Smart Materials - Examples

by Jessica Tjandra

1) Structural colour (e.g. Butterfly wings)

Butterfly wings are colourful because they diffract and scatter light waves.

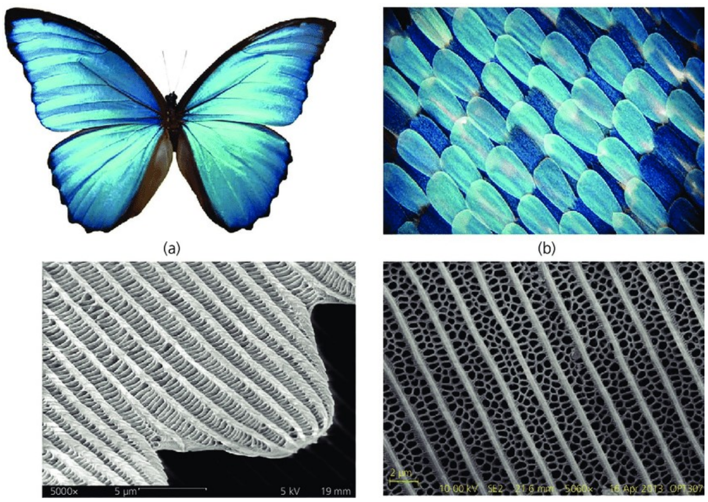
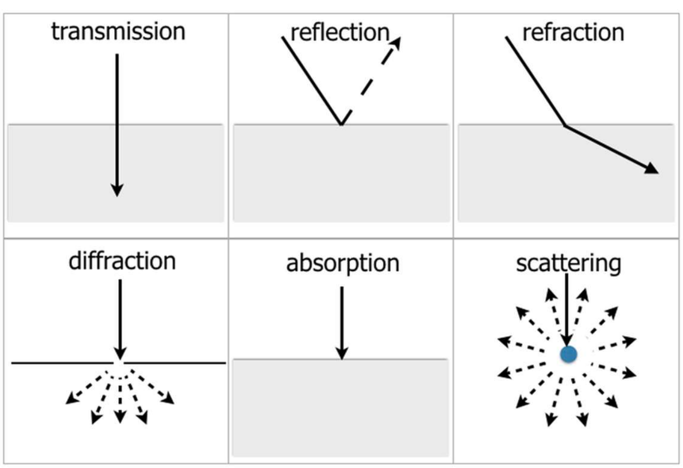


Figure 1a-d) Images of Morpho rhetenor (common blue) butterfly wings at different magnifications, showing that they are composed of thousands of scales with complex hierarchical structures. (Source: DOI 10.1680/jbibn.16.00048)

Diffraction of light is a different process than reflection of light, which produces colour in pigments and dyes.

Figure 2) Different ways in which light behaves at an interface. Image from https://clarkscience8.weebly.com/behavior-of-waves.html)



2) Aerogels

Aerogels are one of the lightest solid materials ever made. They are made from a gel, with its liquid component being replaced with gas. Aerogels have such a low density that it appears translucent and scatters light. Due to its porous structure, it is a great thermal insulator, and potential applications in building insulation are being researched. Due to its complex manufacturing techniques, aerogels today are still too expensive for building insulation, although in 2007 Georgia Institute of Technology's Solar Decathlon House Project uses aerogels in its semi-transparent roof.

Interestingly, silica aerogel has extensively been used by NASA to capture space dust and provide thermal insulation for Mars rovers and space suits. This is because aerogels are very light, therefore cost-effective for space missions. Other uses of aerogels include novel drug delivery systems thanks to its high surface area to volume ratio -allowing drugs to be adsorbed easily.

3) Self-healing materials

Self-healing materials can repair themselves from damage. Even though self-healing materials are only researched from early 21st century, it has been used for centuries. The ancient Romans used a mix of a type of volcanic ash with quicklime and water to make their mortar. This mix form crystals of a mineral that holds the mortar together, therefore preventing any crack formation.

Self-healing polymers usually have complex organic bonds that can recombine once broken. These are usually disulfide bonds which can undergo cleavage reversibly.

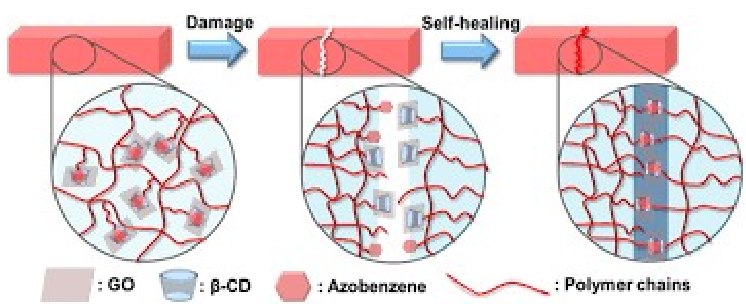


Figure 3) Image from https://composites.utk.edu/papers%20in%20pdf/acs.macromol.8b01124.pdf

Self-healing materials can assist in wound healing through the development of flexible wound dressings. Furthermore, researchers in South Korea have developed self-healing smartphone screens that can heal 95% of cracks within 20 minutes. This technology involves adding a polymer bilayer film and a linseed oil layer which acts as a self-healing coating on the LCD -therefore could offer a solution in cutting worldwide electronic waste. Fun fact: linseed oil is currently extensively used to protect expensive works of art.

4) Shape-changing materials

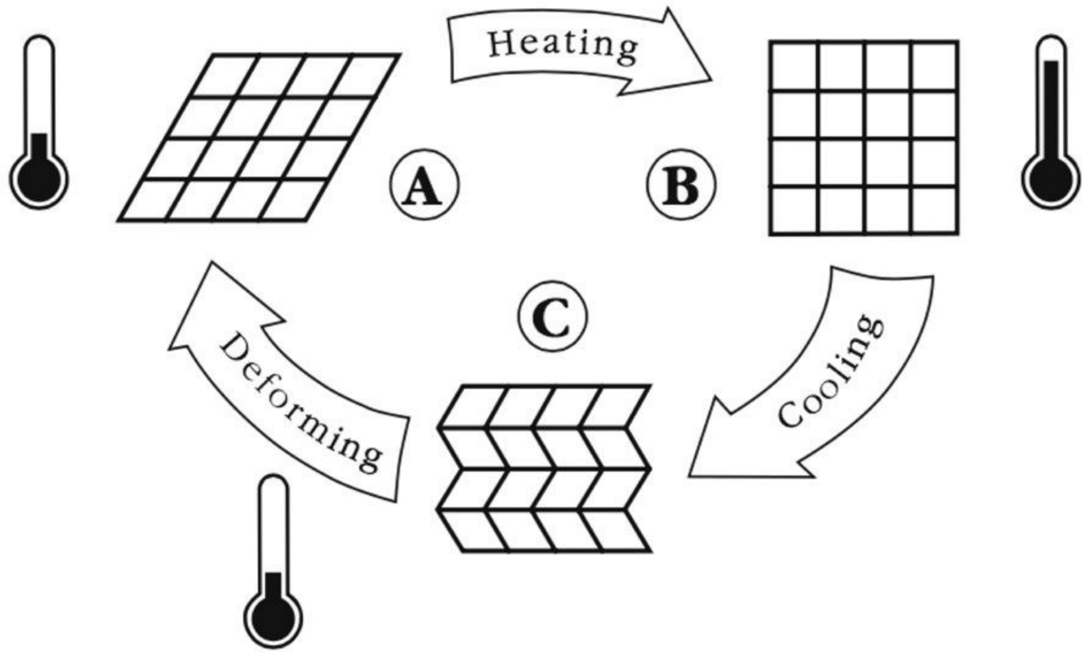


Figure 4) Diagram showing how shape memory alloys work -from https://www.assemblymag.com/articles/94935-shape-memory-alloys-new-ways-of-using-heat-for-a-technology-advantage

Shape-changing materials are a group of materials that can remember its original shape prior to being deformed. Often made of metals, they are also called **shape-memory alloys**. These metals have a quality called superelasticity -it will bend when deformed and return to its original shape when the deforming force is removed, just like a rubber band.

One of the most common examples of shape-changing materials is **nitinol** (chemical formula: NiTi). This is used extensively in cardiovascular stents, which aims to remove blockage from blood vessels and maintain blood flow. They look like springs and are placed just off the heart, in one of the largest blood vessels in the body. Instead of performing surgery so close to the heart, surgeons utilise the shape memory properties of NiTi and instead deformed the spring into straight wires at low temperatures (diagram: from B to C to A), which can be threaded through smaller blood vessels. Typically, surgeons will tether the stent from veins elsewhere in the body. Once placed near the heart, the stent will respond to body temperature and revert back to its original shape (A to B). This is a lifesaving, but also minimally-invasive, procedure for patients with coronary artery disease!

In the aerospace industry, Rolls-Royce has developed adaptive serrated nozzles at the back of its jet engines using shape memory alloys.

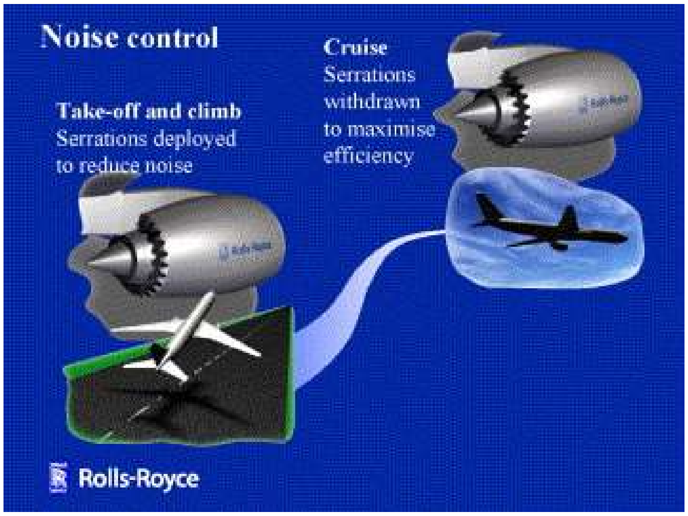


Figure 5) Image from https://www.sciencedirect.com/science/article/pii/S0921509306008227

5) Sensing materials

Sensing materials can respond to thermal or electrical energy and are widely used in actuators and sensing devices. Thermochromic materials are made of liquid crystals which change structure depending on the temperature.

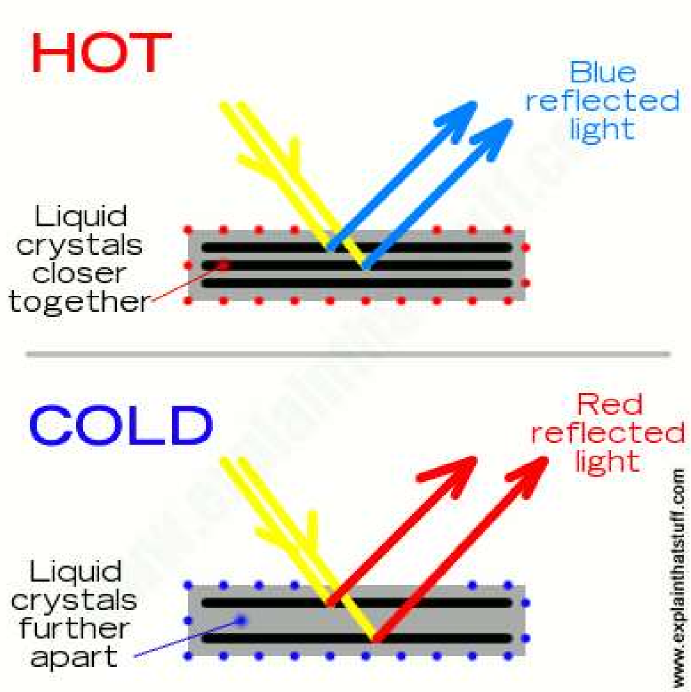


Figure 6) Image from https://www.explainthatstuff.com/thermochromic-materials.html

These materials can be used in gadgets such as thermometers, battery testers and dyes.