# reversible sunglasses

**GOAL:**

Visitors will understand how nano-scale switches in molecular structure can make plastic lenses darken in ultraviolet light.

**MATERIALS:**

Real Product

- UV lightbox
- Photochromic lenses in eyeglass frame
- White paper or white plastic square from Environmental Clean Up (optional)

Macro-scale

- Graphic of reversible photochromic reaction (optional)
- Model of photochromic molecules
- Handheld blacklight
- Sample chips of photochromic dyes

**PROCEDURE:**

**Set-up:**

1. Plug in lightbox and lay out all supplies.

2. Pull string to set molecular model to the folded position.

**Doing the demonstration:**

1. Show visitors the lenses; ask them if they notice anything unusual about them.

2. Place the lenses in the lightbox, close the lid, and turn on the light for 30 seconds. Switch off the lightbox and display the lenses. (Optional: if working in low light or on a dark surface, you may want to place them on white paper or the white plastic to make the effect easier to see.) Ask visitors what they see. Explain that the lenses are not ordinary lenses; they are eyeglasses that are colorless inside and turn into sunglasses outside. The light in the box emits ultraviolet (UV) light, the same kind of radiation emitted by the sun, so the lenses darkened when exposed to UV light.

3. Explain that these lenses are coated with a “photochromic” dye – photo = light, chromic = color, so light causes these lenses to change color. When exposed to UV light, they get dark, absorbing and protecting your eyes from the radiation. In the absence of UV light, they revert to colorless. Show visitors the lenses again; as you have been talking, the color will have already started to fade.

4. Explain that the mechanism by which the photochromic dye works is on the nano-scale level, and that the molecular model of the dye will help demonstrate the effect. (Optional: for more advanced visitors, use the graphic to show the actual molecular structure.) Tell the visitors they are under normal light inside, so the molecules are folded up in a bent conformation. Ask what color they see on the surface (it is primarily white).

5. Then tell the visitors to pretend to go outside, and have a volunteer act as the “sun.” The volunteer will shine the handheld blacklight on the base of the model, revealing instructions to “BREAK BOND.” Have the visitor pull and release the string, changing the conformation of the model to a flat, open position with a highly reflective surface. Explain that when UV radiation hits a photochromic molecule, it actually changes the shape of the molecule, just as the structure of the model changed. This change in shape causes the molecule to reflect light differently.

6. Now tell the visitors to pretend to come back inside, and switch off the handheld blacklight so the instructions disappear. Pull the string to reset the model to the folded position and explain that when there is no more UV light, the molecule reverts to its original state.

7. Photochromic dyes can be produced in many different colors by small modifications of the base molecules. Allow visitors to place the sample chips in the lightbox and turn it on for a few seconds to explore some of the colors.

**Clean-up:**

1. Release string on molecular model and store it in its flat, open position.

2. Gather all materials and return to storage.

**EXPLANATION:**

The most common use of photochromic dyes today is in eyeglass lenses. These are often referred to as “Transitions” ™ lenses, after the well-known brand of the same name. The first photochromic lenses were popularized in the 1960s and made of glass. Glass lenses used the reversible reaction of a silver salt compound to change color.

Modern photochromic lenses are made from plastic coated with photochromic molecules that reversibly change their structure when exposed to different wavelengths of light. The most common families of molecules used for photochromic lenses and dyes are called spironaphthoxazines and naphthopyrans. UV radiation causes a bond in the molecule to break, rotate, and reform, changing its structure to a planar conformation. This allows electrons in different parts of the molecule to resonate with each other and absorb light in the visible spectrum, changing the color of the lens. When the UV source is removed, the original bond is re-formed, returning the molecule to its original folded conformation. As the molecules fold, the darkening of the lens gradually fades and the lens returns to its colorless state.

To produce these lenses, photochromic dyes in a crystalline powder state are dissolved in a solvent. The lenses are then soaked in the dye so that millions of photochromic molecules are incorporated into the front surface of the lens at a depth of approximately 0.15 mm. This process allows the molecules to be absorbed into the lens at a uniform depth, allowing for even darkening. In contrast, the older glass lenses had the silver compound distributed throughout the glass, causing uneven darkening in different areas of the lens depending on its thickness.

Because photochromic lenses react specifically to UV light, there are situations outdoors where darkening will not occur. For example, many kinds of glass, such as the glass used in car windshields, are made with a UV-protective coating, so photochromic lenses will not darken in a car where the windshield is already blocking out the UV light.

The molecular mechanism of photochromic dyes is similar to how retinal molecules in our eyes change structure, or *isomerize*, in response to visible light. While this type of molecular switch may not fit a strict definition of nanotechnology because the property is not an inherent function of size, photochromic dyes are an excellent example of how technology can mimic nano-scale functions of the human body.

## WHAT COULD GO WRONG?

The photochromic lenses do not fade particularly quickly. This gradual rate is intentional, because your eyes need time to adjust to changing light levels. However, temperature also has an effect; the reaction works faster in colder temperatures.

**Do not open the UV lightbox while the light is on.** It can be used in either manual mode (needs to be plugged in) or timer mode (runs on battery for a 45-second interval). We recommend using manual mode in order to control how much time the light is on. The sample chips get very dark if exposed for 45 seconds and take a long time to fade.

The molecular model may occasionally need a sharp tug when pulling the string to set it to its folded state. However, the release by the visitor should not require any effort.

## GENERAL MAINTENANCE:

Keep blacklights (both the lightbox and handheld) switched off when not in immediate use to prolong bulb and battery life. Although the bulbs emit low levels of UV radiation and are safe to use in a museum environment, discourage visitors from looking directly at the handheld light to reinforce the idea that UV light can be harmful to the eyes.

The sample chips of photochromic dyes are very popular, especially since they change color so quickly – keep an eye on them so they do not disappear.