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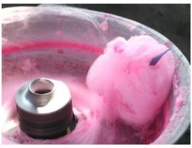
How are Glass Fibers Made?

The term "glass" includes many different materials, some with which you are familiar. *Soda-lime glass* is the most common type of glass and is used to make such things as window panes and glass jars. *Borosilicate glass* is another common type of glass that is more heat resistant than other forms of glass. Glass fibers, used to make fiber-glass, are made from glass that is similar to windows or drinking glasses.

To learn how glass fibers are made, we start with understanding that because glass can change from a solid to a liquid and then back to a solid is why it is such a unique material! This property allows gaffers (people who "blow" glass) or machines to work with and shape the glass into products such as vases or bottles.

To make glass fibers, glass is heated until molten (liquid), then forced through superfine holes. This creates glass filaments that are extremely thin. As the fibers are cooled, they transition back to a solid from a liquid.

You've eaten cotton candy haven't you? That yummy treat is made by heating sugar (*a solid*) until it reaches a molten (*liquid*) state and squeezing it through small holes into a larger bowl that is spinning. The thin sugar fibers *solidify* almost immediately in the room temperature air and begin to collect on the outer edges of the bowl. When you eat the cotton candy, the heat from your tongue causes the fibers to dissolve into a *liquid* form again. A double glass transition: solid to liquid to solid to liquid!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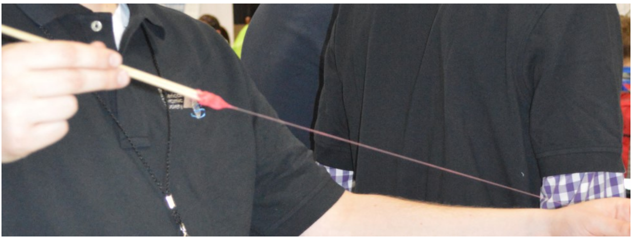
Let's explore!

You can demonstrate a way that shows how glass fibers are made. Make sure you have a parent to help you with this.

Unwrap four of the Jolly Rancher© candies of the same color and put them into a Pyrex© or custard cup. Put the cup in the microwave and heat on high for 8 seconds. If the candy is not yet molten, repeat for up to 8 seconds. Remove from the microwave and stir with the bamboo rod. ***This will be a high temperature liquid (140-170° C) capable of burning. Please handle with appropriate insulation.*** <u>Do not touch the cup bottom with your unprotected hand!</u>

You will form a candy glass ball on the end of the rod. Touch the candy ball to the side of the cup and start to pull the fiber. Notice that the fibers are fairly flexible when they are first pulled, but will harden the longer they are exposed to the air due to the small diameter of the fiber and the temperature difference between the air and the molten candy. Try this several times. How long of fiber were you able to pull?



Fiberglass-reinforced composites are used to make such things as swimming pools and spas, doors, surfboards, sporting equipment, boat hulls, and a wide array of exterior automobile parts. Optical glass fibers similar to the ones you pulled from the candy carry phone signals and form the backbone of today's Internet.

Learn more about ceramics, glass, and materials at ceramics.org/ceramicsarecool.

Demonstration originally developed by Missouri S&T, Materials Science & Engineering, http://mse.mst.edu

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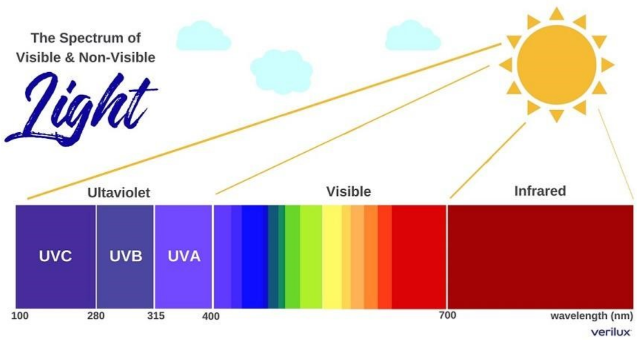
Magic Color Beads and UV Light

Inside this package you will find ten white plastic beads. These are special plastic beads that contain a chemical substance or pigment that changes color when exposed to ultraviolet (UV) light. When exposed to UV light, the beads will become red, orange, yellow, blue, or purple. If the beads are removed from UV light, they will slowly return to their white color. The beads can change between white and colors thousands of times.

So where do we find UV light? The sun gives off light we can see (visible light) and some that we cannot see (ultraviolet and infrared). Just as there are different colors or wavelengths in the visible spectrum (red, yellow, green, blue), there are different wavelengths of UV light. Long wave UV-A has wavelengths from 400-315nm and is what is emitted from a “blacklight” we use to make posters glow (fluoresce). It is also needed by our bodies to synthesize vitamin D. Shorter wavelengths known as UV-B (315-280nm) are the major cause of sunburn. The pigment in these beads reacts to wavelengths from 360 to 300nm. (See the chart on the other side.)

Now that we know these beads react to UV light, let’s test where we find UV light and the ability of different materials to block out the UV light. You now have your own UV light detectors!



Experiment

-Place five beads in the opaque brown plastic bag included in this package. Leave the other five beads in the clear bag and expose both bags to the sunlight. What happens?

-Try placing the beads in other containers you find at home or school, including metal, paper, plastic, glass, clear, opaque, and colored.

-Place some beads in direct sunlight and others in the shade. Where is the UV light the strongest?

-Coat the beads with different SPF sunscreens (keep two beads without) then expose them to sunlight. How do they compare?

-Cover some beads with a pair of sunglasses. Try different sunglasses. What happens?

-Expose the beads to different kinds of light sources: fluorescent, incandescent, colored, LED, blacklight, etc. Do the beads respond to any of these artificial lights?

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The Science of Silly Putty®

If you have played with Silly Putty®, you know how fun it can be! Silly Putty® can bounce like a rubber ball, break from a sharp blow, be stretched, and will flow into a puddle after a period of time. If you flatten it and press it over a comic or newspaper print, it will copy the image.

So how in the world can it do so many things? Is it a solid or is it a liquid? The most important compound in Silly Putty® is polydimethylsiloxane (PDMS). This is the simplest member of the polymer family known as the silicones.

PDMS is viscoelastic. This means that it acts like a viscous liquid and flows over long time scales. However, over short time scales (for example, being rolled into a ball and thrown at a hard surface), its behavior is elastic, and it will bounce back.

The presence of PDMS alone, and its viscoelasticity, doesn't fully explain how Silly Putty® behaves. Another ingredient, boric acid, also makes a telling contribution. The boric acid helps to create "crosslinks" between adjacent polymer chains. These help to give silly putty its putty-like nature, and also help explain its strange behavior.

The boric acid reversibly reacts with these to form short-lived crosslinks between polymer chains. Slow deformation gives these crosslinks time to break and reform, allowing viscous flow, but rapid, forceful deformation does not, so elastic behavior is instead seen.

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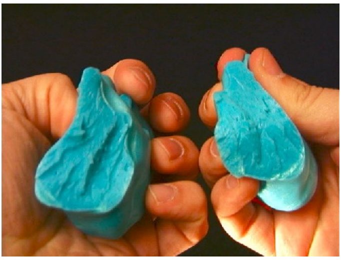
Let's experiment!

1. Remove your Silly Putty® from its package and form it into a nice round ball. Drop it onto a hard surface. What happens? It bounces back to you just like a rubber ball and demonstrates its elastic behavior.

2. Take that ball and stretch it. Does it bounce back to its original ball shape? No, it remains in its plastic deformed state and may even continue to slowly flow.

3. Roll the Silly Putty® back into a ball shape and flatten it. Securely grasp the putty in your two hands and quickly tear it apart by shearing. What happened? (Hopefully you tore it and not just stretched it--if not, move faster.) The Silly Putty® will fracture like a brittle material complete with fractured edges that look like broken glass.



4. Roll the Silly Putty® into a ball again and set it on the table top. What happens after several minutes? The Silly Putty® will flow like a very thick liquid.

You just experienced four major mechanical behavior types of Silly Putty®!

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Demonstration originally developed by Missouri S&T, Materials Science & Engineering, http://mse.mst.edu

Source: www.compound.com

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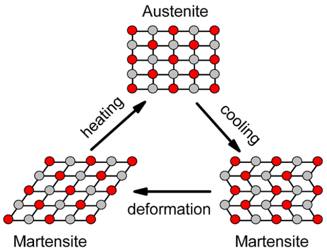
What is a Shape Memory Alloy?

Let’s start by defining what we mean by a “shape memory alloy.” An *alloy* is a metal containing two or more elements. *Thermal shape memory* is the ability of a material to return to its original shape when heated.

The piece of wire in this demo is called Nitinol and is an alloy made of nickel and titanium which has two phases or states, a high temperature (*austenite*) state and a low temperature state (*martensite*), shown in the drawing below. The difference in the two states is the arrangement of the atoms in the wire.

The low temperature phase is weaker, allowing the material to be bent and pulled out of shape. When deformed at a low temperature and then heated, Nitinol will return to the shape established when in the high temperature, stronger phase. By heating the material, the atoms are given enough energy to rearrange themselves back to their high temperature phase. This ability to remember and revert to the original shape gives this material the name “shape memory.”



In comparison, a piece of normal steel wire (whose composition is generally iron and carbon) will be unaffected by the addition of heat and will maintain its deformed shape.

Nitinol is a popular choice for a variety of applications: as a material in temperature control systems, springs in orthodontic braces, and for eyeglass frames.

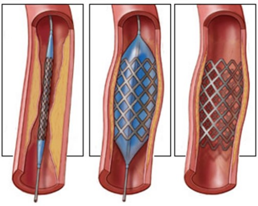
Let's explore!

The piece of Nitinol wire in this kit was heat treated or set to be straight in its original (austenite) phase. During this demo, the atoms in the wire will undergo a phase transformation between the low temperature martensite and the high temperature austenite.

Take the wire and wrap it around your finger to form a spring shape*. It will remain in that shape until it is heated to its transformation temperature. Obtain a cup of hot, nearly boiling water (please be careful!). Hold on to one end of the wire and dip the other end into the hot water (you can use pliers if you want). What happened?

If the water was hot enough, you could feel and see the wire trying to straighten itself. That's because once the wire is heated above its transformation temperature, it will return to the austenite phase and its original shape set. Try coiling the wire into a tight spring and tossing it into the water. If done correctly, the nitinol wire will "jump" out of the beaker!

*Do not make sharp corners in the nitinol wire or tie it into knots. The wire is limited on how much deformation it can recover from.



Important for the medical world, Nitinol stents can be inserted into a blocked artery where the temperature of the body is warm enough to trigger a reversion to its original expanded shape, opening the artery enough for proper blood flow.

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Does heating an aluminum nail make it harder?

Different types of metal have distinct properties that make them useful for certain types of projects. Aluminum, for example, is a popular material, especially in construction. It is very easy to bend, form, and cut, which makes it a great material to work with.

Many metals need to be hardened or softened, depending on what type of project they are used for. The way a metal is *processed* affects its strength. The nails in this package are an excellent example. Both came from the same package when purchased. They are made from aluminum alloy 6061, and as purchased have a deformation strength of about 40,000 psi.

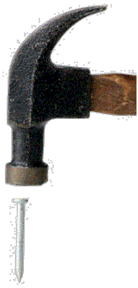
For demonstration purposes, a batch of these nails was subjected to a heat treatment designed to *weaken* the metal. The resulting strength is only 8,000 psi - one-fifth of the non-treated nails!

But what if we want to make the nail stronger? We add heat! How can that be? It is all about the processing! "Annealing" is a heat treatment process in which the material is heated to 780°F for 2-3 hours, followed by a *slow, controlled cooling* to *soften* the alloy.

"Quenching", on the other hand, is a heat treatment similar to annealing, but the aluminum nail is *rapidly cooled* to *strengthen* it. Then the nails go through an aging heat treatment process between 350-500°F, and stay in the oven for 12-24 hours. This process can make the nails five times stronger!

Experiment

To observe some differences between the two nails, drop each one from waist height onto a concrete floor and listen to the sound. The weak nail impacts with a “thunk”, while the hardened one emits a sharp “ping” and bounces upon impact. Then do one of the following:



(1) Try to bend the nails with your bare hands — one is easy and one is difficult.

(2) Try driving each nail into a block of wood. The difference should be obvious.

So why use aluminum? For one, its highly recyclable. This means that it’s not nearly as bad for the environment compared to some other materials. It’s actually one of the most sustainable metals out there.

It’s lightweight and strong. Pound for pound, it’s actually stronger than steel. It’s around 1/3rd the weight of steel, but it can carry 2/3rds of the same load that structural steel carries.

Steel nails are cheaper and stronger, but should never be used for the installation of aluminum siding. When the aluminum siding is in contact with the iron in the nail, it forms a “battery” in which the iron rapidly corrodes. When the heads disappear from the nails, the aluminum siding falls from the house. To properly install aluminum siding, aluminum nails should be used.

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Demonstration originally developed by Missouri S&T, Materials Science & Engineering, http://mse.mst.edu

https://makeitfrommetal.com/practical-and-common-uses-of-aluminum/

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What is Fiber Optics?

Fiber optics is the science of transmitting data, voice, and images by the passage of light through thin, transparent fibers.

Fiber optics (optical fibers) are long, thin strands of very pure glass about the diameter of a human hair. They are arranged in bundles called optical cables that carry information between two places using entirely optical (light-based) technology.

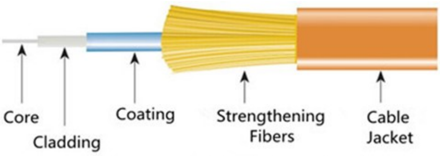
So how do these tiny strands of glass transmit light?

If you look closely at a single optical fiber, you will see that it has the following parts:

Core - the thin glass center of the fiber where the light travels.

Cladding - the outer optical material surrounding the core that reflects the light back into the core.

Buffer coating - Plastic coating that protects the fiber from damage and moisture.

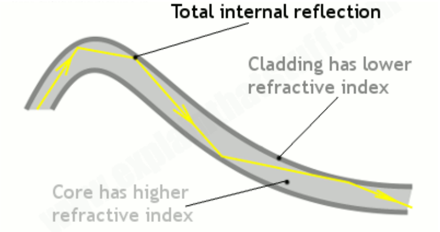


Fiber Optic Cable Construction

Each tiny photon (particle of light) travels down a fiber optic cable by bouncing repeatedly off the walls of the core.

Experiment

The LED keychain provides you with a high intensity light (photon) source to send a signal down the fiber optic cable. The cable in this kit is actually a plastic cable made from polymethyl-methacrylate (PMMA), more commonly known as Plexiglas or Lucite. This particular cable is commonly used for architectural lighting and for this experiment will make it much easier for you to see the light transmitted. Place the LED lens tightly against the end of the cable where the fibers are flush with the black protective coating. Turn on your LED light source and observe the other end of the cable where the fiber strands are exposed. You will notice that the light is transmitted out the ends of the fibers, but if you look from the side you will observe little or no light. You might expect a beam of light, traveling in a clear glass pipe, simply to leak out of the edges. But if light hits glass at a really shallow angle, it reflects back in again—as though the glass were really a mirror.



This phenomenon is called total internal reflection. It's one of the things that keeps light inside the pipe. And because the cladding does not absorb any light from the core, the light wave can travel great distances.

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Demonstration originally developed by Missouri S&T, Materials Science & Engineering, http://mse.mst.edu

Sources: https://www.explainthatstuff.com/fiberoptics.html
https://electronics.howstuffworks.com/led.htm

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What is Fluorescence?

Fluorescence is a phenomenon in which certain materials are able to give off visible light after absorbing nearly invisible light of a certain wavelength, such as ultraviolet light.

Fluorescent glass is unique in that it can appear ordinary under visible light and then can emit vivid colors when excited by certain wavelengths. The fluorescence in glass occurs with the presence of rare earth elements (lanthanides), which absorb invisible UV photons and then emit visible photons in the range of 400-700nm so that we see color.

When the rare earth ions are excited, an electron absorbs the short wavelength energy and is raised to an excited state. In a hundred thousandth of a second, the electron returns to the ground state by the emission of a photon of a longer wavelength. In other words, fluorescent behavior is the absorption of short wavelength light and the subsequent emission of a longer wavelength light.

Some of the rare earth color emissions:

Eu	Europium	red/dark pink
Sm	Samarium	orange
Tb	Terbium	green
Ce	Cerium	cyan
Dy	Dysprosium	yellow
Tm	Thulium	blue

Europium, for example, is used to produce blue, red, and white radiances in computer monitors and television screens. It is also used in energy efficient light bulbs.

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With this card you will find a piece of glass that is transparent and nearly colorless. You will also find a small UV light to use to view the glass piece. Make sure to follow safety precautions when using the UV light.

After looking at the glass in normal light, darken the room and examine the piece of glass under the black light. What do you see now? You will notice a visible show of various colors from the “clear” glass due to the rare earths contained in the glass!

Fluorescence in glass has many applications including medical imaging and biomedical research, such as the use of fluorescence spectroscopy as a diagnostic and research tool in many fields of medical sciences.

Fluorescence is found in many materials that you may have at home, such as laundry detergents, fluorescent lighting, petroleum jelly, turmeric (a spice), olive oil, tonic water, and ketchup. Teeth naturally fluoresce, but human-made dental crowns usually don’t.

Rare earth elements have been used for a long time in established industries such as catalysts, glassmaking, lighting, and metallurgy, which combined account for 59% of the total worldwide consumption. They are also being used in newer, high-growth areas such as battery alloys, ceramics, and permanent magnets, which account for the other 41%.

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Glass pieces and other information provided by Mo-Sci Corporation, https://mo-sci.com/blog/