Multi-channel illumination optical system

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Abstract

Most optical systems used in lithography include both illumination and imaging parts. The illumination part projects the light source into the plane of the objects of the optical system. In most cases, illuminators use the Kohler type of illumination, when the light source is projected to infinity. However, in some cases in illuminators, it is necessary to use the "Critical" type of illumination when the light source is projected directly into the plane of the objects of the optical system. In this case, it becomes possible to control the plane of objects, that is, to change the configuration of the object without reticle change. That is, in this case, it will be possible to change the configuration of the object without changing the reticle. In this case, the object must include a set of SLM (special light modulators) that form the desired configuration, which must be transferred to the image plane.

Thus, by managing the SLM set, you can change the configuration of the object and thus exclude its replacement. That means that one reticle can be used to obtain different images.

In this case, the SLM kit makes it possible to eliminate the replacement of the reticle when changing the geometric configuration of the object, which is achieved by changing the transmission (reflection) of the light flux.

Introduction

Using a universal optical component that does not require replacement to obtain various images in the wafer plane makes it possible to speed up the printing process and also reduce the cost of chip production technology. The main topic of this article is to describe an illumination multichannel optical system that allows finding an acceptable result.

For this purpose, each channel of an optical system forms a relay that creates a real image. Each channel of such an optical system must consist of at least two optical components to obtain a valid SLM image in the reticle plane. In this way, several independent SLM images are simultaneously formed in the reticle plane, which simulates the required circuit. In this case, in the image plane, the images are transformed depending on the switching off or on of a single channel or their group. As a result, there is no need to replace reticles when printing various schemes.

The multichannel relay optical schematic

The simplest optical design of a fly-eyes relay consists of two optical lens components, front, and rear. The front optical components create a telecentric beam (for the aperture rays) and the rear components create an image (focusing this beam on the reticle). Since the optical system is multichannel, the reticle depicts a complete SLM picture of objects located in the object plane. This means that when the brightness of the light flux passing through the individual SLM on the reticle changes, the illumination of the light spot changes (that is, the brightness of the image changes). Thus, objects of various configurations and brightness can be obtained on the reticle.

A complete image of the object is created on the reticle, consisting of images of individual channels. By changing the brightness of individual SLMs, the different configurations of the microchip can be got without changing the reticle. The general optical schematic of the fly-eyes relay [1;2] is shown in Fig. 1.

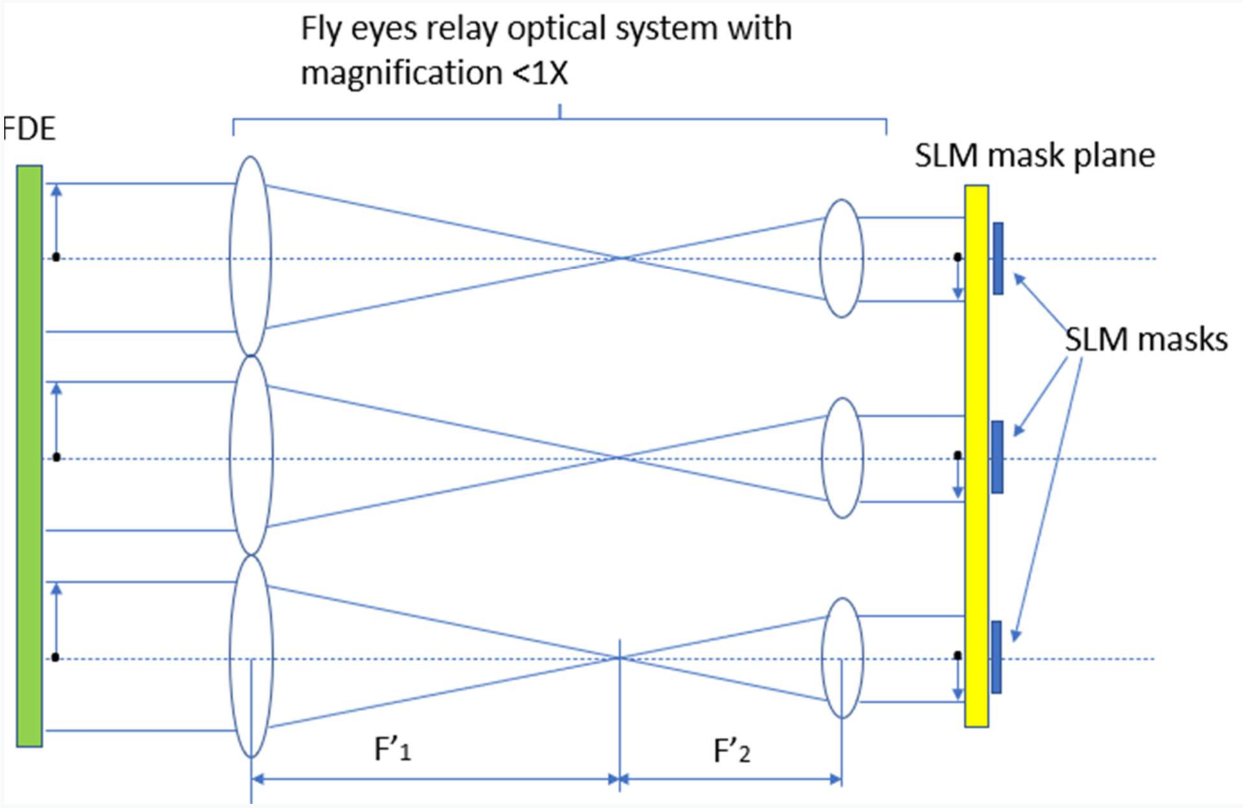

Fig. 1 The Fly-eyes relay optical schematic

Where FDE is the field-defining element, F'_1, and F'_2 are the focal lens of fly eyes relay optical components. The linear magnification **Γ** of such an optical system is calculated by the following formulas:

$$\Gamma=(n_2 F'_2)/(n_1 F'_1); \quad \text{or}$$

$$\Gamma=(n_2 \sin\alpha)/(n_1 \sin\alpha');$$

Where n1 and n2 are indexes of refractions in the first and second relay lenses, respectively. The F'1 and F'2 are the fly-eye relay optical elements' focal lengths and α; α' are numerical apertures in the object and image spaces. Thus, depending on the focal ratio of the relay lenses, both an enlarged or a reduced SLM image on the reticle can be get.

To expand the working capabilities of the relay optical system, it is proposed to include the second channel in the relay optical scheme. This will allow the simultaneous depict two planes of objects on one reticle and thus obtain a combined image of two objects. To do this, it is necessary to include the beam splitter and one additional lens in the relay optical scheme. This scheme is shown in Fig. 2.

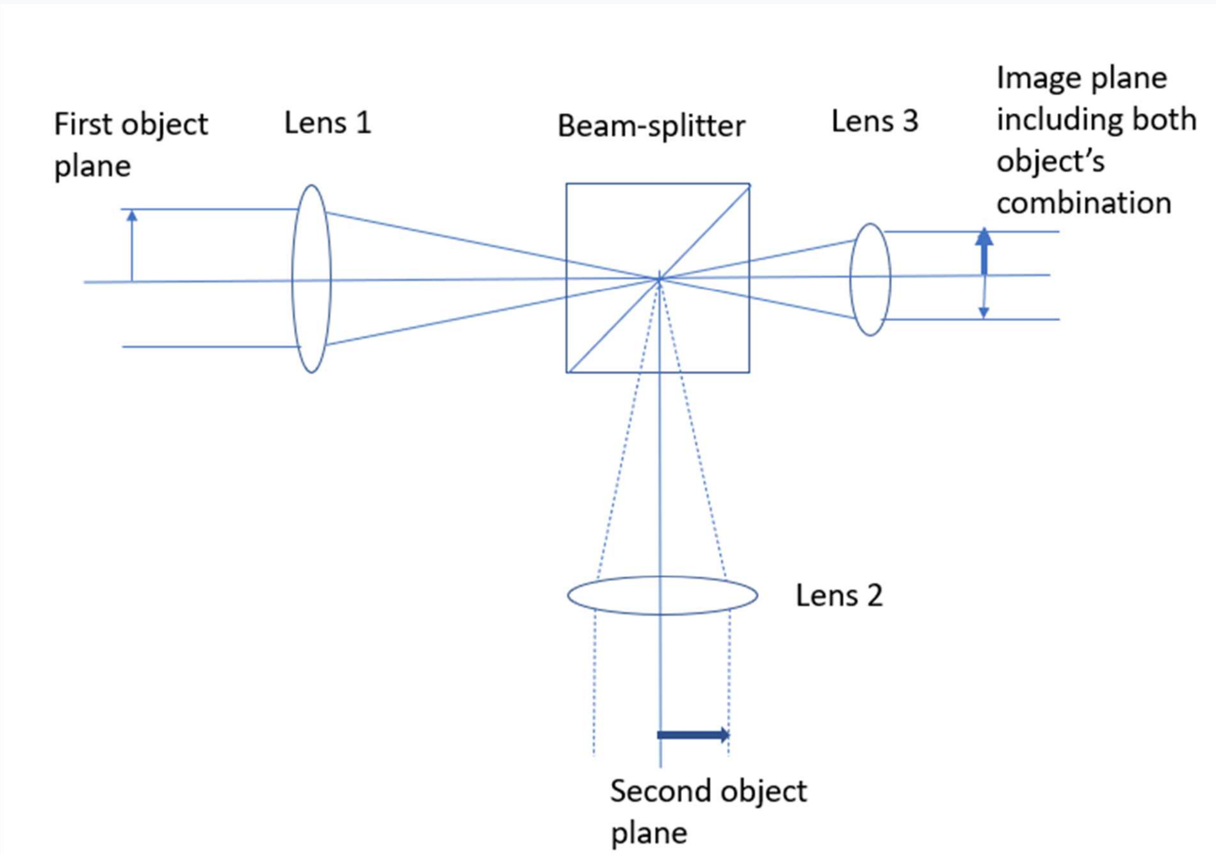

Fig. 2 Optical schematic of the optical system that projects two objects located in different planes into one image plane

When using a two-channel optical relay (Figure 2), the following possibilities appear:

1. Each channel can build an image of an object on a reticle with a different magnification (in this case, the focal lengths of the frontal optical components must be different);
2. In this case, the numerical aperture (NA) in the channels can have different values;
3. In the image plane, it becomes possible to obtain various complex (composite) configurations of objects.

If for the first optical relay channel in the object plane, FDE is located then in the second channel in the plane of objects it is necessary to place a fiber (one or) bundle that allows getting the creation of an alternative object. The second channel can be used to correct the image quality from the first channel and also changes the structure and shape of the light spot, which allows for expanding the light capabilities when obtaining complex images.
Thus, the presence of two lighting channels allows you to find the best geometric shape for the light spot. And besides, in the presence of two light spots overlapping each other, it becomes possible to construct an interference pattern, which expands the scope of this lighting method.

Practical relay system implementation

The geometric dimensions of SLM are several microns and therefore the relay must create light spots in the image plane of the corresponding area. Therefore, the linear magnification **Г** of the relay must be <1X. This is necessary to create a light spot whose diameter corresponds to the size of the SLM. In some cases where small-size SLMs (several µm) are used, two or three relays system must be used, each with magnification <1. The magnification of such an optical system (**Г**) is determined by the following formula [3;4]

$$\Gamma = \Gamma_1 \Gamma_2 .. \Gamma_n;$$

Where $\Gamma_1 \ldots \Gamma_n$ are magnifications of separate relays included in the optical system. To obtain the required size of the image (light spot) of a cell on the SLM, it is necessary to determine the magnitude of the linear magnification, which depends on the ratio of the focal lengths of the relay lenses, or the ratio of NA at the input and output of the relay optical system.
It should also be noted that when designing an optical system of several relays, the rule must be observed that the numerical aperture of the subsequent optical system should be greater than or equal to the numerical aperture of the previous optical system. That is $\mathbf{NA_{i+1} > NA_i}$
Where **i** is a number of the relay system.

Conclusion

An optical scheme is presented that implements the "Critical type of illumination" which can be used in the Semiconductor industry. This type of lighting system is considered, in which there is no need to replace the reticle when printing microchips.
Therefore, this method is more economical, since it eliminates the need to manufacture numerous reticles, which greatly simplifies and speeds up the process of printing microcircuits.
Instead, the SLM is reconfigured, in which the image of the microcircuit is projected onto the reticle, that is, different images can be sequentially obtained on one reticle and printed.

Also, the method for obtaining such a combination of optical systems, which allows "resolving" the smallest details in the image, is considered.

References

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[3] B. Begunov “Geometrical optics (page 152), 1966

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