DESIGN AND REALIZATION OF A PHOTOLITHOGRAPHY ALIGNMENT AND UV EXPOSURE EQUIPEMENT FOR PEDAGOGICAL AND LABORATORY EXPERIMENT PURPOSES

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Résumé

Cette présentation est relative à un projet développé en coopération entre deux pôles français de Microélectronique et un laboratoire brésilien de microsystèmes. Ce projet a consisté à développer et mettre au point un système d'alignement et d'exposition au rayonnement ultraviolet pour des opérations de photolithographie de laboratoire. L'idée de base a été de concevoir un ensemble de très grande simplicité, utilisable sans formation particulière par tout chercheur ou étudiant en milieu universitaire et ne nécessitant qu'une maintenance sommaire sans la nécessité d'une salle blanche de haute technologie. Les performances et caractéristiques de cet équipement utilisant une matrice de diodes électroluminescentes émettant dans l'UV sont voisines de celles fournies par les industriels pour les laboratoires de recherche. Les domaines d'applications concernent le prototypage de structures et la formation pratique des étudiants dans le domaine de la photolithographie. Les performances visées sont celles des aligneurs industriels de laboratoire. Le texte de cette communication a été rédigé en anglais pour ne pas pénaliser sa diffusion par nos collègues brésiliens.

Mots clefs: Machine d'alignement et d'insolation, microélectronique, microtechnologies

Abstract

This paper presents a project developed in cooperation between two French Microelectronic Centres and a Microsystems Brazilian Laboratory. The goal was to design and fabricate a very simple photolithography alignment and UV exposure machine for both main purposes: pedagogical formation for initial education students and for research laboratories involved in the deposition and the growth of thin films for devices applications. The basic idea was to design a very simple equipment which does not need any specific training and can be used by students or searchers without heavy facilities such VLSI technology clean rooms and associated expensive equipments. The features and characteristics of this equipment involving a violet LED matrix as UV light source are close to industrial alignment equipment for research laboratories. The field of applications covers the prototyping of basic devices and the training for students at master level.

Keywords: Alignment and exposure equipment for photolithography, microelectronics, microtechnology.

1 INTRODUCTION

This project was devoted to the design and fabrication of a simplified alignment and exposure equipment for photolithography in education or research centre. The main goal was to design a very simple set that can be used without any specific training by all the researchers or the student in an academic environment and with only a very basic need of maintenance. The fields of applications are numerous and mainly concern the prototyping of basic devices, the control of processes or the practical training of students in microtechnology. To reach such a performance, the major idea consists in involving a matrix of electroluminescent diodes instead of classical mercury lamp which needs high power supply, a permanent functioning, a complex optics and a beam shutter. This LED matrix leads to much more simple equipment. The features of such equipment are expected to be close to industrial ones dedicated for academics and research laboratory. After a presentation of the design and of the fabrication of this machine, the first results and characteristics are described and discussed.

2 PRINCIPLE OF EXPOSURE

The UV exposure is obtained from a beam generated by a matrix of electroluminescent diodes emitting at the wavelength of 408nm. The dispersion being of more or less 5 nanometers, the

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diodes produce enough photons in the UV domain to react with the classical photoresist. The matrix contains 109 diodes that cover all the exposure area. If the diodes are uniformly distributed and the distance between the array and the samples high enough, there is no need of optics or additional optical diffuser. This last one was expected in a first phase but abandoned after the first good results obtained without this optical additional part. With this apparatus,, the electrical power consumption of the LED matrix is only several watts, avoiding any cooling system. Because the answer of the LEDs to an electrical signal is very fast and very stable in a controlled temperature, the exposure duration becomes reproducible and easy to set in. Let us note that the low electrical power and the short duration of the lighting lead to a very low energy dissipation that does not modify the environmental temperature, and give more stability to the process.

3 ALIGNMENT SYSTEM

To perform the alignment of a mask on the wafer, both observation and positioning of the mask are needed.
The observation system is based on two CCD cameras the separation distance of which being governed by a micrometric moving mechanism. A monitor connected to an image sharing box (a classical box available for surveillance camera networks) allows simultaneous displays of both images and thus allows the alignment of a mask on a processed substrate, following the usual procedure
The positioning is based on the spatial displacement that can be controlled with good enough accuracy. A set of plates moved by micrometric screws in the three space directions but also in rotation fills well the needs.

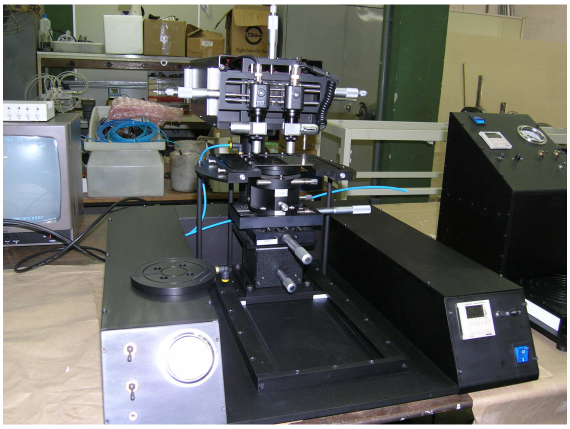

Figure 1: photography of the alignment and exposure machine based on the generation of UV photons produces by a matrix of LEDs. The corresponding wavelengths are centred on 408 nm.

As well as the LEDs matrix, the couple of cameras is set up on a rotating head. Half a turn of this head is manually produced after alignment to perform the exposure. A manual blocking system avoids any motion of the rotating head including cameras and LEDs matrix during the alignment phase.
Figure 1 shows a global view of the equipment. The two cameras are visible above the positioning system. In figure 2, the rotating head that includes the LEDs matrix and the cameras is half-turned after alignment to make the exposure. On this photograph the diodes are lightening. The cameras are visible on the left of the rotating head.

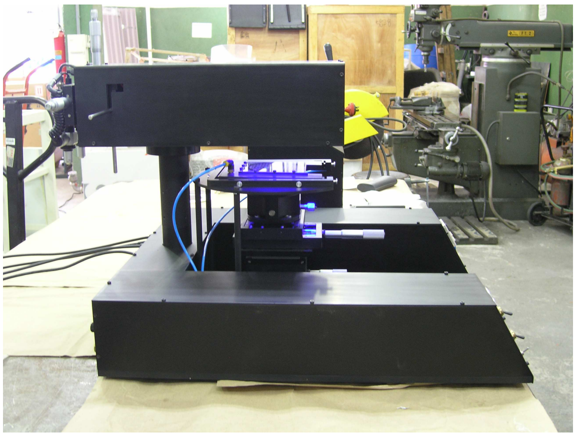

Figure 2: photography of the alignment and exposure machine during exposure. The rotating head is half turned after alignment in order to position the LEDs matrix on the mask and sample.

The sample holder stage can be displaced in the three directions of the space X, Y, Z, but also in rotation, θ, thanks to a set of micrometric screws. Each lateral displacement plate has a range of travel of 50mm that is large enough for a lot of applications as soon as the sample is well positioned on the upper plate. The vertical range is 12 mm that is large enough to introduce a wafer under the mask. In rotation, the angle can vary in the range ±15°. Figure 3 shows the stage with the several plates. The first observed resolution is 1µm.

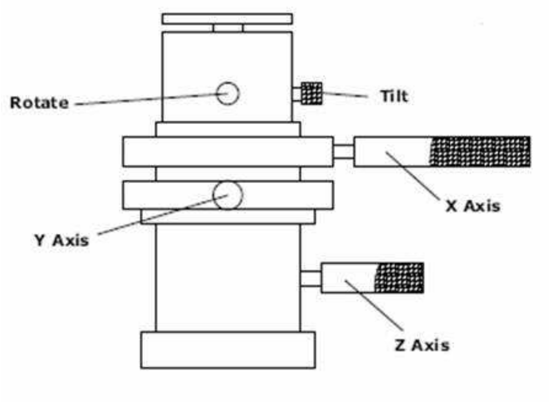

Figure 3: micrometric positioning stage composed of four plates; three space

directions and also rotation are controlled. This system allows the mask alignment on the sample.

4 MASK AND SAMPLE HOLDERS

A mask-holder plate is compatible with several sizes of masks, from 100mm x 100mm to 150mm x 150mm in a first time; an adaptation is easy and already planed for other sizes and more especially for small masks (5mm x 5mm) that are common in academic environment or for prototyping laboratory samples. The mask is fixed to the mask-holder by vacuum, generated by a small and simple low voltage electric pump. The vacuum level is displayed on the left arm of the main frame.

Wafer from one inch to six inches can be processed, but also very small test samples no larger than 3mm x 3mm. The wafers are maintained in position thank to the vacuum system.

5 ALIGNMENT AND EXPOSURE PROCEDURES

The base of the alignment, ie positioning the mask on the processed wafer, consists in analysing the superposition of test motives on two parts of the wafer distant enough to enhance angular shifts. The both cameras are distant from 40mm to 100mm that can be controlled by a micrometric stage. The both cameras are moving thanks to the specific mechanical. Figure 4 shows a scheme of this set including the both cameras. The two lateral micrometric screws drive the lateral moving and adjustment.

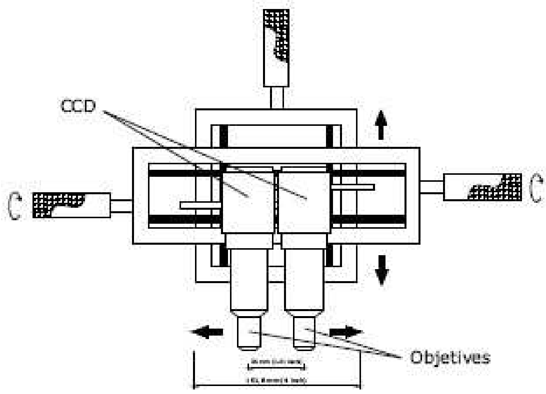

Figure 4: micrometric positioning stage of the both cameras. To control the alignment, the distant between the cameras are adjusted. The vertical position is also adjusted in order to focus the beams on the back face of the mask.

The vertical displacement controlled by micrometric screws allows focusing the optical beams on the back side of the mask. The distance between the objectives and the mask remains in the range of 10mm that is convenient to load the mask-holder on the system. Both cameras include two LEDs in the visible spectrum (green in our case) in agreement with the answer of the CCD detection matrix and compatible with the photoresist sensitivity.

Figure 5 is a photograph of this system, when the two CCD cameras are positioned at the minimum distance. For maintenance, the two cameras are very easily dismantled. The both wires visible on the picture are used to supply the both lightening LEDs set up in small cylinders.

Figure 5: Photograph of the both CCD cameras positioned on their micrometric common stage at their minimum distance of 40mm.

Figure 6 shows the synoptic of the system including cameras on their common stage, LEDs matrix light source, and electrical drivers.

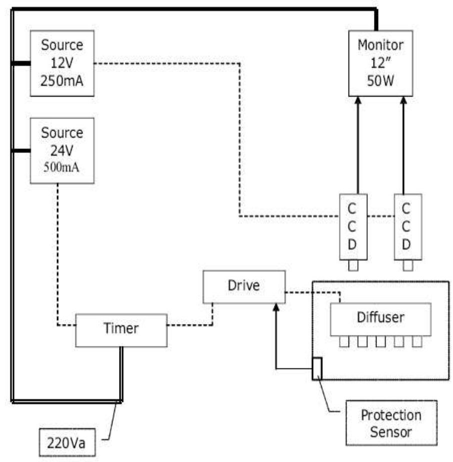

Figure 6: Synoptic scheme of the exposure system including the LEDs diode matrix, the cameras and the associated monitor, the timer which controls the duration of the exposure, and the DC electrical supplies. The total consumption is very low in comparison with classical industrial equipments

The contact between the mask and the wafer is driven by vertical micrometric screw. The contact is physically detected by the air leakage noise produced by the space between mask and mask-

holder. The calibrated micrometric screw position is thus checked to set a reference.
After alignment, the sample and the mask are put in contact thanks to the recorded position. The exposure phase is driven by rotating the head as described above. A timer fixes the exposure duration. It is also possible to have a manual exposure thank to specific switch.
Because the time answer of the diodes is very short, the exposure duration occurs during the electrical excitation of the diodes only. The diodes are functioning only during the exposure time. As already mentioned, this step leads to a strong simplification of the functioning in comparison with classical equipment involving mercury lamp that needs on one hand a long heating duration (about half an hour) and on the other hand a frequent calibration resulting of an evolving due the heating.
As already mentioned, the total power consumption supplied by the two DC current sources is rather low (ome Watts).

6 FIRST TESTS

The first tests were performed and had first concerned the light emission. Figure 7 shows the system during the exposure. The LED array emitting optical signal is visible. The lightening occurs on the lateral part of the sample stage, but there are no more technical or technological consequences of the parasitic light.

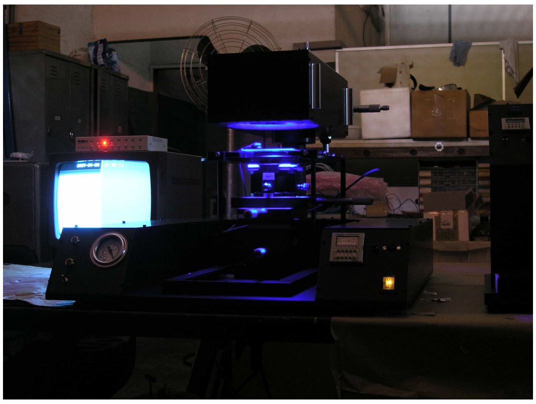

Figure 7: system under exposure phase. The monitor gives evidence of the sharing of the screen for the both camera images.

The following of the tests consisted to perform a test pattern. The patterns shown in figure 8 are got in the following conditions:

- Exposure duration: 40s,
- Pre-baking of the photoresist: 115°C during 90s,
- Developing duration: 17s.

The tested photoresist type in this example is: *OFPR-8600 de Tokyo Ohka.*

The pads are 20µm x 20µm. The interconnect lines are 2µm wide. The quality of the developing appears good enough in this first test for many classical expected applications.

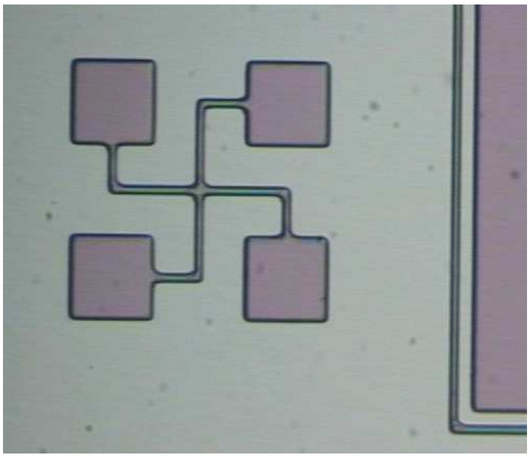

Figure 8: result of exposure of a test pattern. The pads are 20µm x 20µm. The quality of the developing appears good enough for many expected applications.

Figure 9 shows results dedicated to a resolution test. The quality of the array pattern after developing is really encouraging.

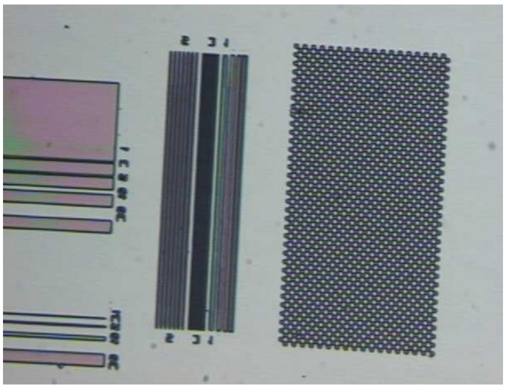

Figure 9: result of exposure of a resolution test pattern.

7 GENERAL CHARACTERISTICS OF THE EQUIPMENT

Sizes: 50 x40x40 cm
Weight: 40 kg
Maximal electrical consumption: 500W
Vacuum aspiration of mask and sample on their holders
Alignment and control by CCD camera
Exposure by LEDs UV400
Demonstrated resolution: 2µm

8 CONCLUSIONS

We have developed this UV insulation machine to answer at best to the requirements of people involved in teaching or prototyping projects. This equipment has been designed very simply by using low power UV LEDs matrix, classical micrometric mechanical devices and CCD cameras. From the results performed on microelectronics test structures, it appears that despite this basic configuration, the resolution performances match with most requirements of microelectronics teaching circuits or prototyping samples in micro technologies development research. In addition, maintenance and even all adaptation or dedicated modifications are very easy to make in the lab environment.

At last, due to its extreme low cost, this equipment can be easily duplicated for pedagogic or availability convenience.

REFERENCES

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