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LIGHT TOUCH

Edible Optics

Five years have passed since **Stephen R. Wilk** wrote about edible lasers for OPN. This month he takes a look at edible optics—lenses, prisms, films and even optical fibers made of sugar and salt.

Not too long ago I found myself thinking about the candy glass used in moviemaking. It's a brittle sheet of transparent sugar used in place of real glass, usually for stunts. When broken, candy glass is less likely to cause injuries than regular glass—and it's edible. It got me wondering about other edible materials that could be used to make visible optical elements.

For the purposes of this exercise, I will limit my discussion to solid, dry, room-temperature materials that can be used to construct an optical device in the visible spectrum. This excludes water and water solutions (including ice), alcohol, and materials made with copious amounts of water, like gelatin. That leaves me with sugar and salt—both can be safely consumed, but may not be particularly pleasing to the palate or gentle on the digestive system.

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Sugars

Sugar can be made into transparent sheets and lenses—like candy glass. For optical applications, candy glass needs to be solid and transparent. It's made by combining sugar, cream of tartar (to prevent crystallization) and corn syrup. When mixed properly, this recipe yields a brittle, clear sheet. If you goof up the ingredient ratios or cooking temperature, you can end up with a flexible slab or glass with an unwanted yellow tint. Candy glass also tends to be deliquescent—it absorbs water from the air, causing it to lose its shape if not used quickly. One way

Refractive Indices of Edible Optical Materials

Index	Material
1.0	Air*
1.47	Borosilicate glass*
1.49	Potassium chloride
1.54	Sodium chloride
1.57	Sucrose
1.59	Sodium potassium tartrate
1.63	Isomaltitol

*Included for reference

EDIBLE OPTICS

Rock Candy

Most people are familiar with rock candy, which is polycrystalline sucrose with individual crystals measuring a few millimeters on a side. However, larger crystals of 10 – 20 mm can be seen in some samples. In the August 1951 issue of The International Sugar Journal, I uncovered a report of a seven-pound crystal, which took 14 years to grow from solution. Unfortunately, only the center inch or so was optically clear.

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Japanese Water Cake

It looks like a gigantic drop of crystal-clear water, but it's actually a soft cake called mizu (water) shingen mochi. Served only at two Kinseiken bakeries in Japan's Yamanashi Prefecture, the trendy dessert is made with water from the Japanese Alps, agar and sugar, and is served with kinako powder and brown sugar syrup. You need to eat it quickly because it starts to melt within 30 minutes.

@berry_summer

Table Salt

A halite (sodium chloride) specimen of clear, stacked echelon and offset cubes.

Rob Lavinsky, iRocks.com

to avoid these problems is to use single-crystal sugar, known commercially as "coarse white sugar" or "decorating sugar." The crystals typically measure no more than 1 – 2 mm on a side, although larger crystals are possible. The refractive index of single-crystal sugar, i.e., sucrose, is 1.57.

A faster way to produce candy glass with great clarity and large crystal size is to replace sucrose with isomaltitol, commonly called IsoMalt. IsoMalt is a polyol, or sugar alcohol, with the chemical formula $C_{12}H_{24}O_{11}$, and the daunting International Union of Pure and Applied Chemistry name of (2R,3R,4R,5R)-6-[[(2S,3R,4S,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)-2-tetrahydropyranyl]oxy]hexane-1,2,3,4,5-pentol. First produced in the early 1980s by the German company BENEO-Palatinit, it is a component of the sweetener "DiabetiSweet." IsoMalt is currently used to produce decorations for high-end cakes, like lens forms for edible cameras. While edible, it can have a laxative effect if consumed in large quantities.

IsoMalt is also very easy to work with; it can be melted in a microwave, cast into silicone molds, and hardens in just 15 minutes. Using this procedure, you could make plano-convex or plano-concave lenses, or more complex forms from two-piece silicone molds. IsoMalt is very hard and resistant to moisture. In solid form, it has a refractive index around 1.63.

Salts

Sodium chloride, also known as table salt, has long been used to construct optical elements. Starting in the mid-19th century, it was one of the few materials available for making high-quality infrared lenses. Spectroscopes used prisms of rock salt (the mineral form of sodium chloride) to cover broader wavelength ranges than glass prisms would allow. Salt windows are still widely used today. But salt, like sugar, absorbs moisture from the air, which causes it to melt. Therefore, rock salt prisms are stored in desiccator jars or attached to electric heaters to drive off moisture. I remember working with a large rock salt window years ago with a refractive index of 1.54. Potassium chloride, a common salt substitute, can also be used as an optical material in this way. Its refractive index is 1.49.

Sodium potassium tartrate, or Rochelle salt, is easily grown into large crystals that can be used to manipulate light. Its piezoelectric properties led to its use in gramophones, microphones and earpieces during the mid-20th century. Rochelle

One could make a magnifying glass out of any of these sugars and salts, or a telescope or microscope from a combination of lenses—perhaps a sweet-and-salty achromatic lens?

salt has a refractive index of 1.59 and is now primarily used as a food additive and laxative.

One could make a magnifying glass out of any of these sugars and salts, or a telescope or microscope from a combination of lenses—perhaps a sweet-and-salty achromatic lens?

Optical fibers

Optical fibers are another type of optical device that can be fabricated from edible materials. Sugar can be spun into long fibers, like cotton candy or candy floss. U.S. Patent 6,416,800, granted on 9 July 2002 to Paul J. Weber and Brian D. Andresen, is for an edible fiber optic display illuminated at one end by a conventional light source. In the patent text, Weber and Andresen explain that the sugar fibers don't have to conclude the optical chain; they could be used to convey the light to other edible structures, including candies, frozen confections and gelatin.

The use of sugar fibers as an analog to glass fibers actually played a role in developing glass fiber-drawing technology. According to science writer and OSA Senior Member Jeff Hecht, working out the mathematics to model the simultaneous drawing of a glass core and cladding from a double crucible was so taxing that in 1968, researcher Richard Dyott of the British Post Office Research Station in Dollis Hill, London, (a major center for fiber optic research in the 1960s) tested the process using sugar instead of glass.

Molten sugar formed a thick liquid from which thin fibers could be drawn, just like glass, but it melted at 107°C—much lower than the melting point of glass, and less corrosive, too. Using sugar also allowed Dyott to experiment with brass crucibles instead of expensive platinum crucibles. Later, George Newns continued the work, substituting a molasses "core" and a clear sugar "cladding" for the differently-dyed sugar Dyott had used in his experiments. The resulting fiber was useless as a means of conveying light, but served as an analogue for modeling the processes.

I'd like to close with a warning: Even though you can eat these potential optics materials, it's not necessarily a good idea to do so! OPN

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To Learn More ...

- J.Hecht. *City of Light: The Story of Fiber Optics*, Oxford University Press (1999).
- C. Graber. "Make Edible Fiber Optics," Sci. Am. Explor. (Spring 2001).
- S.R. Wilk. "Edible Lasers: What's the Next Course?" Opt. Photon. News **20**(5), 14–15 (2009).

Creating Candy Glass

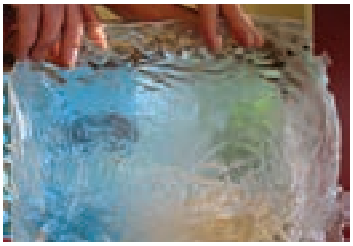
1. Mix ingredients in a saucepan.
- ½ cup water
- 2 cups white sugar
- ¼ teaspoon cream of tartar
- ½ cup glucose

2. Boil your sugar solution until the mixture is thick and it reaches 150°C, around 30 minutes.

Tip: Keep an eye on the stove. If you let the mixture get too hot, it will start to go brown. And if it hits 175°C, the sugar will burn and go black and gooey.

3. Pour the mixture into a baking tray mould and allow it to cool, around 20 minutes.

Tip: Use the mixture as soon as possible. The longer you leave your sugar glass in the tray, the stickier and gooier it will become.



4. Sugar glass, ready to go.

Tip: Be extra careful, as the mixture retains its heat for a long time and can still burn.

Recipe adapted from CSIRO Publishing

- Go to **www.osa-opn.org/edible_optics** for more edible optics recipes.