# Optimal Parameters for Design of Optical System in Maskless Exposure

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## Introduction

Recently the development of TFT Photo-lithography Equipment is required. However, it is very difficult to develop it because the required technology for this equipment is so high. Recently, many countries in the world are interested in development of Maskless Photo-lithography technology. It is possible to cut down running cost to remove photo mask and to get bigger display easily to free the limitation from photo mask size.

Maskless exposure system to use Digital Mirror Device (DMD) instead of Photomask makes small spot array by Micro Lens Array (MLA) and patterns on photoresist through the scanning of stage

The important things in optical system of Maskless exposure are to have maximum irradiance and high uniformity of irradiance distribution, to have uniformity of spots distribution and large depth of focus. Also, it needs to minimize crosstalk through the one-to-one matching of DMD and MLA.

In this paper, we extract the key design parameters of the optical system in Maskless exposure through the theoretical analysis

## Properties of Optical System

Let's assume the optical system with 3.5um line & space and 0.5um control resolution of line width. Fig. 1 shows the optical scheme of Maskless exposure system. It consists of source, integrator, condenser lens, DMD, projection lens 1(PL1), MLA, spatial filter and projection lens 2(PL2).

Light source used Laser Diode (LD) where the wavelength is 405nm, output beam diameter 0.65mm and NA=0.2 (beam divergence). In general, the energy efficiency of optical system depends on Etendue in proportion to square of Lagrange Invariant L. Invariant of source is 0.325x0.2=0.065. Rod lens as an integrator is used in order to obtain the uniform irradiance and considered the size to minimize Invariant on the output surface of Rod lens in order to increase energy efficiency.

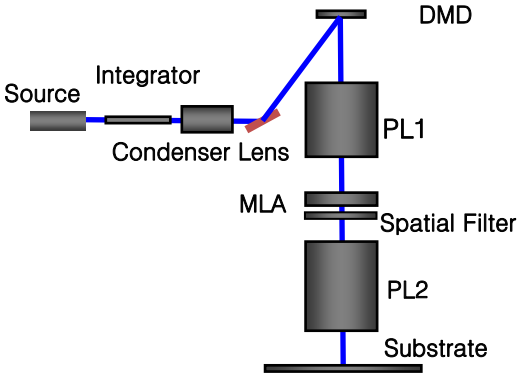


Fig1. Scheme of optical system

We select the Rod lens with 3.5mm by 2.5mm square cross section (aspect ratio =1.4) because the aspect ratio of DMD is 1.4. In this case, Invariant on output surface of Rod lens is to be 2.15x0.2=0.43. This value will be a reference in deciding the optical parameters of condenser lens and projection lens from the viewpoint of energy efficiency.

Condenser lens transmits the uniform irradiance from output surface of Rod lens to DMD. The size of DMD is 10mm x 14mm, so we can choose NA 0.22 in object space and magnification 4.4 with 10% spare. In this case, Invariant on DMD will be 9.46 x 0.05=0.473.

Actually for any type of patterns on photoresist, it needs to rotate spot array and it can be achieved by rotation of DMD according to z axis. In order to obtain optimum design parameters for PL1, it is necessary to consider a distance of adjacent spots and a rotation angle of DMD. A distance of adjacent spots according to scanning direction has to have an integer, and let's assume it is 14um. As the control resolution of line width is 0.5um, we can obtain a distance of adjacent spots (A) is 14.0089257mm and

magnification of projection lens is 1.02404428 (14.0089257/13.68), where 13.68um is DMD pitch. Also, from Fig. 2, the rotation angle of DMD will be 2.0454 degree.

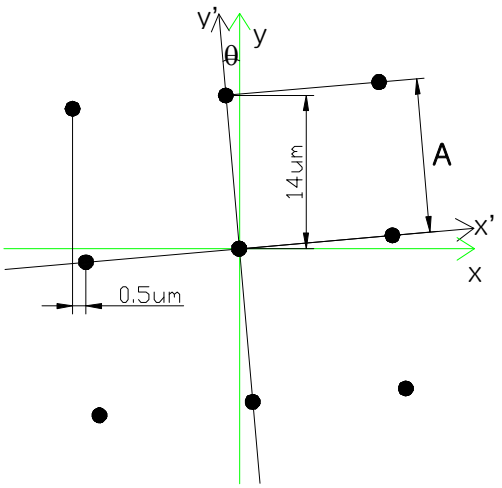


Fig 2. Spot Array

It is reasonable to choose NA of PL1 so that the 2nd zero point of Airy Disk on image plane of PL1 equals to the half size of MLA. We can choose NA 0.065 with MLA half size 7um. Invariant on image plane of PL1 is 9.46x0.065=0.615 and all energy from illumination system or DMD will be passing PL1 without loss. Fig. 3 shows point spread function for optical system with NA=0.065 without aberrations.

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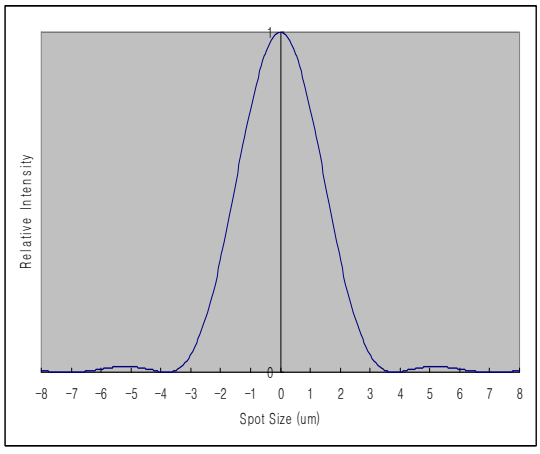


Fig. 3 Point spread function for NA=0.065 without aberrations (the 2nd zero of Airy disk is approximately 7um)

The role of PL2 is that small spots from MLA project on photoresist and it has to have high resolution performance and distortion free.

Let's find out NA of PL2 for Maskless exposure system to have minimum line & space 3.5um. Let's assume the minimum line width 3.5um is made by 4 spots. Using the control resolution of line width is 0.5um and from Fig 4, we can see minimum spot size by PL2 has to have minimum 2um from α+0.5x3=3.5um. So, let's choose FWHM of spot size is 1.8um with 10% spare, and then NA of PL2 will be 0.12 and depth of focus ±14um.

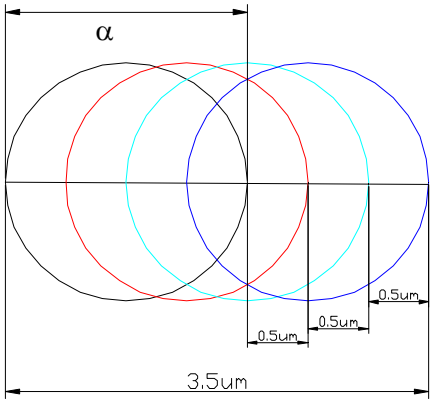


Fig. 4 Minimum line width 3.5um is made by 4 spots to have "α" um spot size.

In addition, we will use a spatial filter on focal position of MLA. The main reason to use this spatial filter is that spots by MLA are not uniform. Also, it is possible to control spot size on substrate by changing of spatial filter with different aperture size.

## Conclusions

The optical system of Maskless exposure consists of several components and it is very important to find out optimum design parameters. In this paper, we have introduced optimum design parameters, NA, magnification, spot size, rotation angle of DMD etc.., through the theoretical analysis.

[1] US Patent, Patent No. US 6,529,262, "System and Method for performing Lithography on a substrate", 2003.