Science & Technology for the value-addition of gemstones of Sri Lanka

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Sri Lanka is one of the five major gem-producing countries in the world (others are; Brazil, South Africa, Thailand and Myanmar). According to Central Bank reports, 2% of the total export revenue of the country comes from gem exports. The gem industry is a high value added industry and the value-addition per carat (weight measuring unit, 1 carat = 200mg) of gemstone is as high as 70% - 90%.

Gems are minerals and have widely varied chemistry. According to mineralogical and physico-chemical properties gemstones are classified into gem varieties. From about two hundred gem varieties that found in world, about seventy are found in Sri Lanka. Following are the major varieties out of them;

- Sapphires (Al_2O_3)
- Spinels ($MgAl_2O_4$)
- Topaz ($Al_2SiO_4(F,OH)_2$)
- Chrysoberyls ($BeAl_2O_4$)
- Beryls ($Be_3Al_2(SiO_3)_8$)
- Tourmalines (a complex borosilicate)
- Garnets ($Ca_3Al_2(SiO_4)_3$)
- Zircons ($ZrSiO_4$)
- Quartz (SiO_2)
- Moonstones (KAl_3SiO_8)

Gems are mined as rough stones. Before entering the market they are subjected to cutting and polishing, at the lapidaries. This is the basic value-addition step of gemstones and it is actually a physical process.

The value of a gemstone depends on four factors, which are known as 4 Cs. They are;

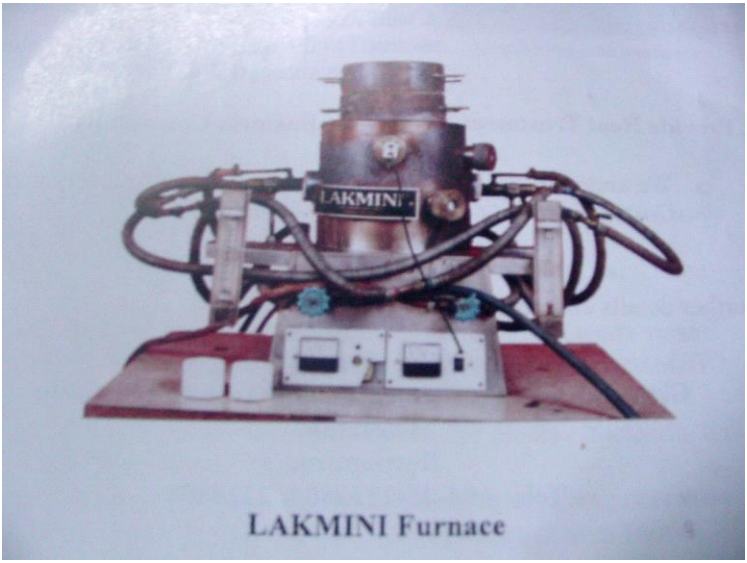
- Colour
- Clarity
- Cut
- Carat weight

Upgrading these properties could add value to gemstones. A cut and polished gemstone has a definite carat weight and cut, but its clarity and colour could be further upgraded by subjecting it to treatment techniques, which are basically physico-chemical reactions. Commonly used treatment techniques are (Nassau, 2001);

- Heat treatment
- Colour diffusion (surface diffusion)
- Bulk diffusion (lattice diffusion, e.g. beryllium treatment)
- Irradiation
- Impregnation
- Laser treatment
- Surface treatments (e.g. plating and chemical vapour deposition)

All of these techniques are secondary value-addition steps. To carryout them successfully, a wide knowledge of science & technology is essential.

The heat treatment of gemstones is well established and popular in Sri Lanka. A few government establishments (*e.g.* Gem and Jewellery Research and Training.) and many private institutions practice this technique. It is a process where gemstones are heated by a furnace (Plate 1), up to high temperatures but not exceeding the melting points of gemstones (Nassau, 1984).



Popular heat treatment furnace (Courtesy of Lanka Refractories Ltd.)

The body colour of a gemstone is a result of;

- transition metal ions and their oxidation numbers,
- colour centres and
- charge transfer transitions

During heat treatment, high temperature chemical reactions (*e.g.* oxidations and reductions of transition metal ions in gemstones) take place. This will finally results in a change in colour. Many gem varieties (*e.g.* sapphires, zircon, topaz, quartz *etc.*) could have added value by heat treatment, but their colour changing temperatures are different from one variety to another.

Heat treatment of "geuda" to yield blue sapphires is popular in Sri Lanka. Geuda is low value sapphire, which is milky or gray in colour. It can be turned into high value blue sapphire by heat treatment. According to market blue sapphires are about 2-3 times more valued than the geuda.

In geuda stones TiO_2(s) (rutile), Fe^{2+} and Fe^{3+} ions present. When geuda stones are heated under reducing conditions (using CO (g) as the reducing agent) at around 1800^0C (melting point of sapphire is 2050^0C) the following chemical reactions take place (The Sri Lankan Geuda, 1993);

$TiO_2(s)$ dissolves and diffuses into the structure of geuda

$TiO_2(s) \longrightarrow Ti^{4+} + 2\ O^{2-}$ reaction 1

$2\ O^{2-} \longrightarrow O_2 + 4e$ reaction 2

reaction 1+2, $TiO_2(s) \longrightarrow Ti^{4+} + O_2 + 4e$

$Fe^{3+} + e \longrightarrow Fe^{2+}$

$Fe^{2+} + Ti^{4+} \longrightarrow (Fe, Ti)^{6+}$

$(Fe, Ti)^{6+}$ ion (Ferro titanium complex ion) gives the blue colour of blue sapphire resulted by the heat treatment of geuda.

Research on colour diffusion of topaz was successfully carried out in Sri Lanka. In this method a paste of diffusion material including transition metals pasted on the surface of the colourless topaz stones, and then left to dry. Then these stones are subjected to heat treatment at temperature around 900 ^{0}C. Transition metals present in the paste will diffuse into the stone and induce a colour layer on the surface of the stone. By this technique different coloured topaz could be obtained from colourless topaz stones.

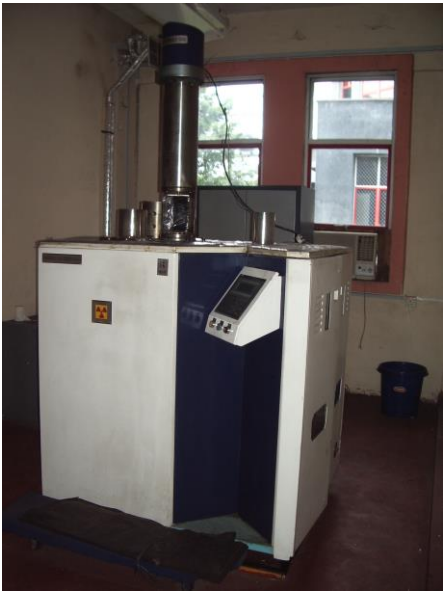
Research on gamma irradiation of water-clear quartz was carried out at Atomic Energy Authority of Sri Lanka by the author. In this method quartz is subjected to small dosages of gamma rays produced by a Co^{60} gamma irradiator. Colourless quartz was turned into smoky colour quartz, which is more valuable than water-clear quartz. When considering the chemistry of this process, quartz is SiO_2 and during its formation on earth, Al^{3+} replaces a minor quantity of Si^{4+} of the SiO_2 lattice.

$(SiO_4)^{4-}$ Si^{4+} replaced by Al^{3+} $(AlO_4)^{5-}$

Electronic arrangement around $(AlO_4)^{5-}$ is not stable when compared to $(SiO_4)^{4-}$ and an electron could be easily displaced by supplying necessary energy. By gamma irradiation this required energy could be supplied easily.

$(AlO_4)^{5-}$ an electron displaces $(AlO_4)^{4-}$

This makes an electron deficient or a hole on the $(AlO_4)^{4-}$ ion. Since this hole could absorb energy from the electromagnetic radiation resulting in colour to the quartz, which is known, as hole colour center. This hole colour center results in a smoky colour to the colourless quartz.



Co 60 Gamma irradiator at Atomic Energy Authority of Sri lanka

To conclude this article it could be said that the heat treatment of geuda is well established in Sri Lanka. Research on colour-diffusion of topaz and gamma irradiation of quartz is also successful and would be introduced to the market.

More research into the physico-chemical aspects of value-addition of gemstones is needed. By applying such treatments 100% - 500% value-addition on cut and polished gemstones could be achieved. Therefore such research may contribute to the country's economy through the export of more value added gemstones.

References

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