

Sapphire



General

Category

Mineral Variety

Chemical formula

aluminum oxide, Al_2O_3

Identification

Color

Every color except red (which is ruby)

Crystal habit

massive and granular

Crystal system

Trigonal

Cleavage

None

Fracture

Conchoidal, splintery

Mohs Scale hardness

9.0

Luster

Vitreous

Refractive index

1.762-1.778

Pleochroism

Strong

Streak

White

Specific gravity

3.95-4.03

Fusibility

infusible

Solubility

insoluble

Other Characteristics

Coefficient of thermal expansion $5e-6-6.6e-6/K$

Sapphire refers to gem varieties of the mineral corundum, an aluminum oxide (Al_2O_3), when it is a color other than red. Sapphire can be found naturally or manufactured in large crystal boules. Sapphire is used in many applications because of its remarkable hardness including infrared optical components, watch faces, high-durability windows, and wafers for the deposition of semiconductors such as GaN nanorods.

The mineral corundum consists of pure aluminum oxide. Trace amounts of other elements such as iron, titanium and chromium give corundum their blue, yellow, pink, purple, orange or greenish color. Sapphire includes any gemstone quality varieties of the mineral corundum except the fully saturated red variety, which is instead known as ruby, and the pinkish-orange variety known as padparadscha.

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1. Natural sapphire

Sapphires and rubies are formed at great depth in the earth mantle or the lowest part of the crust^[1]. Although blue is considered the *normal* color for sapphires, they can be found across a full range of spectral colors as well as brown, colorless, grey and black. Those other than blue in color are considered *fancy color* sapphires. Some natural sapphires can be found as completely transparent, or "white." White sapphires usually come out of the ground as light grey or brown and are then heated to make them clear. However, in very rare circumstances they will be found in a clear state.

Blue sapphire



The 422.99-carat Logan sapphire, National Museum of Natural History, Washington D.C. It is one of the largest faceted gem-quality blue sapphires in the world.

Various shades of blue [dark and light] result from titanium and iron substitutions in the aluminum oxide crystal lattice. Some stones are not well saturated and show tones of grey. It is common practice to bake natural sapphires to improve or enhance color. This is usually done by heating the sapphires to temperatures of up to 1800 °C for several hours, or by heating in a nitrogen deficient atmosphere oven for seven days or more. On magnification, the *silk* due to included rutile needles are often visible. If the needles are unbroken, then the stone was not heated; if the *silk* is not visible then the stone was heated adequately. If the *silk* is partially broken, then a process known as low tube heat may have been used. Low tube heat is the process whereby the rough stone is heated to 1300 °C over charcoal for 20 to 30 minutes. This removes grey or brown in the stone and improves color saturation.

Fancy color sapphire

Purple sapphires are lower in price than blue ones. These stones contain the trace element vanadium and come in a variety of shades. Yellow and green sapphires have traces of iron that gives them their color. Pink sapphires have a trace of the element chromium and the deeper the color pink the higher their monetary value as long as the color is going toward the red of rubies. Sapphires also occur in shades of orange and brown, and colorless sapphires are sometimes used as diamond substitutes in jewelry. Salmon-color padparadscha sapphires often fetch higher prices than many of even the finest blue sapphires. The word 'padparadscha' is Sinhalese for 'lotus flower'. Recently many sapphires of this color have appeared on the market as a result of a new treatment method called "bulk diffusion".

Color change sapphire

Color shift sapphires are blue in outdoor light and purple under [incandescent] indoor light. Color changes may also be pink in daylight to greenish under fluorescent light. Some stones shift color well and others only partially, in that some stones go from blue to bluish purple. Such color-change sapphires are widely sold as "lab" or "synthetic" alexandrite, which is accurately called an alexandrite simulant (also called alexandrium) since the latter is actually a type of chrysoberyl---an entirely different substance whose pleochroism is different and much more pronounced than color-change corundum (sapphire).

Star sapphire



The 182 carat (36.4 g) Star of Bombay, housed in the National Museum of Natural History, Washington D.C., is a good example of a blue star sapphire.

A **star sapphire** is a type of sapphire that exhibits a star-like phenomenon known as asterism. Star sapphires contain intersecting needle-like inclusions (often the mineral rutile, a mineral composed primarily of titanium dioxide) that cause the appearance of a six-rayed 'star'-shaped pattern when viewed with a single overhead light source.

The value of a star sapphire depends not only on the carat weight of the stone but also the body color, visibility and intensity of the asterism.

Treatments

Some sapphires are heat-treated or otherwise enhanced to improve their appearance and color, though some people object to such practices and prefer natural untreated stones. Heat treatments tend to improve the sapphire's color and clarity, and it is unusual to find un-heated stones for sale. Diffusion treatments are somewhat more controversial as they are used to add elements to the sapphire for the purpose of improving colors.

Mining

Sapphires are mined from alluvial deposits or from primary underground workings. The finest specimens are mined in Sri Lanka; both the Logan sapphire and the Star of Bombay originate from Sri Lankan mines. Sapphires are also mined in Australia, Madagascar, Thailand and Myanmar. Madagascar leads the world in sapphire production (as of 2007) specifically in and around the city of Ilakala. Prior to Ilakala, Australia was the largest producer of sapphires (as of 1987). Ilakala is prone to violence, but sapphires are found everywhere including on the ground and in the river mud. Pakistan, Afghanistan, India, Tanzania and Kenya also produce sapphires. The US state of Montana has produced sapphires from both the El Dorado Bar and Spokane Bar deposit near Helena. Well-known for their intense, pure blue color, yogo sapphires are found in Yogo Gulch, near Utica, Montana. Gem grade sapphires and rubies are also found in and around Franklin, North Carolina, USA. Several mines are open to the public.

2. Synthetic sapphire



A synthetic star sapphire in a silver ring.

Synthetic **sapphire** crystals can be grown in cylindrical crystal boules of large size, up to many inches in diameter. As well as gemstone applications there are many other uses:

The first ever laser produced was based on the *ruby*, the red variety of corundum. While this laser has few applications, the Ti-sapphire laser is popular due to the relatively rare ability to tune the laser wavelength in the red-to-near infrared region of the electromagnetic spectrum. It can also be easily modelocked. In these lasers, a synthetically produced sapphire crystal with chromium or titanium impurities is irradiated with intense light from a special lamp, or another laser, to create stimulated emission.

Pure sapphire boules can be sliced into wafers and polished to form transparent crystal slices. Such slices are used as watch faces in high quality watches, as the material's exceptional hardness makes the face resistant to scratching. Since sapphire ranks a 9 on the Mohs Scale, owners of such watches should still be careful to avoid exposure to diamond jewelry, and should avoid striking their watches against artificial stone and simulated stone surfaces. Such surfaces often contain materials including silicon carbide, which, like diamond, are harder than sapphire and thus capable of causing scratches (Scheel 2003).

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Sapphire is highly transparent at wavelengths of light between 170 nm to 5.3 μm , as well as being five times stronger than glass. This leads to use of synthetic sapphire windows in high pressure chambers for spectroscopy.

Wafers of single crystal sapphire are also used in the semiconductor industry as a substrate for the growth of gallium nitride based devices.



Cermax xenon arc lamp with synthetic sapphire output window

One type of xenon arc lamp known as Cermax (original brand name - generically known as a ceramic body xenon lamp) use sapphire output windows that are doped with various other elements to tune their emission. In some cases, the UV emitted from the lamp during operation causes a blue glow from the window after the lamp is turned off. It is approximately the same color as Cherenkov radiation but is caused by simple phosphorescence.

3. Historical and cultural references

- According to Rebbenu Bachya, and many English Bible translations, the word *Sapir* in the verse Exodus 28:18 means *Sapphire* and was the stone on the Ephod representing the tribe of Issachar. However, this is extremely disputed as though it is true that the English word *sapphire* derives from the Hebrew *sapir* (via Greek *sapphiros*), Sapphires were actually not really known about before the Roman Empire (and were initially considered to be forms of jacinth, rather than deserving of a word to themselves), and prior to that time *sapphiros* referred to blue gems in general. It is thought by scholars that the *sapphire* of the Bible was actually lapis lazuli - which was frequently sent as a gift between middle-eastern nations in Biblical times (Texas Natural Science Center, 2006). There is a wide range of views among traditional sources about which tribe the stone refers to.
- Blue sapphire is associated with Saturn (Wojtilla, 1973), yellow sapphire with Jupiter in Vedic astrology. It is understood that word Sapphire seems to be a corrupted form of *Sanipriya* (Sanskrit:- *Sani* = Saturn, *Priya* = Beloved). Buddhist monks who moved to Middle East introduced the Stone as *Sani piriya* and eventually become *sapir* and *sapphire*.
- Sapphire is the birthstone associated with September.
- The 45th wedding anniversary is known as the sapphire anniversary.
- Sapphires are one of the four most valued stones. The other highly valued stones are rubies (sapphires that are red, caused by chromium impurities), emeralds, and diamonds.
- Sapphire City is the capital of the Munchkin Country in *The Giant Horse of Oz*.

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