Built-in Lens Mask Lithography

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1.Introduction Cost effective micro lithography is demanded for fine micro devices. However, resolution of a conventional proximity exposure system is not sufficient below several micron feature size. On the other hand, a reduction projection system is enough to resolve it but the cost of the tool is too high compared to proximity exposure tools.
To solve the problem, we newly propose novel optical lithography using built-in lens mask to enhance resolution and focus depth in conventional proximity exposure system using novel mask system.
2. Concept of the Built-in Lens Mask The built-in lens mask consists of additional novel patterns with multi-level phase compensation structures to realize diffraction micro lens on the mask plate. The exposure light is diffracted by the additional patterns having modified phase transcription to emulate propagation wave plane of optical system using lens. As a result, focused optical image is obtained on the focus plate without optical lens system of the tools and enhance the resolution.
Complex amplitude of plane wave $\overline{A}_0$ propagation toward k=(kx,ky,kz) direction is expressed as

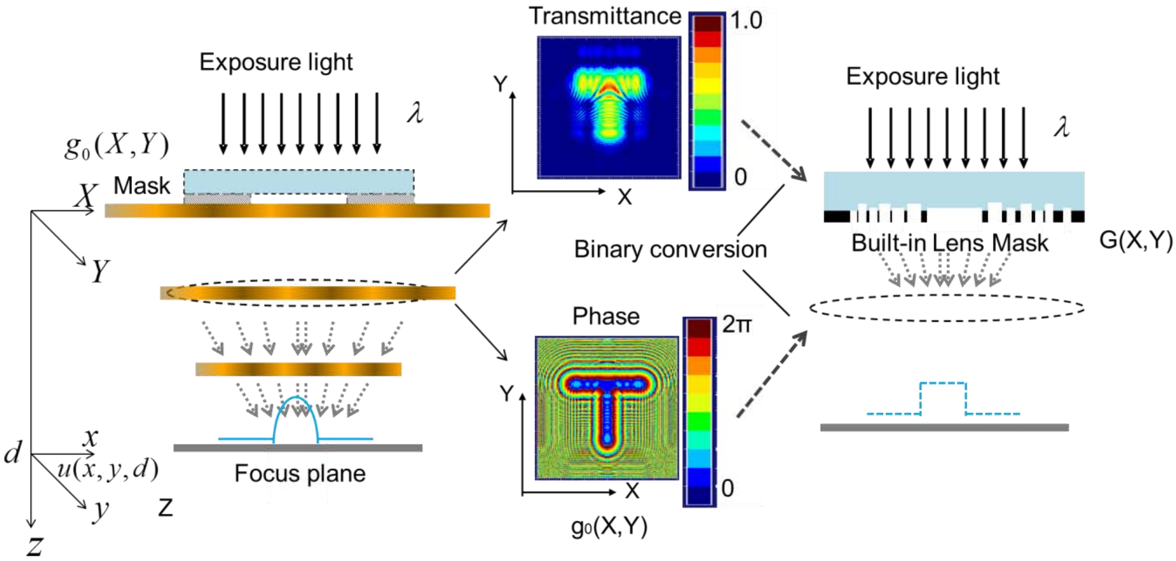
$$\overline{A}_0(k_x, k_y, d) = \iint u(x, y, d)\exp\left[i\left(k_x x + k_y y\right)\right]dxdy \qquad 1)$$

,where $u(x, y)$ is complex amplitude on the resist and z is distance from the resist plane (x,y). Then, the complex amplitude g_0(X,Y) at (X,Y) plane, which is located from resist plane with gap d, is expressed as

$$g_0(X,Y) = 1/(2\pi)^2 \iint A_0(k_x, k_y)\exp\left[-i\left(k_x x + k_y y\right)\right]dk_x dk_y \qquad 2)$$

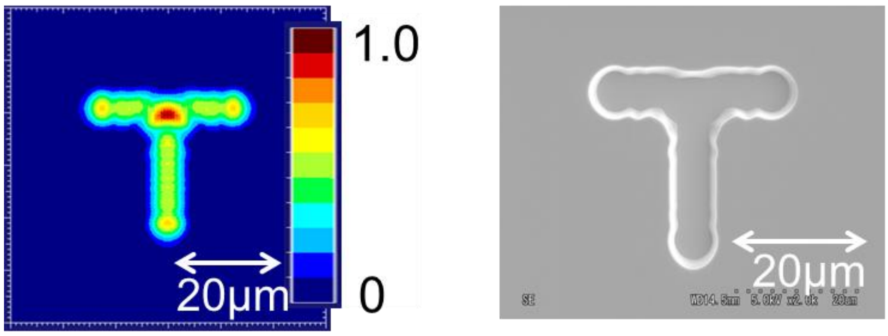
, where $A_0(k_x, k_y) = \overline{A}_0(k_x, k_y, d)\exp\left[i\sqrt{k_x^2 + k_y^2}\,d\right]$.

When we define the required optical intensity distribution $u(x, y, d)$, the complex amplitude g_0(X,Y) is determined. In other word, if we could emulate the complex amplitude g_0(X,Y) at (X,Y) plane, we would obtain required optical intensity distribution $u(x, y, d)$ at resist plane. To realize the complex amplitude g_0(X,Y), we binaries the complex amplitude as G(X,Y), having binary optical transmittance 1 or 0, and phase shifting 0 or π radian, which can be realized by novel hard photo mask using conventional phase shift mask fabrication technique as illustrated in Fig.1. We named it as a Built-in Lens Mask.
3.Result and Discussion To verify the Built-in lens mask lithography, the optical performance is simulated by numerical analysis and the mask structure is designed. The computational works predicts that the resolution will be enhanced by around 3 times compared with the conventional proximity lithography. To confirm the performance of the built-in lens mask, experimental study is carried out using conventional proximity exposure tool by i-line source. Fig.2 shows simulation and experimental results using conventional proximity lithography for 50 μm gap. The resolution is around 5.0 μm. On the other hand, Fig.3 shows the results by the built-in lens mask lithography. 2 micron line pattern with 50 μm is successfully transferred on resist. It is confirmed that the built-in lens mask lithography successfully enhances resolution and depth of focus.
We believe the newly proposed built-in lens mask lithography is promising for cost effective micron and / or submicron lithography system for micro structured devices using conventional proximity exposure systems. Also, we expect to apply for high end reduction projection lithography and enhance the resolution.



a) Conventional system b) Built-in lens mask system

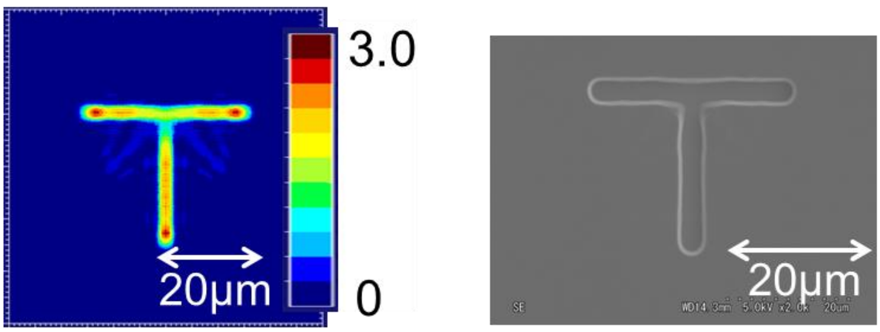
Fig.1 Schematics of the Built-in lens mask lithography



(a) Simulation (b) Experiment

Fig2. Resolution in conventional proximity lithography

(line width: 3.5 μ m, wavelength: 365nm, resist:JSR:IX845, gap :55 μ m, collimation angle: 1.5°)



a) Simulation (b) Experiment

Fig.3. Resolution in built-in lens mask lithography

(line width: 2.0 μ m, wavelength: 365nm, resist:JSR:IX845, gap:55 μ m, collimation angle: 1.5°)