Electron beam enhancement of colorless Topaz

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Topaz is found on most continents of the earth. The color varieties are; transparent colorless, red, pink, orange, brown, yellow, blue and green, with the cherry-red imperial and pink topaz from Brazil being the most valuable. The blue topaz colored by radiation from natural radioactive materials in the ground during millions of years is also found. Its natural blue color, in deposits found so far, is a pale light blue that is not given much attention. The most common topaz is the colorless topaz, which is found in abundance and for that reason is worth very little.

During the last two decades the technique of using radiation for coloring these colorless topaz into a more desirable and permanent blue color, has been refined and today the electron beam enhancement is used for mass production of large quantities of blue topaz. This technique has made the blue topaz the most common of the topaz used in jewelries.

Colors of radiation treated Topaz

The most common colors of topaz resulting from radiation treatments are:

Sky Blue topaz (moderately strong light blue) is the result of treatment of colorless topaz with either gamma rays from Cobalt 60 sources or electrons produced by electron accelerators, followed by a heat treatment.

Topaz treated by high energy electrons from a linear accelerator results in the **Sky Blue** color

London Blue topaz (slightly grayish medium dark to dark blue) is the result of treatment of colorless topaz with neutrons produced in nuclear reactors, followed by heat treatment.

Topaz treated by neutrons from nuclear reactors result in the **London Blue** color

Swiss Blue topaz (strong to vivid medium to medium dark blue) is achieved by the use of a combination of neutron treatment followed by treatment with either gamma, or electron treatment and heating.

Topaz treated by a two-step process, both with neutrons and electrons, result in the **Swiss Blue** color

Coloring factors in Topaz

Most colors of topaz are caused by color centers in the stones, except for the pink-to-violet and the pink component of some orange, which are caused by chromium impurity (K. Nassau, 1984).
Almost all colorless topaz turns brown on irradiation, already at a very low dose (5 to 10 Mrad), and other color varieties of topaz are affected by the brown component added. This became apparent when the US-Mail in 2001, started to irradiate mail in electron accelerators as a method to kill Anthrax spores, which

could be distributed in mail by terrorists. Concerned jewelers and their customers realized that some gemstones could change color with this treatment and wanted information whether alternative carriers, who did not use irradiation, should be used.

The very low dose brown color intensifies with increased irradiation doses and is followed by a greenish-brown color at medium doses (500 - 1,000 Mrad), a brownish-blue color at higher doses (1,000 - 5,000 Mrad) and eventually to a blue color at very high doses (5,000 - 20,000 Mrad). The brown color derives from two different types of color centers. One is of fading nature and the other of a more stabile nature (K. Nassau, 1984). Most frequently appearing brown color centers is of the fading types, and exposure to light or heating at around 200°C result in fading of the color.

Type of irradiation methods

Topaz is as mentioned earlier most frequently treated by irradiation from Reactors, Cobalt 60 irradiators and Electron Accelerators.

Electron irradiation from high-energy electron accelerators is today the most widely used process for coloration of Sky blue and Swiss blue topaz.

The advantage over gamma irradiation is mainly the high dose rate, which allows the treatment to be carried out in a very short time.

Neutron irradiation make the topaz radioactive and in need of a cool-off time (from a few months to years) before they can be released for further processing such as electron treatment, annealing, cutting or polishing.

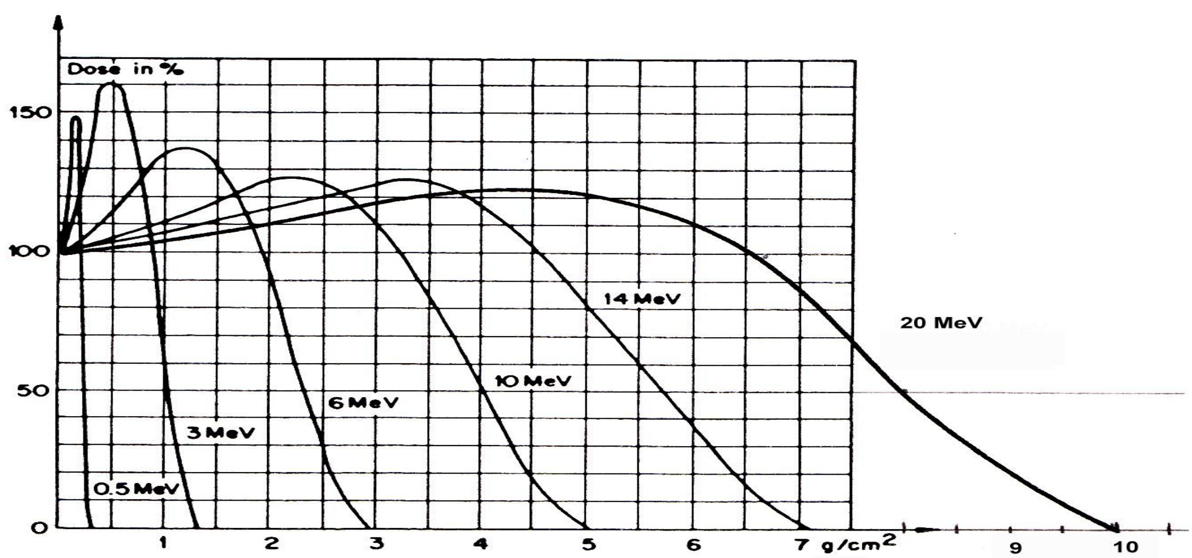
Accelerators used for irradiation treatment of Topaz

Electron Accelerators mostly used for color enhancement of topaz are of the types, which produce a high energy 10 – 20 Million Volts (MeV), and has a high power 10 – 60 kilo Watt (kW)

The accelerators power (kW) is important for the processing rate/time of the stones exposure to the electron beam. A 10 kW accelerator has the capacity to produce 15,000 ct to 45,000 ct per day and a 60 kW accelerator 100,000 ct to 300,000 ct per day.

The energy (MeV) is important for the penetration of the electrons through the stones, a higher energy will produce a higher penetration. If the electrons don't penetrate the stone, they will stop/get trapped in the stone and, due to the low electrical conductivity of topaz, the electrical charge in the stone will increase. If this charge becomes high enough, an electrical discharge in form of a lightning in the stone occurs, and an internal lightning/inclusion that looks like thin lines or, in case of a larger discharge, a small white cotton ball.

To prevent this damage the choice of energy, MeV, need to match the density of the amount of topaz that is exposed to the electron beam. The electrons need to pass through and out of the stone after they have induced their coloring effect. Suitable for small and medium stones is 10 MeV, and for larger stones energies up to 20 MeV is necessary. With higher energy levels (well above 10 MeV) some radioactivity can be induced in the topaz, with the level of radioactivity depending on quantity and nature of impurities present in the topaz (K. Nassau, 1984). A cooling off period from a few days to a few weeks is necessary until the radioactivity decays to acceptable/regulated level.



Dose distribution in materials as a function of beam energy (MeV). (E. Svendsen, 2003)

Process cooling

Because of the high power (the higher the kW - the higher the temperature) deposited in the stones during the electron beam processing, it is important to cool the stones. In most cases water is used for the cooling and the stones is either placed in running water or water is sprayed over the stones during the processing. Typical signs of insufficient cooling are thermal cracks surrounded by numerous lightning or small disc-like inclusions visible when the stone is tilted slightly. If the cooling fails the stones will rapidly be so hot that they will shatter and loose all color, with a high economic loss as a result. The cooling system's water-flow must therefore be tightly controlled and interlocked so that the accelerator immediately stops the radiation if the cooling system fails.

Post irradiation annealing

After the electron beam treatment, changes in the topaz brown and blue color centers have occurred. The brown color is fading already at temperatures around 200°C, while the blue color is stabile to temperatures up to 600°C. Heat treatment of the topaz for several hours at around 200° C is therefore performed in order to achieve strong blue colors.

Radioactivity in topaz

In most cases electron accelerators at 10 MeV is used for treatment of topaz and these facilities cannot produce radioactivity in topaz.

Topaz treated with 20 MeV electrons can be activated for days or a few weeks.

Topaz treated with neutrons in a nuclear reactor turn radioactive for a longer time (the longer the exposure – the higher the activation), usually from a few months up to years.

For this reason the health authorities have issued very strict rules for measuring of the activity in the topaz before they can be released from these facilities.

Conclusion

Colorless topaz have through this high-capacity treatments turned into a beautiful and still affordable gem, and its unique quality of transparency and lack of inclusions does not call for synthetic alternatives.

References

Nassau, K. (1984) Gemstone Enhancement. Butterworth-Heinemann Ltd, Oxford.

Personal communication. (2003) Svendsen, E., Iotron Industries, Port Coquitlam.

Photos from AGTA's leaflet, BLUE TOPAZ, Natural Beauty Enhanced by Technology