Lithography

Learning Outcomes

- To understand how lithography, including photolithography and soft lithography is used to make electronic and biomedical devices and nano- and micro- scale 3D printed objects
- To make simple patterns using photolithography and soft lithography type processes
- To understand how microfluidics are used in biological analysis
- To understand that chips can be made in many designs depending on the purpose of the chip
- To understand that analysis of materials at the micro and nano scale require less space, fluid, and can be done differently because of how properties of materials change at a small scale – the basis of "lab on a chip"

Washington EALR Alignment

9-11 PS2F All forms of life are composed of large molecules that contain carbon. Carbon atoms bond to one another and other elements by sharing electrons, forming covalent bonds. Stable molecules of carbon have four covalent bonds per carbon atom.

9-11 PS2G Chemical reactions change the arrangement of atoms in the molecules of substances. Chemical reactions release or acquire energy from their surroundings and result in the formation of new substances.

9-11 PS2H Solutions are mixtures in which particles of one substance are evenly distributed through another substance. Liquids are limited in the amount of dissolved solid or gas that they can contain. Aqueous solutions can be described by relative quantities of the dissolved substances and acidity or alkalinity (pH).

Oregon Content Standards Alignment

H.2 P.1 Explain how chemical reactions result from the making and breaking of bonds in a process that absorbs or releases energy. Explain how different factors can affect the rate of a chemical reaction.

Lithography

Background

Lithography was a term originally used to define a type of printing process invented in the 1700s in which a pattern was transferred onto a flat stone or surface. A hydrophobic material, wax or greasy crayons, would be used to draw or print the material being copied. This would create areas that were hydrophobic and hydrophilic. Ink, a hydrophobic material, would be attracted only to the hydrophobic areas, separating the ink from the water creating the print. Lithographs could be used to make an unlimited amount of prints.

Today, lithography is also a term used to describe how structures such as computer chips are designed. Features, including fluid channels and electrical circuits, can be made by adding light (photolithography) or polymers (soft lithography) to certain areas of a substrate, or "chip". The areas not covered by these materials can then be etched away to reveal the negative image of the original similar to how lithographs were used. Until recently, lithography was only used to make structures that were at most only a few layers thick. The size of the materials presented problems with aligning lithographic layers as well as the precision of focus. Current technology has allowed lithographic techniques to be used to 3-D print nano- and micro- scale objects.

All modern electronics are made using photolithography. Typically, silicon wafers are used as the substrate due to their conductivity properties and the availably of the material. The main steps in the photolithography process are (Figure 1):

1. Coat a substrate with a photosensitive material, called a photoresist.
2. Cover the substrate and photoresist with a mask, which will block light in certain areas.
   Expose the substrate with light, which will cause a chemical change to occur in the exposed areas of photoresist (where the light is not blocked by the mask).
3. Develop the photoresist. In positive photolithography, the EXPOSED areas of photoresist are dissolved away in the developer. In negative photolithography, the UNEXPOSED areas of photoresist are dissolved away in the developer.
4. Now, you have a substrate with a pattern of photoresist on it. You can then do one of two processes:
   a. Etch – the substrate is etched away in areas not protected by the photoresist
   b. Lift-Off – a metal is deposited over the entire substrate. The photoresist is then removed, leaving behind metal only in the areas not covered by the photoresist.

   In either case, you now have a permanent pattern remaining on your substrate. The photolithography process may be repeated more than 20 times to create all of the layers in a computer chip.

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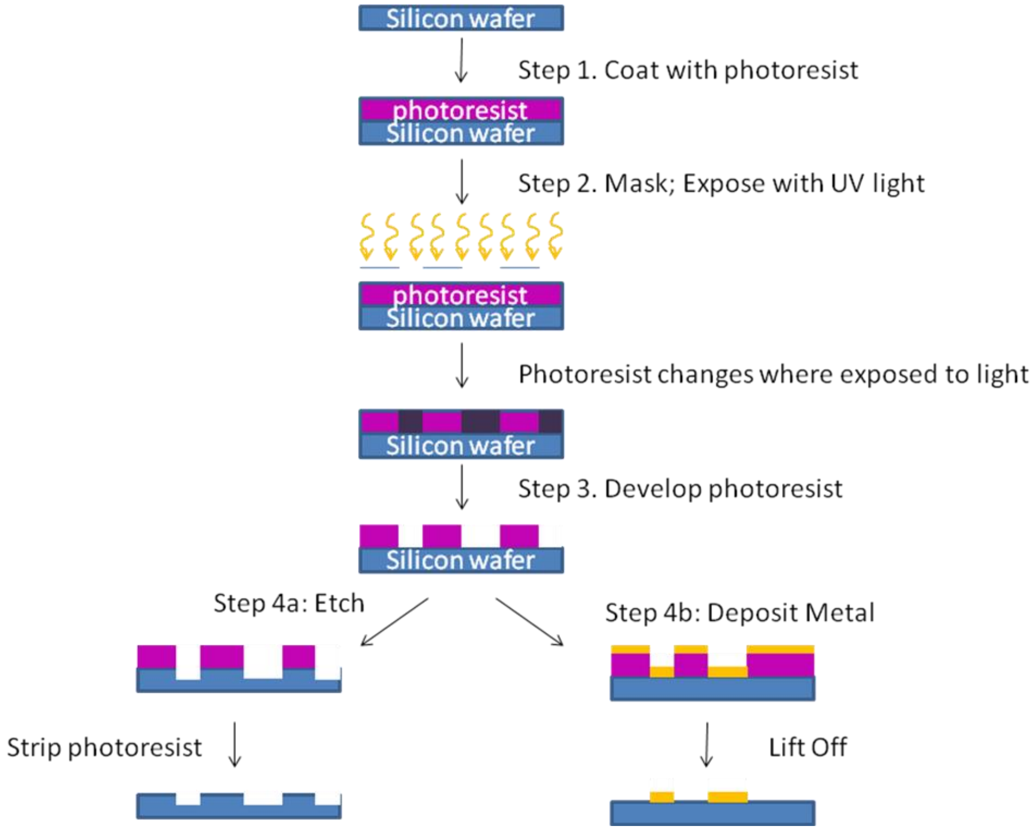

Figure 1. Steps of the photolithography process.

A newer area of lithography is called soft lithography. In soft lithography, a master mold is made using traditional photolithography techniques. Then, a polymer (or "soft" material) is poured into the master to replicate the pattern of the master. The resulting polymer structures can be used for a variety of applications. One main application is to create microfluidic devices, which control the flow of fluids. This can be used for analysis in medicine and biology. The benefit of using microfluidic devices is that all of the processes that need to be done for analysis, including mixing solutions, separating solutions, and analyzing components of solutions, can be done on a much smaller scale using smaller volumes of solutions without the need for lots of glassware or a large laboratory space. These devices are commonly called Lab on a Chip because they are able to perform the functions and tests that previously needed to be done in lab facilities.

*Note: these labs can also be used to teach the concepts of: polymerization (and photopolymerization); solubility (esp. relating to polymer molecular weight and degree of crosslinking); fluidics and flow (turbulent v. laminar flow); processing of Si chips.

Applications

- Lab on a Chip
- Electronic chips
- Nano – and micro- scale 3-D printed objects

Vocabulary

- Acids and bases
- Lab on a Chip
- Laminar flow
- Lithography
- Microfluidics
- Negative photolithography
- Parallel processing
- pH
- Photolithography
- Polymer
- Positive photolithography
- Substrate
- Surface tension

MSDS/Safety

Photolithography

This lab should be performed in a well-ventilated or hooded area. Students should wear gloves and goggles during the photolithography lab. Students should take care using the UV lamp and should never look into the light or expose to the body. MSDS or other chemical information sheets are provided at the end of this unit for all chemicals used. All of the waste material should be collected in a waste container and then properly disposed of as organic waste.

3-D Printing

This lab should be performed in a well-ventilated area. Students should wear gloves and goggles during the lab. Students should take care using the UV lamp and should never look into the light or expose to the body. MSDS or other chemical information sheets are provided at the end of this unit for all chemicals used. All of the waste material should be collected in a waste container and then properly disposed of as organic waste.

Soft Lithography

Acids and bases are used in this lab. Before disposing of the material care should be taken to ensure the waste is neutralized.

Materials

For the photolithography lab, some of the steps can be done either before the lab by the instructor or during the lab by the students. There are two materials lists and lab instructions that follow for the photolithography lab. Version A is designed for the situation in which the instructor makes the prepolymer solution. The second set, Version B, is written for the students to make the solution. The following is a complete list of materials needed for the labs:

Photolithography

Per every student

- 1 photomask per student - 1 ¾" x 1 ¾" image in a 2" x 2" black square printed on transparencies
- 4" x 3.5" transparency piece
- 2 coverslips (22 x 50 mm, No. 1, Corning) or transparency piece (22 mm x 50 mm)
- 2 glass microscope slides (75 x 50 x 1 mm)

Per every 3 students

- 1 mg of ONE of:
  - oil blue (solvent blue 14, Aldrich)
  - oil red (solvent red 27, Aldrich)
  - fluorescent yellow 3G (solvent yellow 98, Aldrich)
- 3.5 g isobornyl acrylate (Aldrich)
- 2.0 g 2,2-bis[4-(2-hydroxy-3-methacryloxypropoxy)phenyl]propane (bis-GMA; Polysciences, Inc.)
- 0.18 g 2,2-dimethoxy-2-phenyl-acetophenone (DMPA, Aldrich)
- 100 mL beaker
- 1 small amber vial with eye dropper top
- Sonicator
- UV lamp (365 nm wavelength)

3-D Printing

- Poly(ethylene glycol) diacrylate [CAS 26570-48-9 ; Sigma Aldrich # 437441]
- Phenylbis (2,4,6-trimethylbenzoyl)phosphine oxide (Irgacure 819) [CAS 162881-26-7; Sigma Aldrich #511447]
- Sudan I [CAS 842-07-9; Sigma Aldrich # 103624]
- 100 mL graduated cylinder
- Amber bottle (100 mL or larger)
- Scale
- Weighing boats
- Spatulas
- Stir plate and stir bar
- 50 mL beaker
- Data Projector
- Computer (with PowerPoint)
- Converging lens (magnifying glass)
- First surface mirror
- Ring stands, clamps, and clamp holders
- Staging device
- UV light
- Razorblade
- Gloves
- Goggles

Soft Lithography

Per every 3 lab groups:

- 170 g of lemon-flavored Jell-O (2 small boxes or one large box)
- 1 pouch (7 g each) of unflavored (the Original) Knox Gelatine
- Hot plate
- Stirring rod
- 500 mL beaker
- 250 mL beaker

Per lab group

- Drinking Straw
- Metal pan
- Three disposable 3mL syringes and labels
- Four small pieces of pH paper
- 4 Coffee stirrers (~3" long)
- 5 Petri dishes
- PAM no-stick cooking spray
- Single- and double-sided tape
- 3 vials
- Vinegar solution or HCl
- Antacid and water or NaOH