1. Macro-scale Photolithography

Objective: To demonstrate, in the macro-scale, the process of photolithography as one of the "top-down" methods for nanofabrication. A piece of photosensitive paper is used as a prepared substrate to undergo pattern transfer and a simple developing process in this demonstration.

Supplies and Equipments:

1 sheet photosensitive paper (available in craft stores as Sunprint® Kit)

1 cut-out stencil or 'mask' made of construction paper or opaque plastic

1 low-intensity 365 nm Ultraviolet (UV) lamp

1 bucket of water

3-4 paperclips

Procedure:

1. Show the stencil mask to the class, ask them to name the image on the mask.
2. Place the mask on top of the *blue side* of the photosensitive paper. Use paperclips to secure them and show it to the class again.
3. Shine UV light through the mask for 1.5-2 minutes or until the photosensitive paper turns almost white. Move the UV lamp around to ensure uniform exposure. Do not overexpose. On a sunny day, direct sunlight can be used instead of the UV light but longer exposure time (up to 5 minutes) is recommended.
4. Remove the mask. Submerge the photosensitive paper in water for about 1 minute to develop the pattern and dry flat.
5. Show the transferred pattern on the photosensitive paper to the class. The exposed region should turn blue, the covered region white.

2. Nanosphere Lithography: Blown-Up Version

Objective: To demonstrate, in the macro-scale, the process of nanosphere lithography as another “top down” nanofabrication method. Glass marbles are used in place of nanospheres to create a pattern. Fine glitter is deposited to transfer the pattern onto a transparency slide substrate.

Supplies and Equipments:

1 sheet transparency slide

1 overhead projector

40-50 glass marbles, each about 1” in diameter

1 cardboard frame with about 6”x 6” interior to contain the marbles

1 clear glue stick (e.g., UHU® Stic)

1 tube fine glitter with shaker top (for uniform deposition)

Procedure:

* This demonstration is done on top of the overhead projector throughout.

1. Place the cardboard frame on top of the transparency slide. Apply glue onto the slide in the interior of the frame.
2. Arrange the marbles to fill the frame, creating arrays of triangular interstices. Use as many marbles as needed to make the arrangement stable.
3. Sprinkle the glitter evenly onto the transparency slide, trying to cover as many interstices as possible. The thickness of the deposited glitter does not matter much for showing only 2-D patterning here.
4. Carefully lift off the marbles, revealing the patterned glitter. Clean off extra glitter.

3. Macro-scale Surface Area to Volume Ratio

Objective: To demonstrate, in the macro-scale, how the ratio of surface to total atoms changes as the volume decreases. Glass marbles are arranged as "atoms" in different volumes of material. The ratio of the surface "atoms" to the total "atoms" is calculated for each volume. As the volume decreases, the ratio of surface to total atoms increases. Therefore, when the volume or size of a material is brought down to the nanoscale, its properties will be largely governed by surface properties.

Supplies and Equipments

4 beakers, each of size 800 ml, 150 ml, 50 ml and 20 ml

300 14 mm glass marbles in one color (as surface "atoms")

200 14 mm glass marbles in a different color (as inner "atoms")

1 magic marker for labeling

Procedure:

*Prepare step 1 and 2 in advance, as they are quite time-consuming.

1. Arrange the marbles to fill the beakers, using one color for the surface "atoms" (ones in contact with the beaker and ones in the top layers) and a different color for the inner "atoms." Count the number of each color of marbles used in each beaker.
2. Label each beaker by the number of surface "atoms" divided by the number of total (surface + inner) "atoms", both as fractions and decimal figures.
3. Let students pass the beakers around, noting that all "atoms" in the smallest beaker are surface "atoms." As the volume decreases, the ratio of surface to total atoms increases. The ratio essentially becomes one (100% surface atoms) for the smallest beaker.

4. Larger Surface Area for Enhanced Chemical Reactivity

Objective: To demonstrate that chemical reactivity can be enhanced by decreasing particle size and therefore increasing surface area. Nanoparticles, with smaller sizes and larger surface areas, are more chemically reactive compared to the bulk material. Gold, for example, is chemically inert in bulk form. Gold nanoparticles, on the other hand, are so chemically reactive that they can be used to catalyze certain chemical reactions. In this demonstration, students will observe how fast Alka-Seltzer, in powder and bulk forms, reacts with water to produce air bubbles and color change. The red cabbage extract (a natural pH indicator) is used only to add colors to this demonstration. Plain tap water should also work quite as well.

Supplies and Equipments:

2 Alka-Seltzer tablets or other effervescent antacid medicine

1 set of mortar and pestle

2 petri dishes

2 100 ml beakers

1 zip-lock plastic bag

3 red cabbage leaves

1 cup tap water

Procedure:

1. Tear up the cabbage leaves into small pieces, place them in the zip-lock bag, then add the tap water. Seal the bag and squeeze the leaves until the water turns dark blue. Pour about 60ml of the red cabbage extract into each of the two beakers.

2. Grind one Alka-Seltzer tablet into powder using mortar and pestle. Place the powder in one petri dish. Place the remaining whole tablet in the other petri dish.

3. Tell the class to look carefully. Quickly and simultaneously pour the solution into each petri dish. Note the color change and the bubbles profusely coming out of the powder, but much less out of the tablet. The powder will be consumed by the reaction much faster than the tablet because of the powder's larger surface area and thus its enhanced chemical reactivity.

5. Smaller Means Faster

Objective: To demonstrate that with smaller size (and hence lighter mass), mechanical motion can occur much faster. For example, the resonant frequency of a mass on a spring is inversely proportional to the square root of the mass. Since similar relationships can be determined for rotational motion, single molecule rotors are expected to have exceptionally high rotational frequencies.

Supplies and Equipments:

2 identical springs, each with spring constant k about 0.22 lb/in or 0.1 kg/in

1 200 g mass (e.g., a plastic bag full of metal ball bearings with the top tied close with non-elastic yarn or metal wire. Allow a loop of yarn or wire to attach to one end of the spring)

1 800 g mass

2 metal stands

2 clamps

1 stopwatch

Procedure:

1. Attach one clamp to each stand, making sure there is enough clearance for the mass on the spring to vibrate freely. Setting up on the edge of a table might be helpful. Attach and secure one spring to hang vertically from each clamp.
2. Attach one mass to each spring and let go. Ask the students to observe how fast each mass moves up and down.
3. Ask for three volunteers, two to count the resonant frequency of each mass on the spring (i.e., how many times the mass hits its lowest position) and one to time the counting for 30 seconds.
4. Ask the two students to present their counts. The resonant frequency of the 200 g mass should be approximately twice that of the 800 g mass. In other words, the 200 g mass vibrates twice as fast on a spring as do the 800 g mass.

6. Optical Property and Modern Use of Gold Nanoparticles

Objective: To demonstrate different optical property (i.e., changing colors) of gold particles of different sizes and their ability to act as biosensors for medical purposes. The gold nanoparticles in gold colloid are slightly negatively charged, enabling them to remain uniformly suspended in de-ionized water in form of colloidal gold. With the nano-sized gold particles, the colloid appears red and transparent. However, the addition of salt will introduce positively charged particles into the colloids and cause the negatively charged gold particles to agglomerate. The mixture, now containing gold particles of larger sizes, will appear gray and cloudy when interacting with light. (When left untouched for days, the mixture will appear colorless with sedimentation of larger gold particles at the bottom of the vial. The colloidal property of the mixture is clearly lost when the particles agglomerate into larger sizes.) The addition of sugar, on the other hand, does not cause particle agglomeration. The mixture with sugar will still appear red, with no color change. The gold nanoparticles therefore act as biosensors for the presence of salt in this demonstration.

Supplies and Equipments:

2 vials with lids, each contains approximately 10 ml. of colloidal gold (high purity gold particles suspended in de-ionized water, commercially available as MesoGold® from Purest Colloids, Inc. See www.purestcolloids.com for details)

1 pack of salt

1 pack of sugar

Procedure:

1. Show the two vials to the class. Let the students describe the color they see. The gold colloid should appear ruby red and transparent.
2. Ask for two volunteers. Let one add some sugar to the first vial and let the other add some salt to the second vial. Tell them to close the lids and shake well to ensure complete dissolution.
3. Ask the volunteers to show their vials to the class. The solution should appear gray upon the addition of salt but should still appear red, with no color change, upon the addition of sugar.

7. Leakage Current in Microprocessors

Objective: To demonstrate, by analogy, the way tunneling causes leakage current and thus heat dissipation in microprocessors. Tunneling is a quantum mechanical effect in the nanometer scale when electrical insulator fails to block current flow. Such tunneling current (or leakage current) causes the otherwise electrical insulators to heat up. Although, no actual tunneling current does occur in this demonstration, the dissipation of heat (and thus energy lost) from the light bulbs is analogous to the heat caused by tunneling current in computer's microprocessors. As expected, as the power of the light bulb increases, more energy is lost through heat.

Supplies and Equipments:

3 identical light bulb sockets

3 light bulbs of different powers, each of 40watts, 100watts and 200 watts (Clear, uncoated light bulbs are preferred as the heat contrast will be more differentiable to the touch.)

Procedure:

1. Secure the light bulbs in the sockets in order of increasing power and turn them on.
2. Tell the class the corresponding power for each bulb.
3. Ask for one volunteer to feel the heated light bulbs. Let the volunteer describe how they feel after touching each light bulb (e.g. Is it warm, hot or extremely hot? How long can he or she touch each one continuously?)