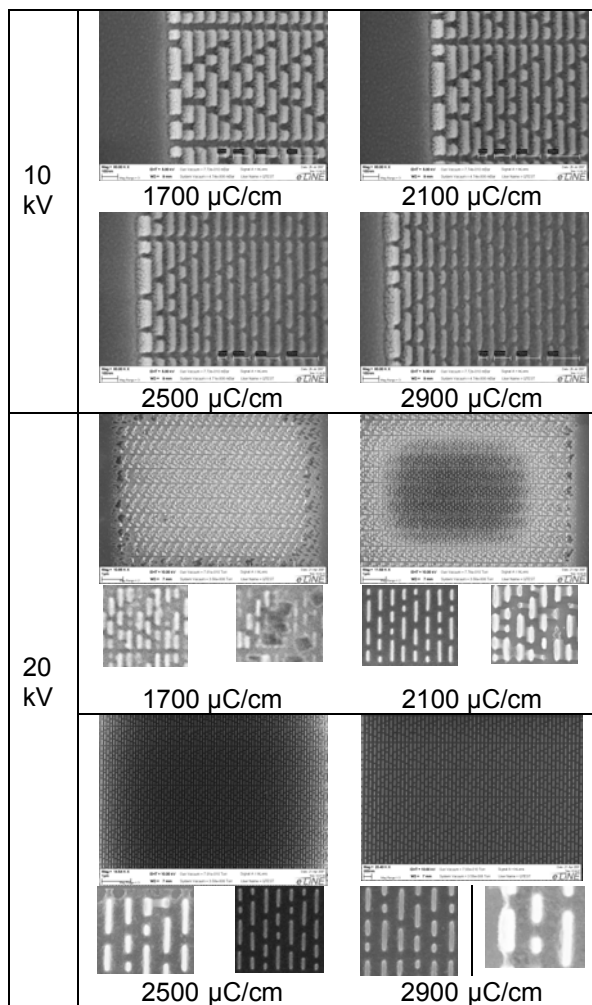


FIGURE 4. The pattern results according to EHT in the 10 μm aperture size.

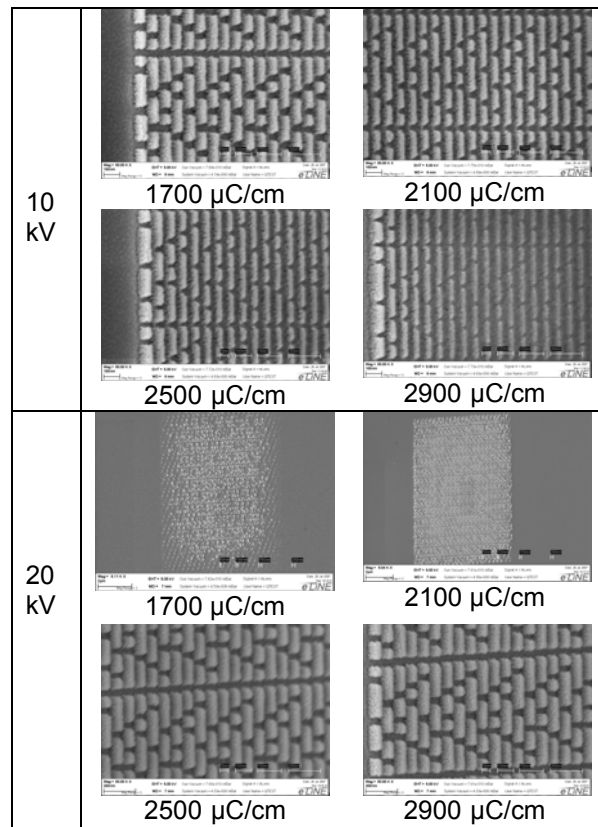


FIGURE 5. The pattern results according to EHT in the 30 μm aperture size.

We study the optimum development process condition with development time and temperature to solve the swelling and bridging problem as shown in Fig. 6(a) and (b). These problems can be solved by optimizing development time and temperature such as 45 sec and 45 $^{\circ}\text{C}$ respectively.

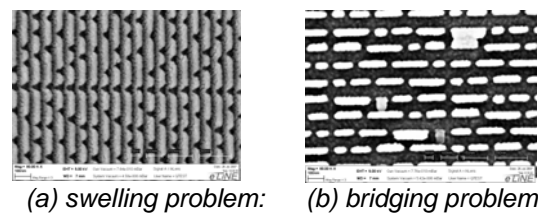


FIGURE 6. The problem of development in HSQ negative resist.

THE FABRICATION OF DESIGNED SPIRAL PATTERN FOR STORAGE MEMORY MEDIA

The parameter is set to the following:

Dose is 2700 $\mu\text{C}/\text{cm}$, EHT is 20kV, aperture size 30 μm , develop time is 45sec, development temperature is 45 $^{\circ}\text{C}$

Through the results of exposure and development condition test, we can precisely fabricate the discontinuous line pattern with orthogonal array within 3% precision as shown in Fig. 7.

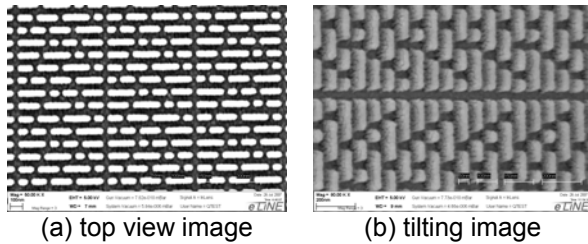


FIGURE 7. The optimized discontinuous line pattern with 50nm scale using the e-beam lithography.

Based on the optimized exposure and development condition, we fabricate the designed spiral pattern with inner radius 80 μm and outer radius 160 μm . Fig. 8 shows the fabricated spiral patterns taken at four different sections after development. And the fabricated spiral pattern can be out of range from small difference below 3% precision compared to the designed pattern.

The fabricated ER pattern master using e-beam lithography will use as template to make a Ni stamp for injection molding.

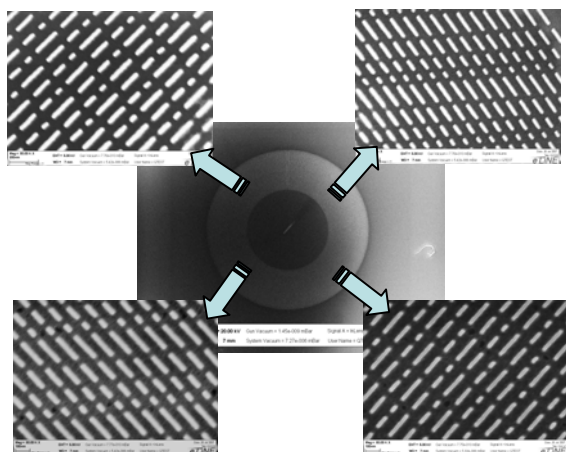


FIGURE 8. The FE-SEM image of discontinuous spiral pattern.

CONCLUSION

We develop the original master fabrication of spiral pattern with periodic array. For this, we devised self-programmed software which can design the spiral patterns to be made up of 4 discrete lines. This program can overcome the problem that is impossible in the commercial pattern design program for e-beam lithography or other CAD softwares.

Also, we fabricated the original ER master below 3% precision through the optimum process conditions for e-beam lithography and development.

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