PRACTICUM IV

Production Technologies

Practical # 2

BASICS OF LITHOGRAPHY

Purpose of work: Studying the basics of electron-beam lithography and photolithography. Determination of the sensitivity of an electronic resist using dose test. The technology of obtaining contacts to microstructures using photolithography.

Introduction

The fabrication of an integrated circuit (IC) requires a variety of physical and chemical processes performed on a semiconductor substrate. In general, the various processes used to make an IC fall into three categories: film deposition, patterning, and semiconductor doping. Films of both conductors (such as polysilicon, aluminum, and more recently copper) and insulators (various forms of silicon dioxide, silicon nitride, and others) are used to connect and isolate transistors and their components. Selective doping of various regions of silicon allow the conductivity of the silicon to be changed with the application of voltage. By creating structures of these various components millions of transistors can be built and wired together to form the complex circuitry of a modern microelectronic device. Fundamental to all of these processes is lithography, i.e., the formation of three-dimensional relief images on the substrate for subsequent transfer of the pattern to the substrate.

The word lithography comes from the Greek *lithos*, meaning stones, and *graphia*, meaning to write. It means quite literally writing on stones. In the case of lithography (electron beam or photolithography) our stones are silicon wafers and our patterns are written with a light or electron beam sensitive polymer called a resist. To build the complex structures that make up a transistor and the many wires that connect the millions of transistors of a circuit, lithography and etch pattern transfer steps are repeated at least 10 times, but more typically are done 20 to 30 times to make one circuit. Each pattern being printed on the wafer is aligned to the previously formed patterns and slowly the conductors, insulators, and selectively doped regions are built up to form the final device.

Optical lithography is basically a photographic process by which a light sensitive polymer, called a photoresist, is exposed and developed to form three-dimensional relief images on the substrate. In general, the ideal photoresist image has the exact shape of the designed or intended pattern in the plane of the substrate, with vertical walls through the thickness of the resist. Thus, the final resist pattern is binary: parts of the substrate are covered with resist while other parts are completely uncovered. This binary pattern is needed for pattern transfer since the parts of the substrate covered with resist will be protected from etching, ion implantation, or other pattern transfer mechanism.

E-beam lithography is used to manufacture the nanostructures. Here, exposure is carried out from point to point using a focused electron beam. This type of lithography has a higher resolution than photolithography, but it requires sophisticated high-vacuum equipment (electron microscope-lithographer) and has low productivity, therefore, it is mainly used for research purposes.

X-ray lithography also allows one to obtain nanoscale systems using X-ray radiation (as in optical lithography). In this type of lithography, rather complex sources of parallel x-ray radiation, for example, synchrotron, are used.

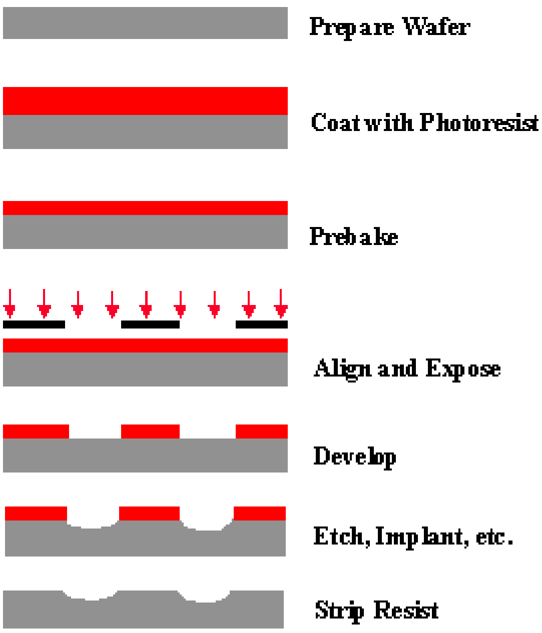

Fig. 1.

The general sequence of processing steps for a typical photolithography process is as follows: substrate preparation, resist spin coat, prebake, exposure, post-exposure bake, development, and postbake. A resist strip is the final operation in the lithographic process, after the resist pattern has been transferred into the underlying layer. This sequence is shown diagrammatically in Figure 1.

Experimental Tasks

Task 1. Studying the basics of photolithography. The formation of the contact pads profile to microstructures using photolithography.

Experimental equipment: Manual Mask Aligner MA-56 Karl Suss, photomask, photoresist AZ1512, centrifuge for applying resist, Hot Plate, optical microscope.

1. Cleaning the substrates (oxidized silicon) in acetone and isopropanol. Applying resist AZ 1512 by a centrifuge (50 s, 6000 rpm).

2. Drying the resist on a hotplate (5 min, 90 C).

3. Exposure of the photoresist (using photolithography equipment) (20 s).

4. Developing of the resist in 0.7 % solution of KOH in water (20s).

5. Control by optical microscopy. Determination of the alignment quality.

Task 2. Determination of the sensitivity of an electronic resist using dose test.
Experimental equipment: Electron beam photolithographer Stereoscan 200, resist PMMA 4%, centrifuge for applying resist, Hot Plate, optical microscope.

The electron beam scans the surface of the electron resist, repeating the pattern embedded in the control computer. For this, special software is used that controls the process of transferring a given pattern (structure) to the surface of a substrate with a resist. In this task, a test structure called a dose test will be used to study the properties of a resist. This structure is an array (for example, a matrix of 10 × 10) rectangles with a linear increasing dose from 100% to 1000%. Exposing a resist using a dose test structure allows you to determine its sensitivity using the optical control method.
1. Cleaning the substrates (oxidized silicon) in acetone and isopropanol. Applying resist PMMA by a centrifuge (60 s, 3000 rpm).

2. Drying the resist on a hotplate (3 min, 130 °C).

3. Exposure of the resist using dose test structure.

4. Developing of the resist in the solution of water in isopropanol (1:8) (20 s).

5. Control by optical microscopy. Determination the sensitivity of the resist.

Content of the report

Prepare a report, including the following:

1. Information about all the parameters of the technological routes of the experimental devices fabrication (application of the resist, drying, developing).

2. Data of optical microscopy and the results of its processing.

3. Analysis of the results of the work. Indicate specific technological inaccuracies and errors, if any, what they led to and how to fix them.

Questions and Discussion

1. List and describe the known types of lithography. Compare their resolution.

2. What methods of optical lithography do you know? Indicate the disadvantages and advantages of the contact exposure method.

3. The principle of operation of an electron beam lithographer.

3. What types of resist do you know? What is the difference between positive and negative resists? What processes in resists occur during drying, exposure and development?

4. What is sensitivity and contrast of the electron resist? What is a dose curve? Describe the method for determining sensitivity.

5. What will change if the accelerating voltage is increased?

6. Will the doses be different when exposing two lines with a width of 0.1 μm and 1 μm?

7. Describe the alignment procedure in lithography.

Literature & Links

1. https://en.wikipedia.org/wiki/Nanolithography

2. https://en.wikipedia.org/wiki/Electron-beam_lithography

3. https://en.wikipedia.org/wiki/Photolithography

4. https://en.wikipedia.org/wiki/Photoresist

5. http://www.lithoguru.com/scientist/lithobasics.html

6. "ПРАКТИКУМ ПО НАНОТЕХНОЛОГИИ, Методическое пособие для студентов ФОПФ МФТИ https://mipt.ru/upload/medialibrary/d7e/bookmanual_140917_opt.pdf (Russian)