CHEMISTRY THE NEXT GENERATION

3 ACTIVITY

Photolithography

age group 16-18

5½ HRS

200 STUDENTS

40 STUDENTS PER GROUP

4 SUPERVISORS

£830

background

Students use **photolithography** – the process of using light to transfer a pattern onto a surface – to create their own **printed circuit boards**. A circuit pattern with tiny lines is placed on a copper film of an insulating surface, and subsequently covered by a polymer. It is then exposed to **UV black light** ('invisible' light that is just beyond the blue end of the colour spectrum), which creates a metal pattern that corresponds to the lines in the original pattern. This top-down approach to nanotechnology is routinely **used in manufacturing computer chips**. Basic photolithographic techniques used include exposing and developing a pattern in the photoresist layer, etching the unprotected copper, and finishing by stripping away the remaining photoresist.

pre-planning required

weeks before

If it's necessary to order a UV light-box make sure this is done in advance, at least one month prior to event (although this depends on supplier). Order the materials and apparatus in advance too. Have a run-through of the practical with the demonstrators a week before the event.

days before

- Brief your demonstrators – point out that they may be asked certain questions – these are highlighted with prompts on the student sheets.
- Trial all separations on each instrument used in the activity.

facilities required

A laboratory that can accommodate 40 students plus teachers and demonstrators. A washing up bowl half-filled with cold tap water on each table for the students to rinse their circuit boards. A kettle to boil water and make up the iron chloride solution.

Suggested timings for the day

10.00	Student registration
10.30	Welcome and introductory talk
11.00	Hands-on session
12.00	Lunch and chance to visit exhibition stands
12.45	Lecture (chemistry exam advice)
13.30	Hands-on session (teachers go to ICT training session)
14.30	Break
14.45	Interactive quiz (with prizes)
15.30	Finish

Answers

1. Misalignment of mask to substrate, over/under exposure, over/under etching *etc*. Each step is very sensitive and must be done carefully.
2. The photoresist is patterned by UV light. Features cannot be smaller than the wavelength of light (365 nm) unless some optical 'tricks' are played. For smaller features, electron beams are used to pattern photoresists.
3. Increased portability, parallel processing (lower production costs), lower material costs, greater durability.

This experiment was originally developed by B. Brough, E. Delonno, T. Faltens, L. Wesoloski, K. Carling and A. Steig at The California NanoSystems Institute, University of California, Los Angeles. This activity is based on a workshop run by Dr Samantha Tang, University of Nottingham.

materials required

Per student

- one circuit board
- one pair of tweezers with a small rubber band

Other material/equipment

- one UV light box
- permanent marker pens
- two photomasks (circuit board patterns on acetate sheets)
- ten photoresist developer applicators
- ten photoresist stripper applicators
- beakers
- iron(III) chloride solution (This is available in an 'etch-in-a-bag' kit. The iron chloride pellets are in a robust plastic bag that you add hot water to, seal up, then swill around to melt the pellets)

The photolithography chemicals can be obtained from Mega Electronics **www.megauk.com**

SAFETY

A risk assessment must be done for this activity.

Photo lithography

introduction – what is photolithography?

Photolithography is a process used in making semiconductors to transfer patterns from photomasks (in this case acetate sheets with a circuit board pattern) to a surface. Often crystalline silicon in the form of a wafer is used – *eg* in a circuit board, although there are several other options including glass, sapphire and metal.

There is a layer of photoresist – a chemical that hardens when exposed to light (often UV light) – on top of the metal layer of the circuit board.

The photoresist is selectively 'hardened' by illuminating it in specific places by using a transparent plate called a photomask with patterns printed on it. This photomask is used together with a light source to shine light on specific parts of the photoresist. Some photoresists work well under broadband UV light, whereas others are designed to be sensitive at specific frequencies to UV light. It is also possible to use other types of resist that are sensitive to X-rays and others that are sensitive to exposure to electron-beams.

In this activity you will be carrying out your own photolithographic process.

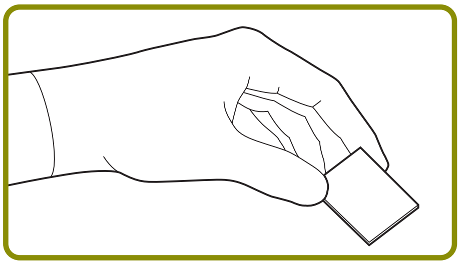
SAFETY

Safety glasses and disposable gloves must be worn.

Exposing the photoresist

1. Get a piece of circuit board. It has black tape covering one side that protects the underlying photoresist layer from the light. On the side without the black tape write your initials using a permanent marker pen. Make sure that you write clearly and in bold lettering as the etching process may remove some of the ink.

2. It is very important to hold the board by the edges and not get any fingerprints on the board. Peel off the black tape to reveal the photoresist.



3. Place the circuit board over one of the patterns on the photomask, photoresist side down (side without your name).

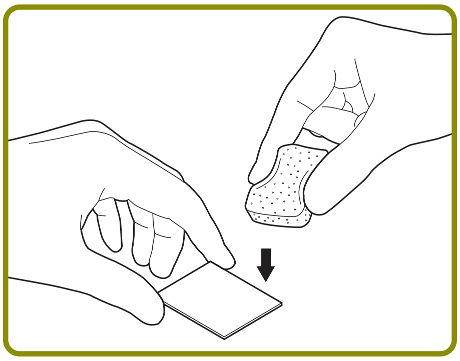
4. When all the circuit boards are ready the demonstrator will turn on the light box for 80 seconds.

Developing the photoresist

1. After the UV exposure has ended and the light box has been turned off, retrieve your circuit board. You should be able to see a faint pattern in the photoresist on your circuit board. The exposed photoresist will have a slightly more yellow colour than the unexposed region, which appears metallic green.

2. Check the developer applicator sponge. If it looks dirty, clean with a damp paper towel.

3. Gently dab on the developer (do not rub) using the applicator sponge. Cover the entire photoresist surface, including the edges. The developer will remove the exposed photoresist.



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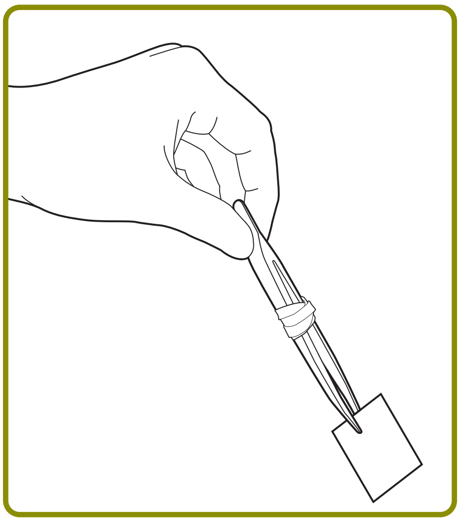
4 As soon as you can see the shiny copper, rinse off the developed photoresist with water to reveal the copper underneath.

5 Inspect the pattern. If there are bits of dirt, rinse them away with water.

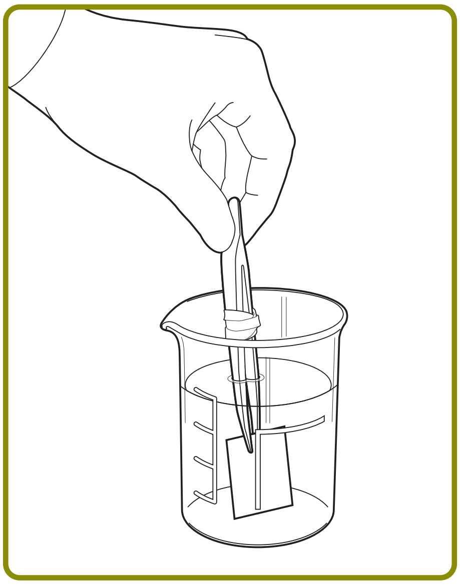
Etching the copper

1 Wrap a small rubber band around the tweezers so that they stay closed.

2 Use the tweezers to pick up the developed circuit board, being careful not to touch the photoresist pattern. Set a timer for 10 minutes.



3 Dip the circuit board into the iron(III) chloride solution to etch the board. Make sure that the entire board is covered. Gently swirl the solution occasionally.

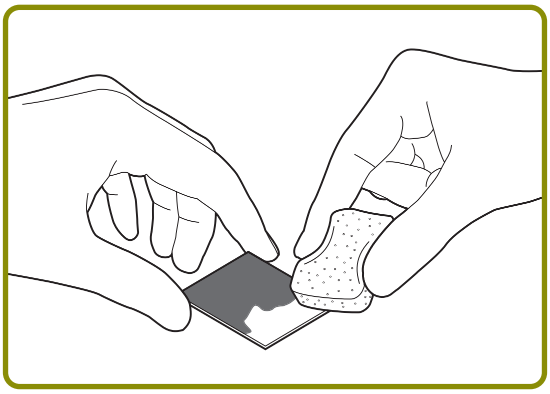


4 After 10 minutes start checking the board to see if etching is complete. Remove the circuit board and dip it into clean water in a plastic tray. Look to see if the copper that is not protected by the photoresist is completely etched away, revealing the plastic underneath. If the copper is not completely etched, place the board back into the solution.

5 When etching is complete, wash the circuit board in clean running water.

Stripping the photoresist

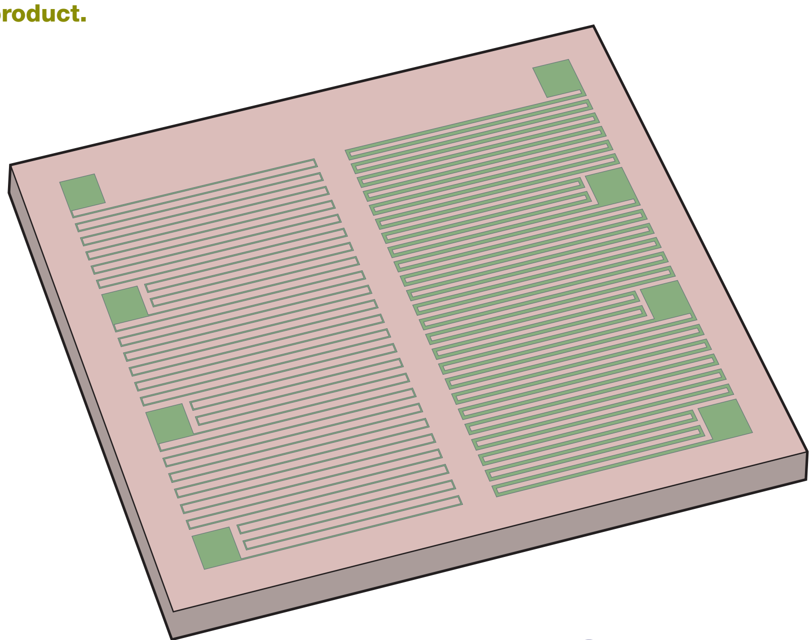
1 Dab on the photoresist stripper to dissolve the photoresist that is covering the copper pattern.



2 Rinse with running water.

3 The copper pattern should appear shiny and metallic.

Congratulations! You have a finished product.



NOTE

Be careful not to over-etch. If you leave the board in the solution for too long the copper that is protected by the photoresist will also etch away.

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questions

1. What are some of the sources of error in the photolithographic process?
2. What are the limitations that determine the minimum sized feature that can be produced by photolithography?
3. Other than increased speed, what are the advantages of making chips smaller?