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EXAMENSARBETE

Distinguishing between Natural and Synthetic Quartz

Camilla Gunnarsson FGA

Luleå tekniska universitet

Högskoleingenjörsprogrammet
Ädelstensteknik
Institutionen för Tillämpad kemi och geovetenskap
Avdelningen för Malmgeologi

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PREFACE

This paper was written as a thesis in spring 2008 for the program Gemstone engineering and design at Luleå University of Technology.

If nothing else is stated all pictures and figures are taken or drawn by the author. The figures are modified after figures in the study material for Foundation and Diploma in gemmology from Gem-A in London.

I want to thank Kristallen AB for letting me use their laboratory and lending me gemstones to examine, Maria Hansson FGA for lending me one natural blue quartz and one lime citrine, Torbjörn Lindwall FGA DGA for being my supervisor and for lending me one natural ametrine and one prasiolite and my examiner Lennart Widenfalk. I also want to thank Uriah Prichard at Morion Company, USA for helping me with information about the synthesis of quartz and other people that I have been in contact with.

Camilla Gunnarsson FGA
Lannavaara

ABSTRACT

To day there is a problem with synthetic quartz being sold as natural quartz on the gemstone market, so what can you look for to get clues about the origin of the quartz?

This thesis is looking at how to identify synthetic quartz and how to distinguish it from natural quartz. To find out, tests were done on natural and synthetic quartz with the help of gemmological instruments, also other ways to identify synthetic quartz with laboratory instruments was looked at. The conclusion was that there is not one test that, on its own, gave enough information to positively identify the origin of the quartz. Several tests where needed to be able to positively identify the quartz as synthetic.

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1. INTRODUCTION

There have been several reports on synthetic quartz on the market and several articles that write about the problem of parcels with natural amethyst being salted with synthetic amethyst. Parcels have probably been salted since before 1985 when Roger Dery of Spectral Gems in Birmingham, Michigan discovered a salted parcel (Drucker, 1998). Many jewellers unknowingly sell synthetic amethysts as natural amethyst. It is estimated that between 30-50% of amethyst on the market is synthetic. Synthetic quartz is being made in all colours, for example green , blue, citrine, ametrine and rock crystal so it is probably not only synthetic amethyst that is mistakenly sold as natural so caution should be taken with all quartz varieties.

One of the reasons that jewellers don't know if a quartz is synthetic is that they don't know what to look for and sending quartz to a laboratory for testing can be expensive.

So what can you look for to identify synthetic quartz? Is there an easy way to distinguish natural quartz from synthetic quartz? This is questions that are going to be answer in this thesis.

2. MATERIAL

2.1 About quartz

Quartz consists of silicon dioxide SiO_2 and is a very common mineral. It can be found as crystalline or polycrystalline material and in many colours for example purple, smoky brown, yellow and many more.

In nature quartz occurs in epithermal veins, hydrothermal metal deposits and carbonate rocks. Quartz is a characteristic mineral of granites and granite pegmatites and it is also found in sandstone and quartzite.

Quartz is usually twinned and the three most common forms of twinning are:

- Brazil law, which is a penetration twin that is a result from transformation.
- Dauphiné law, which is a penetration twin, also a result from transformation.
- Japanese law, which is a contact twin that is a result from accidents during growth.

You can also find a combination of the Brazil and Dauphiné law twins.

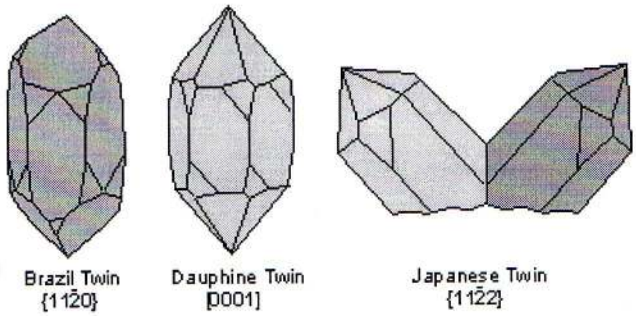

Figure 1.1a. The three different forms of twinning that are common in quartz. Figure taken from www.tulane.edu/~sanelson/eens211/twinning.htm.

Constants list for quartz

Chemical composition	SiO_2 Silicon dioxide is also known as silica.	
Crystal system	Trigonal	
Cleavage	Poor	
Fracture	Conchoidal	
Hardness	7 on Moh's scale	
Specific gravity	2.65	
Pleochroism	Weak to strong depending on variety, usually of a stronger and paler tint of the same colour.	
Lustre	Vitreous	
Refractive index	1.54 to 1.56	
Birefringence	0,009	
Optical nature	Uniaxial +ve. Often, but not always, displays a distinctive interference figure referred to as a 'bull's-eye'.	
Absorption spectrum	Amethyst	May have absorption at 550-520nm but are not diagnostic
	Citrine	Not diagnostic
	Green quartz	Not diagnostic
Fluorescence	None except for amethyst which can show a weak bluish fluorescence.	

Amethyst

The colour of amethyst varies from a deep purple to a light violet. The colour is due to iron which causes a colour centre. The colour is rarely uniform and is frequently distributed in patches or stripes. The name is thought to come from the Greek word *améthystos* which means 'not-drunken' and it may refer to a supposed power of the stone that those who wore it was protected from drunkenness. It is thought that the name amethyst was given to a wide range of gemstones with the colours purple, violet or mauve. In 1708 amethyst was established as a variety of quartz. Amethyst is found as a lining to the inside of hollow cavities.

Inclusions in amethyst can be feather-like structures formed of negative cavities, tiger stripes and cacoxenit (iron aluminium phosphate) that may occur as yellow sheaf-like crystal groups. Only a few amethysts are free from colour zoning.

Citrine

Citrine is yellow to yellow-brown in colour and coloured by iron. Most citrine is heat-treated amethyst. The name citrine comes from the French word citrine which means lemon.

The best citrine materials come from Brazil.

Rock crystal

Rock crystal is a colourless almost pure variety of quartz. The Greek named it 'crystal' or ice as they believed it to be a form of ice that where irreversibly frozen by some process of extreme cold. There are some alternative names for rock crystal that is still used, for example 'Herkimer diamond' which is given to a variety from Herkimer County, New York and 'Marmaros diamond' which comes from Hungary.

Rock crystal is sometimes included with tourmaline or golden needles of rutile which is seen as very attractive. It may also contain two-phase inclusions, blue anatase, goethite crystals, hematite, chlorite and several other types of mineral inclusions.

Ametrine

Ametrine is a colour zoned variety of quartz which consists of both amethyst and citrine. It is usually cut to show both the purple of the amethyst and the yellow of the citrine.

Green quartz

Most green quartz is formed by heat-treatment of amethyst. Most of the heat-treatment produces citrine quartz and not green quartz. Transparent green quartz is some times marketed under the name ‘prasiolite’ which is Greek and means leek-green stone. Lime citrine is a name used for a yellowish- green variety of quartz.

Blue quartz

The colour in natural blue quartz is due to abundant minute bluish rutile needles and it is always cloudy.

2.2 Choice of material

One each of:

- Faceted natural citrine
- Faceted natural rock crystal
- Faceted natural amethyst
- Faceted natural ametrine from Bolivia
- Faceted natural lemon citrine
- Rough natural blue quartz
- Rough synthetic citrine
- Rough synthetic rock crystal
- Rough synthetic amethyst
- Rough synthetic ametrine
- Rough synthetic dark green quartz
- Rough synthetic light green quartz
- Rough synthetic blue quartz

The synthetic quartzes are bought from Morion Company in Brighton, USA. Morion company does not produce the hydrothermal quartz them self but buys it from a Russian company.

3. PROCEDURE

First the synthetic quartz pieces will be examined visually before smaller pieces of them are sawn and polish. After that, the natural quartz and the smaller synthetic quartz pieces will be examined with gemmological instruments. The instruments that will be use are the loupe for the visual examination, microscope, polariscope, conoscope, refractometer, Chelsea colour filter (CCF), dicroscope, spectroscope, UV light that shows short wave and long wave and a digital scale with the necessary equipment for specific gravity measuring. One piece of each type of synthetic quartz will also be faceted to compare with the faceted natural quartz. Other ways to identify synthetic quartz with laboratory instruments such as infrared spectroscopy will also be looked at.

4. DELIMITATION AND PREPARATION

This work is limited to the transparent crystalline varieties of natural and synthetic quartz that is used in the gemstone and jewellery trade, rock crystal, amethyst, citrine, ametrine, green and blue quartz. The instruments used for testing the natural and synthetic quartz are also limited to basic gemmological instruments.

The preparations that had to be made is that after the weight was recorded and photos was taken of the synthetic quartz pieces, smaller pieces of the synthetic quartz was sawn which then where polished, to be able to make all the tests. Then after the tests where done, one piece of each type of synthetic quartz was faceted.

5. GEMSTONE SYNTHESIS

5.1 History

The first report on hydrothermal crystal growth where made by C.E. Schafhautl in 1845 and short there after in 1851 Sénarmont produced microscopic crystals.

Between 1898-1908 reports on the growth of macroscopic crystals were published by G. Spezia, an Italian experimenter, who obtained a new growth of about 15 mm over a 200 day period. In the method he used, the autoclaves hotter part was at the top unlike modern practise where the hotter part is at the bottom.

Before and during World War II the supply of natural quartz crystals was insufficient for the developing of an enhanced industrial program and the need for work on synthetic material became vital, which lead to an extensive German effort to grow quartz crystals. The research was lead by Richard Nacken. After World War II researchers worked together with the U.S Army Signal Corps to developed the German work into a commercially viable process. Brush Development and then Sawyer Research Products Inc developed the low-pressure sodium carbonate process. The high-pressure sodium hydroxide process was developed by Bell Laboratories and Western Electric. These two processes are still used today.

Synthetic quartz used for jewellery where first grown in Russia and later in Japan and China. It was commercially available for the jewellery market around 1970.

5.2 The hydrothermal process

This process is a solution growth technique and it is very similar to the process by which natural quartz crystals are formed. Hydrothermal means that water and heat are necessary for crystal growth.

The reason that quartz isn't synthesised by either melt or flux techniques, is that it would be difficult because of the high melting point of 1670˚C and high chemical resistance[1].

The hydrothermal growth is carried out in an autoclave. An autoclave is a pressure vessel made out of strong steel with extremely thick walls and it is some times called a bomb, because the pressure inside it might make it explode. To minimize the effect of a possible explosion the autoclaves is placed below ground.

Photo 1.2a. Autoclaves underground. Photo taken from Yuzhnouralsky plant "Kristall", http://plant-kristall.by.ru/page4e.htm.

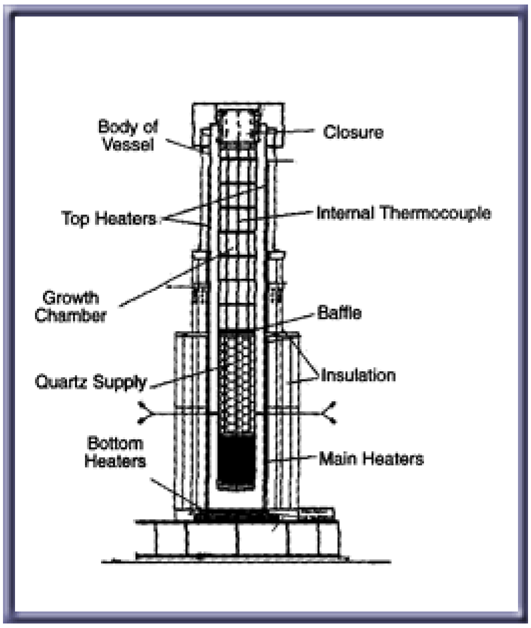

Figure 1.2a. Construction of an autoclave. Figure taken from http://www.roditi.com/SingleCrystal/Quartz/Hydrothermal_Growth.html

You place a nutrient material in the bottom half of the autoclave, usually consisting of natural clear or milky quartz called lasca, traditionally taken from Brazil. In the top half the seed crystals are hung on a platinum wire, the seed plates consist of either synthetic or natural quartz crystals. Between these two parts is a baffle, a metal plate with one or more holes cut in to it, which provide a constant and controlled opening. The baffle control the convection current so that it results in an even growth on all the seed plates.

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[1] Hydrothermal Crystal Growth – Quartz, www.roditi.com/SingleCrystal/Quartz/Hydrothermal_Growth.html

A certain percentage of the autoclave is then filled with an aqueous solution which usually contains an alkali metal hydroxide or a carbonate solution but also other solutions may be used. The lower the percentage of the autoclave that is filled, the lower pressure is obtained for a given temperature. The autoclave is usually filled to about 80-85%.

The alkali metal compound increases the solubility of the quartz as it acts as a mineraliser through the formation of soluble silicate complexes. A mineraliser is a compound that you add to a solution to increase the solubility of another compound, for example quartz. In natural growth of quartz crystals it is believed that sodium chloride is the most common mineraliser[2].

There is a temperature different between the top half, called the growing chamber, and the bottom half, called the dissolving chamber. This temperature difference together with the baffle controls the rate of fluid and heat transfer between the two chambers, the temperature also has a strong effect on the growth rate. The growth rate increases with increasing temperature. Some other factors also influence the growth rate and these are: pressure, mineraliser type and concentration, other chemical additives and seed orientation. A low concentration of lithium is for example added to the solution to increase growth rate. A high growth rate is desirable, but a too high growth rate deteriorates the quality of the grown quartz crystals and may make the product unusable. About 1mm/day is probably a practical upper growth limit for producing good quality quartz crystals.

When the autoclave is filled it is sealed and heated to between 300 and 400˚ with the use of external, resistance heaters. The pressure that is developed inside the autoclave is controlled by the temperature and the amount of solution that have been added.

The temperature difference in the autoclave establishes a natural convection pattern called a closed thermosyphon. In the warmer dissolving chamber the quartz is dissolved in the solution and the warm less dens fluid rises to the cooler growing chamber. In the cooler temperature the fluid no longer can hold all of its quartz content which leads to that excess quartz crystallizes on the seed plates. Then the cool denser fluid sinks back into the dissolving chamber and the cycle continues.

During the first quartz growth in a new autoclave, where either sodium hydroxide or sodium carbonate is used as the mineraliser, a thin adherent layer of sodium iron silicate compound is formed on the wall of the autoclave. This layer prevents the steel autoclave from contributing iron to the solution which gives almost iron free quartz. The quartz in the first conditioning run in a new autoclave is discarded.

There are two similar processes that are used in the synthetic quartz industry. The low pressure and the high pressure processes.

The high pressure process uses sodium hydroxide solution. It has a growing temperature of 380˚C with a temperature difference of 25˚C and the pressure is 1000-1500 bars. The growth rate is up to 1,0mm/day. The capital costs for the equipment are much greater for this process[2].

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[2] Hydrothermal Crystal Growth – Quartz, www.roditi.com/SingleCrystal/Quartz/Hydrothermal_Growth.html

The low pressure process uses sodium carbonate solution. It has a growing temperature of 345˚C with a temperature difference of 10˚C and the pressure is 700-1000 bars. The growth rate is 0,4mm/day. The advantage is that autoclaves which operate at this pressure are of much lower capital expense[2].

The growth rate is different for different crystallographic directions and can be up to three times faster in some directions. The orientation doesn't only affect the growth rate but it also affects the uptake of impurities.

The disadvantages of this method is that you need a special apparatus and that you need seed plates of very good quality and of fair size, it is also impossible to observe the crystal as it grows. This method is also potentially dangerous as there is a risk of explosion

5.3 Different colours of hydrothermal quartz

Coloured crystals are grown by two different technologies: in Fluoride-Ammonia solution or in strong Potassium-Alkali solution. The main colour agent is iron which occurs in different combinations of valence (Fe^{4+}, Fe^{3+} and Fe^{2+}) to give different colours.

5.3.1 Rock crystal

Rock crystal is the colourless version of quartz and it is grown without any added impurities.

5.3.2 Amethyst

The colour of amethyst is due to iron in the form of Fe^{4+}. The amethyst appears reddish-brown when it comes out of the autoclave so it needs to be annealed at up to 12 hours to get its purple colour (Prichard, Morion Company, 2008).

Iron containing quartz grown as amethysts can also be almost colourless when it comes from the autoclave and get its purple colour by subsequent irradiation with gamma rays (Nassau, 1980).

To avoid an unattractive smoky purple colouration, lithium salt may be added to the growth solution.

Amethyst crystals that are grown in strongly alkaline potassium solution may develop an abnormal pleochroism; the reddish-violet colour becomes pale violet.

5.3.3 Citrine

The iron in citrine is added by putting a steel chip into the charge solution and oxidizing conditions are maintained by adding for example alkali nitrate, alkali nitrite or potassium permanganate. As a mineraliser either potassium or ammonium salts are used.

The colour is caused by Fe^{3+} and intensity of the colour depends on the iron concentration, the growth rate and the direction of the growth.

5.3.4 Ametrine

To obtain ametrine a sectored distribution of Fe^{2+} and Fe^{3+} is necessary during the crystal growth so when the crystal is irradiated with gamma rays or electrons, Fe^{3+} (citrine) and Fe^{4+} (amethyst) are created in the different sectors.

5.3.5 Blue quartz

The coloration agent for blue quartz is Co. When the crystals are taken out of the autoclave they are yellow and turn blue after annealing (Prichard, Morion Company, 2008).

The more aluminium that is present in the solution, the more cobalt will enter the crystal which produces a deeper colour.

5.3.6 Green quartz

A green quartz containing Fe^{2+} may result if iron is present in the growth solution under no oxidizing or reducing conditions.

The colour can vary a lot and can be yellowish green, green, a very dark green or even almost a black colour.

6. TESTS AND DISCUSSION OF THE RESULTS

6.1 Visual and microscope

The visual test is done by looking at the gemstones with the unaided eye and with a loupe. You look at internal and external features, e.g. colour, transparency, lustre and inclusions. Here also a microscope will be used to examine inclusions closer.

Natural and synthetic citrine

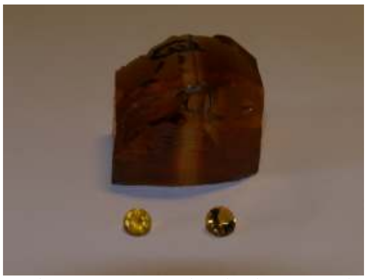

Photo 6.1a. In the back a rough synthetic citrine and in the front, to the left a faceted natural citrine and to the right a faceted synthetic citrine.

The natural citrine is more yellow than the synthetic citrine that is of a more orangey-yellow colour, but natural citrine can be of a similar colour to the synthetic citrine. You can also get synthetic citrine that is more yellow. Both the natural and synthetic citrine is transparent and has a vitreous lustre.

On the synthetic citrine you can see the platinum thread used to hold the seed crystal in the synthesise process and you can also see the colourless seed plate and the typical knobbly surface of synthetic quartz called growth hillocks (Gübelin and Koivula, 2005). This is features you will never see on a natural citrine crystal so when the synthetic citrine is uncut it could be easy to distinguish from natural quarts. The problem is when it is cut and you can't see the seed plate, platinum wires or crystal surface, then you have to look closer at inclusions. If no inclusion is present it's hard to distinguish from natural citrine.

The natural citrine is completely clean from inclusions and the synthetic citrine has colour zoning and is clean except for needle shaped inclusion in the seed plate.

Photo 6.1b. Platinum thread in synthetic citrine.

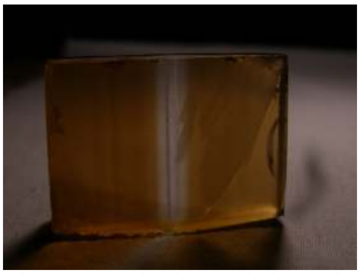

Photo 6.1c. Colourless seed plate and colour zoning in synthetic citrine.

Photo 6.1d. Growth hillocks on synthetic citrine.

Natural and synthetic rock crystal

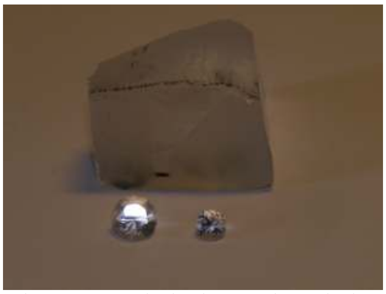

Photo 6.1e. In the back a rough synthetic rock crystal and in the front, to the left a faceted natural rock crystal and to the right a faceted synthetic rock crystal.

Both the synthetic and natural rock crystal is colourless, transparent and has vitreous lustre. Both are free from inclusions.

The synthetic rock crystal shows the typical growth hillocks of synthetic quartz so in its uncut state it is easy to distinguish from the natural rock crystal.

Photo 6.1f. Growth hillocks on synthetic rock crystal.

Photo 6.1g. Crystal surface of synthetic rock crystal.

Natural and synthetic amethyst

Photo 6.1h. In the back a rough synthetic amethyst and in the front, to the left a faceted natural amethyst and to the right a faceted synthetic amethyst.

Both the natural and the synthetic amethyst are purple, transparent and have vitreous lustre. They both have colour zoning.

The natural amethyst is free from inclusions but the synthetic has a so called ‘nail head’ spicule inclusion which is caused by growth blockage and is pointing away from the seed plate (Gübelin and Koivula, 2005). The spicule is a two-phase inclusion containing liquid and a gas bubble. The inclusion is caused by disturbances during crystallization and by rapid growth conditions. The inclusion is associated with synthetic quartz but according to an article in *Gems and Gemology* (Fall 2007, Volume 43, Issue 3) similar inclusions have been found in natural gemstones so they do not confirm a stone's natural or synthetic origin. The synthetic amethyst also shows a colourless seed plate.

If you see the seed plate or have inclusions in the amethyst it can be easy to distinguish from natural amethyst but cut synthetic amethyst can be free from inclusions. If it is free from inclusions it becomes impossible to distinguish from the natural counterpart only by visual or microscopic examination.

Photo 6.1i. Inclusion, colour zoning and colourless seed plate in synthetic amethyst.

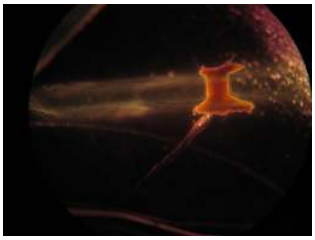

Photo 6.1j. 'Nail head' spicule inclusion in synthetic amethyst.

Natural and synthetic ametrine

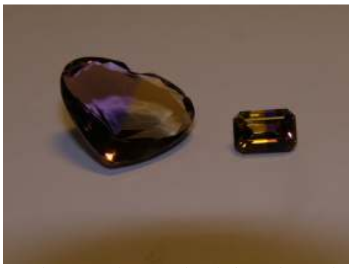

Photo 6.1k. To the left a faceted natural ametrine from Bolivia and to the right a faceted synthetic ametrine.

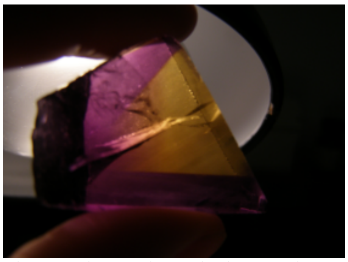

Photo 6.1l. Rough synthetic ametrine.

Both the natural and synthetic ametrine shows the yellow and purple typical for ametrine they are both also transparent and has vitreous lustre. The purple part of the natural and synthetic ametrine has colour zoning.

The natural ametrine is free from inclusions while the synthetic ametrine has so called 'bread crumb' inclusions (Gübelin and Koivula, 2005) and a part of a growth spike inclusion (Gübelin and Koivula, 2005) coming out from the sawn side. The synthetic ametrine also has a platinum thread that is used to hold up the seed plate during the synthesise process and it also has a lot of cracks and a colourless seed plate.

If the seed plate, inclusions and the platinum thread shows it is easy to distinguish from the natural ametrine but when cut it is usually free from inclusions and it is then harder to distinguish.

Photo 6.1m. Platinum thread in synthetic ametrine.

Photo 6.1n. Boundary between yellow and purple and seed plate in synthetic ametrine.

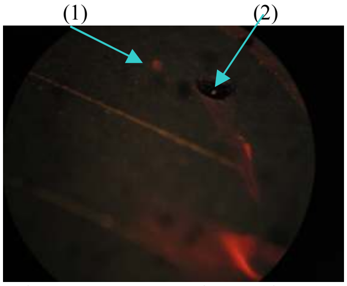

Photo 6.1o. 'Bread crumb' (1) inclusion and part of a growth spike (2) inclusion in synthetic ametrine.

Natural and synthetic green quartz

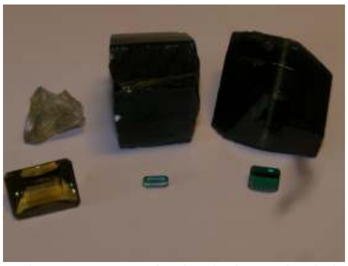

Photo 6.1p. In the back from the left: rough prasiolite, rough synthetic medium green quartz and rough synthetic dark green quartz. In the front from the left: faceted natural lime-citrine, faceted synthetic medium green quartz and faceted synthetic dark green quartz.

The natural green quartz is called prasiolite and a yellowish-green quartz some times is called lime citrine. The lime citrine has a yellow-green colour and the prasiolite has a light green colour. Both are different from the synthetic green quartz which is of a much greener colour. They all are transparent and have a vitreous lustre.

The natural lime citrine has a so called tiger stripe inclusion that can't be seen in synthetic quartz, while both the darker and lighter synthetic green quartz has 'bread crumb' inclusions which can't be seen in natural green quartz. The seed plate contains needle shaped inclusions. The prasiolite is free from inclusions.

In both synthetic green quartzes you can see a colourless seed plate, colour zoning and typical growth hillocks. If a synthetic green quartz is of this hue of green, shows the seed plates and inclusions it is easy to distinguish it from the natural lime citrine and the prasiolite. Synthetic green quartz can also be made in colours more resembling the colour of the lime citrine and the prasiolite and if cut and free from inclusions it can then be hard to distinguish only with the unaided eye, 10x loupe or microscope.

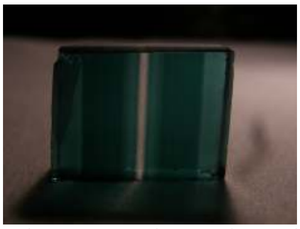

Photo 6.1q. Colour zoning and seed plate in synthetic medium green quartz.

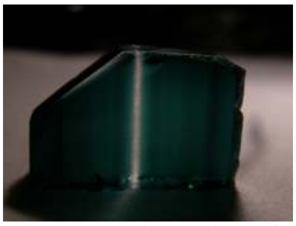

Photo 6.1r. Colour zoning and seed plate in dark green synthetic quartz.

Photo 6.1s. Growth hillocks on synthetic dark green quartz, it can also be seen on the synthetic light green quartz.

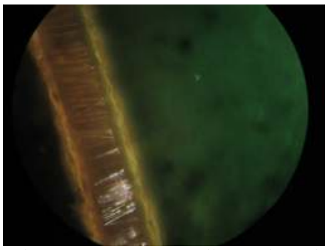

Photo 6.1t. Needle shaped inclusions in seed plate and bread crumb inclusion in synthetic dark green quartz. Similar can be seen in the synthetic light green quartz.

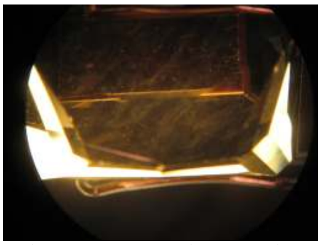

Photo 6.1u. Tiger stripe inclusion in the natural lime citrine.

Natural and synthetic blue quartz

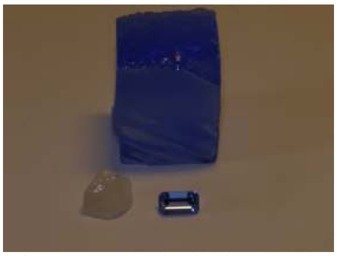

Photo 6.1v. In the back a rough synthetic blue quartz and in the front, to the left a rough natural blue quartz and to the right a faceted synthetic blue quartz.

The natural blue quartz is milky with a blue shimmer, it is translucent and has a vitreous lustre. The synthetic blue quartz is very different from the natural blue quartz as it is of a clear blue colour and it is transparent with a vitreous lustre, this you can’t find in nature so it is very easy to distinguish.

The synthetic blue quartz also shows a colourless seed plate, the typical growth hillocks and very weak colour zoning.

Photo 6.1x. Seed plate in synthetic blue quartz.

Photo 6.1y. Growth hillocks on synthetic blue quartz.

6.1.1 Conclusion visual and microscope

If you have the inclusions typical for synthetic quartz or if the synthetic quartz is uncut it is easy to distinguish from the natural counterpart but if the synthetic quartz has been cut and are free form inclusions it gets much harder or even impossible to distinguish from the natural counterpart using only a loupe or microscope. Blue and in some extent green quartz differs from this as you don't get natural quartz with the same colour or transparency and that makes it easy to distinguish from the natural counterpart. The synthetic green quartz can be made in lighter colours that more resembles the natural lime citrine and prasiolite and are then harder to distinguish.

Some times you can se unusual flame-like colour zones in ametrines with different orientations on the zones between the citrine and the amethyst parts, in natural ametrine the orientation of the colour zones are the same in both parts (Hainschwang, 2008).

6.2 Polariscope

Material		Result
Citrine	Natural	Anisotropic
	Synthetic	Anisotropic
Rock crystal	Natural	Anisotropic
	Synthetic	Anisotropic
Amethyst	Natural	Anisotropic
	Synthetic	Anisotropic
Ametrine	Natural	Anisotropic
	Synthetic	Anisotropic
Green quartz	Lime citrine	Anisotropic
	Prasiolite	Anisotropic
	Synthetic (medium green)	Anisotropic
	Synthetic (dark green)	Anisotropic
Blue quartz	Natural	Anisotropic
	Synthetic	anisotropic

6.2.1 Conclusion polariscope

You can't distinguish natural and synthetic quartz by using only the polariscope as both natural and synthetic quartz is anisotropic the exception is for untwinned synthetic gemstones. In the book *Gemmology* by Peter G. Read it says that synthetic quartz often are made as untwined crystals which is an requirement for electronic oscillators applications and this has been a basic of a test for synthetic quartz, but as it is no need for synthetic quartz grown specially for use in jewellery to be untwined, twinned synthetic quartz may now also be produced. This means that this test no longer can be used as positive identification on its own but can be used as an indicator. Even if it is very unusual, there is natural amethysts, from the Brandenberg area in Namibia, which is untwined and won't show the typical twinning pattern (Hainschwang, 2008). If twinning exists, a special pattern of interference colours will be seen in the polariscope.

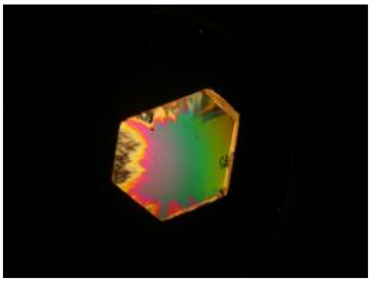

Photo 6.2.1a. Interference colours caused by twinning seen in natural quartz (seen in direction of the optic axis under crossed polarization filter).

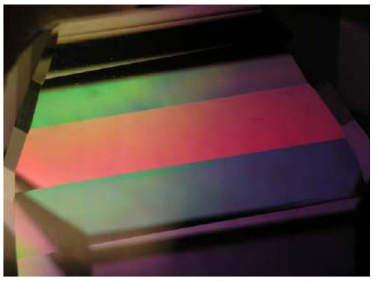

Photo 6.2.1b. The interference colours of an untwined material in the polariscope. Photo taken from Gemlab Research Newsletter 05/2008.

6.3 Conoscope

Material		Result
Citrine	Natural	Uniaxial figure
	Synthetic	Bull's-eye figure
Rock crystal	Natural	Bull's-eye figure
	Synthetic	Bull's-eye figure
Amethyst	Natural	Bull's-eye figure
	Synthetic	Bull's-eye figure
Ametrine	Natural	Bull's-eye figure
	Synthetic	Bull's-eye figure
Green quartz	Lime citrine	Bull's-eye figure
	Prasiolite	Bull's-eye figure
	Synthetic (medium green)	Bull's-eye figure
	Synthetic (dark green)	Bull's-eye figure
Blue quartz	Natural	Couldn't find a interference figure
	Synthetic	Bull's-eye figure

6.3.1 Conclusion conoscope

You can't distinguish between natural and synthetic quartz by using only a conoscope as they both may show either a normal uniaxial interference figure or a bull's-eye figure. The bull's-eye interference figure is a unique figure for quartz.

6.4 Refractometer

Material		Result		
		RI	Birefringence	Optic sign
Citrine	Natural	1,540-1,549	0,009	+ve
	Synthetic	1,541-1,550	0,009	+ve
Rock crystal	Natural	1,541-1,550	0,009	+ve
	Synthetic	1,541-1,550	0,009	+ve
Amethyst	Natural	1,541-1,550	0,009	+ve
	Synthetic	1,541-1,550	0,009	+ve
Ametrine	Natural	1,541-1,550	0,009	+ve
	Synthetic	1,542-1,551	0,009	+ve
Green quartz	Lime citrine	1,542-1,551	0,009	+ve
	Prasiolite	Couldn’t measure on the refractometer		
	Synthetic (medium green)	1,541-1,550	0,009	+ve
	Synthetic (dark green)	1,541-1,550	0,009	+ve
Blue quartz	Natural	1,542-1,551	0,009	+ve
	Synthetic	1,541-1,550	0,009	+ve

6.4.1 Conclusion refractometer

You can’t distinguish between natural and synthetic quartz by using only a refractometer, as both natural and synthetic quartz can have an RI between 1,540 to 1,552. Both synthetic and natural quarts also have a birefringence of 0,009 with a positive optic sign.

6.5 Chelsea colour filter (CCF)

Natural and synthetic citrine
The natural citrine turns yellow in the CCF and the synthetic citrine turns into an orangey-yellow. The seed plate turns into a yellow-green. That the synthetic citrine turns a little more orange through the CCF is probably due to that the synthetic citrine is more orange in colour than the natural citrine.

Natural and synthetic rock crystal
Both the natural and the synthetic rock crystal turn into a yellow-green through the CCF.

Natural and synthetic amethyst
Both the natural and synthetic amethyst turns into a light pink colour through the CCF. The light pink colour is probably due to the purple colour of the amethyst as it doesn’t contain any cobalt or chromium and shouldn’t become pink through the CCF. The seed plate turns into a yellow-green colour through the CCF.

Natural and synthetic ametrine
The yellow part of both the natural and synthetic ametrine turns into a yellow colour through the CCF. The purple part of both the natural and synthetic ametrine turns into a light pink colour through the CCF. The light pink colour is as in amethyst probably due to the purple colour.

Natural and synthetic green quartz
The natural lime citrine turns into a yellow-green colour through the CCF and both synthetic green quartzes turn into a green colour through the CCF. The seed plates turn into a yellow-green colour through the CCF. The prasiolite turns into a light green.

Natural and synthetic blue quartz
The natural blue quartz turns into a yellow colour through the CCF while the synthetic blue quartz turns into a red through the CCF. The red colour is due to cobalt that has been used to colour the synthetic blue quartz.

6.5.1 Conclusion Chelsea colour filter

You can’t distinguish natural and synthetic quartz only with the CCF except for synthetic blue quartz that has been coloured by cobalt and turns red through the CCF. Natural blue quartz doesn’t contain cobalt.

6.6 Dichroscope

Natural and synthetic citrine
The natural citrine doesn’t show any pleochroism and the synthetic citrine shows a very weak pleochroism, light orange/orange. Natural citrine can sometimes show pleocroism.

Natural and synthetic rock crystal
Natural and synthetic rock crystal is both colourless and can therefore not show any pleochroism.

Natural and synthetic amethyst
Both the natural and synthetic amethyst shows pleochroism of light purple/purple.

Natural and synthetic ametrine
The natural ametrine shows a strong pleochroism in the purple part being light purple/purple. The synthetic ametrine shows a strong pleochroism in the purple part being a reddish-purple/purple.

Natural and synthetic green quartz

The natural lime citrine shows a weak pleochroism of light yellow-green/darker yellow-green. The two synthetic green quartzes both show a strong pleochroism of light green/green. The prasiolite doesn't show any pleochroism.

Natural and synthetic blue quartz

Neither the natural nor the synthetic blue quartz shows any pleochroism.

6.6.1 Conclusion dichroscope

You can't distinguish between natural and synthetic quarts by using only a dichroscope except for amethyst or ametrine that has been grown in strong alkaline potassium solution as it may show an abnormal pleochroism, redish-violet colour becomes pale violet and this can be used together with other test to identify a material as synthetic.

6.7 Spectroscope

Natural and synthetic citrine

The natural citrine doesn't show any spectra while the synthetic citrine has an absorption in the purple between 438-400nm. Natural citrine doesn't have a diagnostic spectrum so it can't be used as proof of synthetic or natural origin.

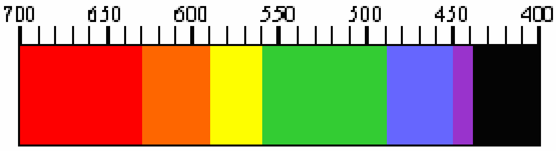

Figure 6.7a. Synthetic citrine spectra.

Natural and synthetic rock crystal

As both natural and synthetic rock crystal is colourless they won't show a spectrum.

Natural and synthetic amethyst

The natural amethyst doesn't show a spectra while the synthetic amethyst shows an absorption band over yellow and green between 583-508nm and absorption in the purple between 414-400nm. Natural amethyst may show a spectra between about 550-520nm but it isn't diagnostic so it can't be used as proof of synthetic or natural origin.

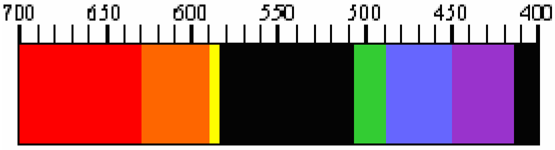

Figure 6.7b. Synthetic amethyst spectra.

Natural and synthetic ametrine

The natural ametrine doesn't show a spectrum in ether the purple or the yellow part. The synthetic ametrine shows a spectrum in both the purple and the yellow part. In the yellow part of the synthetic ametrine there is an absorption in the purple between 429-400nm. In the purple part of the ametrine there is an weak absorption band over the yellow and green between 580-510nm and absorption in the purple between 412-400nm. The spectrum isn't diagnostic and can't be used as proof of synthetic or natural origin.

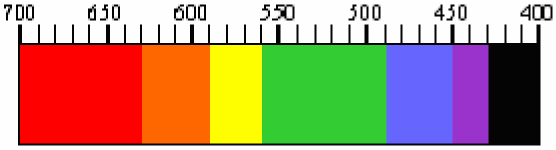

Figure 6.7c. Spectra of the yellow part of the synthetic ametrine.

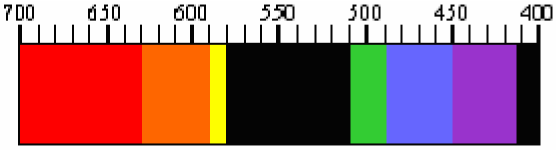

Figure 6.7d. Spectra of the purple part of the synthetic ametrine.

Natural and synthetic green quartz

The natural lime citrine and the prasiolite don't show a spectrum. The synthetic dark green quartz has an absorption band over the red and orange between 700-659nm and an absorption band over some of the blue and the purple between 420-400nm. The synthetic medium green quartz has an absorption band in the red between 700-661nm and an absorption band in the purple between 414-400nm. Natural green quartz doesn't have a diagnostic spectrum.

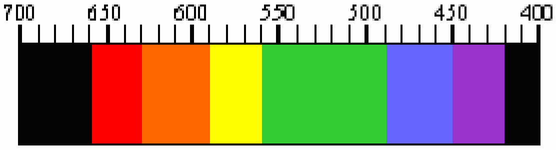

Figure 6.7e. Spectra of synthetic dark green quartz.

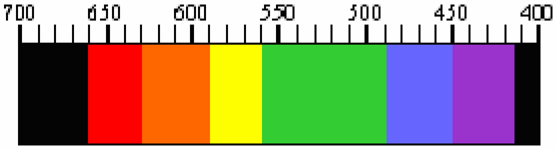

Figure 6.7f. Spectra of synthetic medium green quartz.

Natural and synthetic blue quartz

The natural blue quartz doesn't show a spectra while the synthetic blue quartz shows a cobalt spectra with three absorption bands, one in the red between 661-639nm, one in yellow/orange between 600-589nm and one in the green between 555-540nm. The natural blue quartz can't show this spectrum because it doesn't contain any cobalt.

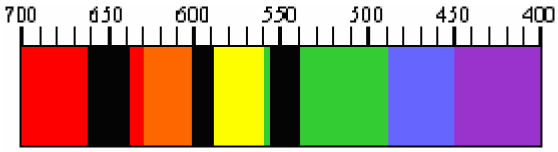

Figure 6.7g. Synthetic blue quartz spectra.

6.7.1 Conclusion spectroscope

You can't distinguish between natural and synthetic quartz with only the help of a spectroscope as quartz don't have any diagnostic spectrum for the exception of the synthetic blue quartz that shows a cobalt spectrum which you won't see in a natural quartz.

6.8 Ultraviolet light (UV)

Material		**Result**	
		SWUV	**LWUV**
Citrine	Natural	Inert	Inert
	Synthetic	Inert	Inert
Rock crystal	Natural	Inert	Inert
	Synthetic	Inert	Inert
Amethyst	Natural	Inert	Inert
	Synthetic	Inert	Inert
Ametrine	Natural	Inert	Inert
	Synthetic	Inert	Inert
Green quartz	Lime citrine	Inert	Inert
	Prasiolite	Inert	Inert
	Synthetic (medium green)	Inert	Inert
	Synthetic (dark green)	Inert	Inert
Blue quartz	Natural	Inert	Inert
	Synthetic	Inert	Inert

6.8.1 Conclusion ultraviolet light

You can't distinguish between natural and synthetic quartzes with only LWUV and SWUV has neither of them shows any fluorescence.

6.9 Specific gravity (SG)

Material		Result
Citrine	Natural	2,66
	Synthetic	2,66
Rock crystal	Natural	2,66
	Synthetic	2,65
Amethyst	Natural	2,65
	Synthetic	2,65
Ametrine	Natural	2,65
	Synthetic	2,65
Green quartz	Lime citrine	2,65
	Prasiolite	2,65
	Synthetic (medium green)	2,65
	Synthetic (dark green)	2,65
Blue quartz	Natural	2,65
	Synthetic	2,65

6.9.1 Conclusion specific gravity

You can’t distinguish between natural and synthetic quartz only with the help of SG measurement as both natural and synthetic quartzes has the same range of SG values.

6.10 Conclusion of all the tests

If you have a rough crystal of synthetic quarts it is quite easy to distinguish from natural quartz as synthetic quartz has a characteristic crystal surface. You may also be able to see the colourless seed plate and a piece of the platinum wire used to hold the seed plate during the synthesise process. This is all features that won’t be seen in a natural quartz crystal.

If the synthetic quartz has been cut is it harder or even impossible to distinguish from natural quartz especially if no inclusions are present that can give clues to the origin of the quartz. Some cut quartz is free from inclusions.

Synthetic blue quartz is an exception as it is easy to distinguish from natural blue quartz even when it is cut, as natural blue quartz doesn’t show the same colour and transparency as the synthetic blue quartz. The synthetic blue quartz is coloured by cobalt and turns red in the CCF and shows a cobalt spectra through the spectroscope which natural blue quartz don’t do as it doesn’t contain cobalt.

The colour of synthetic green quartz is sometimes of a green colour that can’t occur in natural green quartz and is then easy to identify as synthetic.

The polariscope has been used to see the lack of twinning in synthetic quartz but as synthetic quartz may now be made with twinning this test may only be used as an indicator together with other test.

Some amethysts and ametrines that are grown in a strong alkaline potassium solution can show an abnormal pleochroism which together with other tests can help identify the amethyst as synthetic. Ametrines may also show unusual colour zoning with different orientation in the different parts, this can also be used as an indication that the material is of synthetic origin.

To be absolutely sure if a quartz is of synthetic or natural origin further test in a laboratory often is necessary.

7. OTHER WAYS TO IDENTIFY SYNTHETIC QUARTZ

7.1 Infra red (IR)

For samples of amethysts that is grown in near-neutral NH_4F solutions, the absorption bands at approximately 3680, 3664 and 3630 cm^{-1} are proof of synthetic origin, but these amethyst are not commercially grown.

The commercially grown amethysts are grown in alkaline K_2CO_3 solution and there are no diagnostic features in RI spectra of the amethysts. An absorption band at 3543 cm^{-1} is found in the majority of synthetic amethysts grown in this solution but as this band is sometimes also present in natural amethysts it can only indicates that the amethyst may be of synthetic origin and can’t be used as proof of synthetic origin. The 3543 cm^{-1} band may also be absent from some varieties of synthetic amethysts. A band at 3595 cm^{-1} is found in some natural amethysts but it is never found in synthetic amethysts so if this band is present it is proof of natural origin, but if the 3595 cm^{-1} band is absent it can’t be used as proof of synthetic origin as it may also be absent from natural amethysts but it can be used as an indication of synthetic origin.

8. CONCLUSION

When it comes to synthetic blue and in some cases synthetic green quartz it is easy to identify the quartz as synthetic as the colour doesn’t exist in nature, the synthetic blue quartz also has a characteristic cobalt spectra and turns red through the CCF which the natural counterpart doesn’t do. It is also easy to distinguish between natural and synthetic quartz, if they come as uncut crystals, as the synthetic quartz crystal has a typical appearance with growth hillocks and seed plates, they may also still have the platinum wire left in them. The problem arise when you want to find out if a citrine, ametrine, amethyst or rock crystal, that is faceted, is synthetic or not, as there is not one test that on its own can identify them to be synthetic. What you can do on your own is to look at inclusions, twinning, pleochroic colours and colour zoning, each thing can indicate a possible synthetic origin and together they can identify the quartz as synthetic. If you still aren’t completely sure about the origin, you can send the quartz to a laboratory where they also can look at the IR absorption. This doesn’t on its own (as the other tests) tell if the quartz is synthetic but can give clues and together with the other tests it can identify it to be synthetic.

It would be nice to have one test that could positively say that the quartz is of synthetic origin, but to day there isn’t any. Maybe this could be something to do research on in the future as it seems like the gemstone market is in need for an easy and non expensive way to test quartz and there are probably already people doing research to find a better way. It is not that synthetics are unwanted; the reason is that you want to know what you are buying. You might want to buy a synthetic gemstone but when you want a natural gemstone you want to be sure that it isn’t synthetic.

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E-mail contacts:

- Uriah Prichard, Morion Company, Brighton, Massachusetts. www.morioncompany.com 08 May-08 21:13 and 09 May-08 21:04

APPENDICES

APPENDIX 1 INSTRUMENTS

Loupe and microscope


Photo 1.1. 10x triplet loupe, stone tong and stone cloth from Gem-A.


Photo 1.2. Binocular microscope of the brand *Gem Oro Elite 745ZS Zoom Scope*.

In my studies I have used an apochromatic 10x loupe and a binocular microscope.

The loupe is probably one of the most frequently used gemmological instruments and with experience you can, with careful inspection of internal and surface features, identify many gemstones. The 10x loupe is sufficient to reveal most of a gemstones identifying features, as it's of a useful magnification. The 10x loupe should be a so called "Triplet" consisting of three lens elements. The Triplet is an apochromatic loupe which is corrected for both chromatic and spherical aberration.

When you use a loupe it is important that the illumination used is adjusted to get direct light into the side of the gemstone, and then any internal features of the gemstone will appear brightly visible against a relatively dark background.

If you need to use larger magnification a gemmological microscope is an excellent instrument. It can be used to identify natural gemstones by revealing their characteristic inclusions, it can also be used to distinguish between synthetic and natural gemstones and to detect "fakes" or imitation gems. According to the book *Gemmological instruments*, 2nd edition, by Peter G Read the maximum magnification practical to use for gemmological purposes is in the region of 60x to 80x but that the majority of work is being done in the region of 15x to 30x. You get the total magnification of the image by multiplying the magnification of the eyepiece by the magnification of the objective.

Most microscopes are provided with built in illumination consisting of three different types: incident, light-field and dark-field illumination.
Light-field illumination is when light is transmitted through the gemstone and into the objective of the microscope. Dark-field is when light is directed through the gemstone through the sides against a dark background. Dark-field illumination gives better contrast than light-field illumination and for that reason it is the preferred method for

gemmological work. You use light-field and dark-field illumination for observing inclusions and incident light for observing surface features.

Polariscope

Photo 1.3. Polariscope from Gem-A.

The polariscope is used to determine if a gemstone is isotropic, anisotropic or polycrystalline. There are several different versions of the polariscope and most of them are constructed with a built-in light source, a polarising filter over the light source and a second polarising filter through which the stone is viewed.

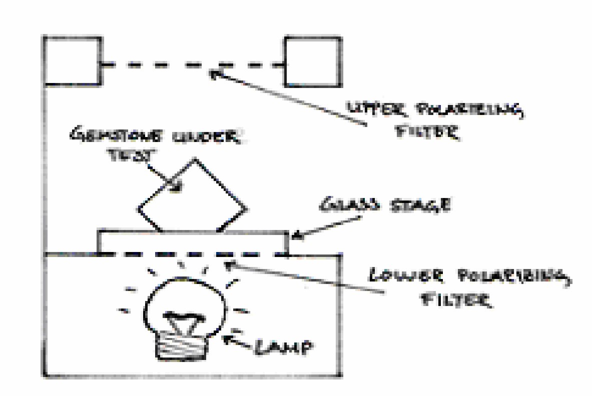

Figure 1.1. Construction of the polariscope.

The gemstone being tested is placed on a strain-free glass table above the lower polarising filter and the top polarising filter is rotated into the ‘crossed’ position. In the ‘crossed’ position the polarised light from the lower filter is ‘extinguished’ or blocked by the top filter. If the gemstone then is rotated 360° and it remains dark during the complete rotation the gemstone is isotropic, if it goes light and dark four times during one complete turn the gemstone is anisotropic and if it remains light during the rotation the gemstone is polycrystalline. Sometimes an isotropic gemstone contains internal strain and it will then look like the gemstone turns light and dark during one complete rotation, this is called ‘anomalous double refraction’. When making this test it is important to check the gemstone in at least two positions if the first position indicates that the specimen is isotropic, as an anisotropic gemstone viewed in the direction of an optic axis will appear to be isotropic.

Conoscope

Photo 1.4. Conoscope from Gem-A.

The conoscope is used together with the polariscope and it is used to decide if an anisotropic gemstone is uniaxial or biaxial or to identify the position of the optical axis. The conoscope consists of a special converging lens or strain-free glass sphere that is placed between the gemstone and the top polarising filter on the polariscope.

To see the interference figure in the lens you first have to find the optic axis and you do that by holding the gemstone between the two polarising filters in the polariscope and rotating it until coloured bands is seen, called interference colours. When you then place the conoscope between the gemstone and the top polarising filter you will se that the coloured bands is intersected by dark cross arms or 'brushes', this is called an interference figure and is caused by the interaction between the optic axis of the stone and the convergent polarized light. You will se different interference figures for uniaxial and biaxial gemstones.

Figure 1.2. Uniaxial (to the left) interference figure. Biaxial (to the right) interference figure if both optic axis is seen otherwise only half is seen.

Quartz has a unique interference figure where the dark cross does not meet in the centre; this figure is called a bull's-eye. This effect is due to the spiral crystal structure of quartz which causes a circular polarization instead of plane polarization of the light.

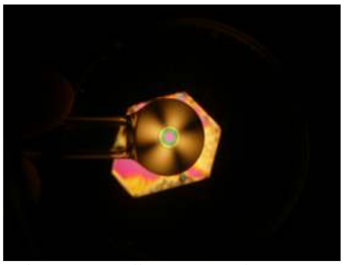

Photo 1.5. Bull's-eye seen in quartz.

Refractometer

Figure 1.6. Refractometer and contact liquid from Gem-A.

The refractometer uses the phenomenon of critical angle to measure a gemstones refractive index (RI). The critical angle is where the angle of incidence of a ray of light from within an optically denser medium is increased to such an extent that a refracted ray of light passes along the interface.

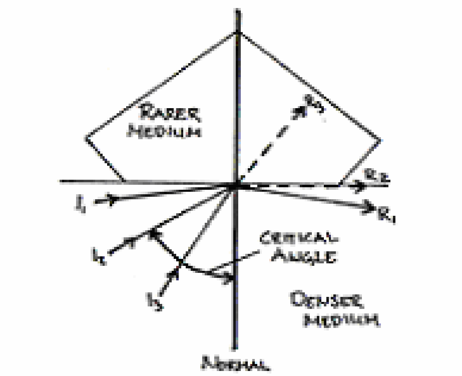

Figure 1.3. Critical angle.

The basic construction of the refractometer is shown in Figure 1.4. The light rays that arrive at the interface between the gemstone and the glass table is either refracted through the gemstone or reflected back into the instrument. The light rays that have an angle of incidence less than the critical angle are refracted through the gemstone while those having a greater angle are reflected back into the instrument. The reflected light rays then passes through an internal scale where it results in a bright section (reflected rays) and a dark section (rays lost through the gemstone). The shadow edge between the two sections indicates the RI of the gemstone.

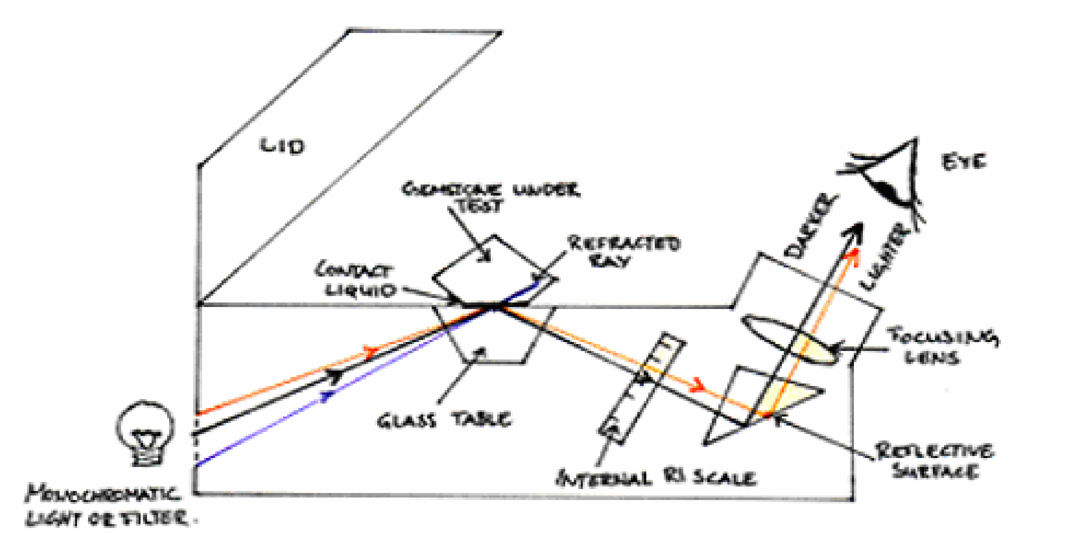

Figure 1.4. Construction of the refractometer.

When using the refractometer you need a contact liquid to obtain good optical contact between the gemstone and the glass table. The contact liquid used has a high RI of about 1.81, the contact liquid limits the gemstones that can be measured as you can't measure a gemstone with an RI higher than the contact liquid. The contact liquid normally consists of a saturated solution of sulphur in methylene iodide plus tetraiodoethylene. A small drop of contact liquid is placed on the glass table and then the gemstone is placed onto the contact liquid. The glass table of the refractometer is very soft and care should be taken when applying the drop or the gemstone so that the glass table doesn't get scratched. When the test is completed the glass table should be cleaned so no contact liquid is left on the surface as it may tarnish the surface of the glass.

The illumination used in the refractometer is monochromatic light having a wavelength of 589,3nm. Either a monochromatic sodium light source or a monochromatic filter is used to get the monochromatic light. The monochromatic light makes it easier to se the shadow edge.

When you use the refractometer you first put a drop of contact liquid on the glass table and then you put a clean and dry gemstone with a flat and polished facet onto the drop. When you then look through the eyepiece you will either see on or two shadow edges, if one shadow edge is seen the gemstone is isotropic and if two shadow edges is seen the gemstone is anisotropic.

If only one shadow edge is seen another facet should be tested to ensure that the gemstone isn't tested in the optical axis as an anisotropic gemstone is isotropic in the optical axis. The RI is where the shadow edge is. If you see two shadow edges you should rotate the gemstone one complete turn. While you rotate the gemstone you will either se that one or both of the shadow edges are moving. If one is moving the gemstone is uniaxial and if both are moving the gemstone is biaxial. The RI is obtained at the highest and lowest point of the shadow edges and the numerical difference of the two RIs are the birefringence.

If only one of the shadow edges are moving and the moving shadow edge is the higher one the gemstone is optically positive and if it is the lower one that is moving the gemstone is optically negative. If both shadow edges are moving and the higher shadow edge is crossing the halfway point the gemstone is optically positive and if the lower shadow edge is crossing the halfway point the gemstone is optically negative.

If you want to measure a cabochon you can use the distant vision technique, you then put the dome of the cabochon onto a drop of contact liquid on the glass table and then you look down the eyepiece from about 30cm away. You will then see the image of the drop and where the drop is divided equally into light and dark you have the RI. With the distant vision technique only an approximate RI can be obtained and you can't measure birefringence or find out the optical character.

Chelsea colour filter

Photo 1.7. Chelsea colour filter from Gem-A.

The Chelsea colour filter (CCF) consists of two gelatine filters that are designed to transmit only deep red and yellow-green light. The CCF was developed to distinguish between emeralds and its stimulants and the particular combination of gelatine filter was chosen to match the emeralds chromium spectra, which permits the transmission of light in the deep red but not in the yellow-green. There are a few natural emeralds that fail to show pink or red through the CCF.

The CCF also provides help in identifying other gemstones, as gemstones coloured by chromium (as the emerald) or cobalt turn red or pink through the CCF. According to the book Gemmology, 2nd edition, by Peter G Read there are no naturally occurring transparent gem minerals (except for pink smithsonite and rare blue spinel) that contains cobalt, and as cobalt coloured materials appear pink or red through the CCF any you should be suspicious of any transparent blue gemstone which shows these colours through the CCF. An exception is natural blue sapphires from Sri Lanka that contains enough chromium to turn pink through CCF.

When you use the CCF it should be held close to your eyes and the gemstone under test should be positioned under a strong light source. The CCF should always be backed up with other gemmological tests.

Dichroscope

Photo 1.8. London dichroscope from Gam-A.

The dichroscope is used to measure pleochroism in anisotropic gemstone. There is different types of dichroscopes, for example the London dichroscope and the calcite dichroscope.

The London dichroscope consists of two polarising filters with their vibration direction 90° to each other. You will be able to se the two different pleochroic colours or shades of colour in each of the polarising filter. The calcite dichroscope consists of rhomb of calcite (Iceland spar) which is placed in a metal tube having an eyepiece and a lens at one end and a square aperture at the other. The pleochroic colours will be seen as two squares beside each other.

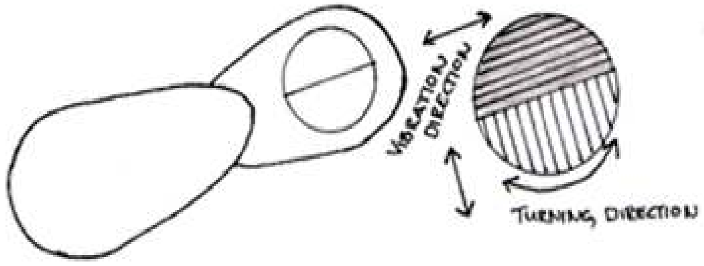

Figure 1.5. Construction London dichroscope.

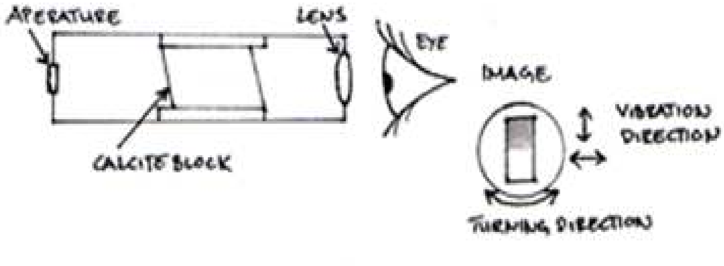

Figure 1.6. Construction of calcite dichroscope.

An pleochroic uniaxial gemstone has two pleochroic colours and an biaxial pleochroic gemstone has three pleochroic colours, you can only see two colours at one time so to be able to sample all three colours the gemstone must be turned and so must also the dichroscope. Not all anisotropic gemstones are pleochroic and it is not always that our eyes are able to see the difference in shades of colour, so it is not always you can see all two or three colours in a uniaxial or biaxial gemstone, but if you se three colours or shades of colours you can be sure that the gemstone is biaxial.

The dichroscope is a helpful instrument but should be backed up with other gemmological tests.

Spectroscope

Photo 1.9. Diffraction grating spectroscope from Gem-A.

Photo 1.10. The Diascan is a scanning diffraction grating spectroscope produced by the Gem Instrument Corporation. It uses a digital display to indicate spectral wavelengths.

A spectroscope measures the wavelengths that a gemstone absorbs by producing a spectrum. Some gemstones produces a characteristic spectra that can identify the gemstone either on its own or together with other gemmological instruments. The spectra consists of wavelengths between 700-400nm and we see it as the different colours of the rainbow, red (700-630nm), orange (630-590nm), yellow (590-560nm), green (560-490nm), blue (490-450nm) and violet (450-400nm).

There are different types of spectroscope, for example the diffraction grating spectroscope and the prism spectroscope. The diffraction grating spectroscope uses, as the name indicate, a diffraction grating to separate the light into its spectral colours while the prism spectroscope use prisms.

The prism spectroscope is constructed with a focusing tube, a prism train, consisting of three or five prisms, a lens and a slit. The spectrum produced by the prism spectroscope is not linearly spaced out but are bunched at the red end and spread out at the blue/violet end.

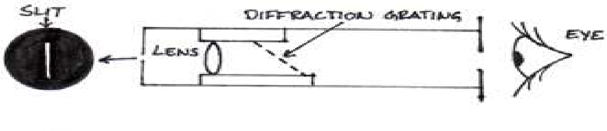

Figure 1.7. Construction of the diffraction grating spectroscope.

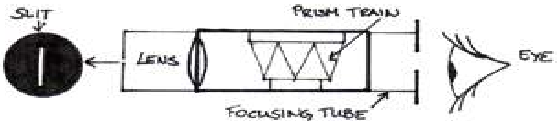

Figure 1.8. Construction of the prism spectroscope.

The diffraction grating spectroscope is constructed with a diffraction grating, a lens and a slit. The spectrum produce is not as pure or as bright as the spectrum obtained by the prism spectroscope but the diffraction grating spectroscope has one advantage as it produces a linear spectrum.

When you use a spectroscope you should either have transmitted or reflected light which you sample with the spectroscope.

Ultraviolet light

Photo 1.11. Ultraviolet light with both LWUV and SWUV from GIA.

When some gemstones are subjected to energy in the form of ultraviolet light (UV) they respond by emitting radiation at characteristic wavelengths (colours). This is a result of the excitation energy causing electrons in the atom of the gemstone to move out of their normal atomic orbits to one of a higher level and when these electrons then return to their original level they emit the excess energy and we see that energy as a colour. UV can be of help in identifying gemstones together with other gemmological instruments, it is also of great use to identify synthetics and treatments.

In gemmological testing you use long wave ultraviolet light (LWUV) that has a principle wavelength at 365nm or shortwave ultraviolet light (SWUV) that has a principle wavelength at 254nm.

Specific gravity

Photo 1.12. Digital scale with a bridge, water cup and a stand.

The specific gravity (SG) can be of help in identifying gemstones together with other gemmological instruments. To measure the SG by the hydrostatic method you need a balance, a cop of water, a bridge and a stand. You first measure the gemstone in air and then you measure the gemstone in water. When you done that you can calculate the SG by using the formula:

$$\text{SG} = \frac{\text{weight in air}}{\text{weight in air} - \text{weight in water}}$$

The measuring of SG by the hydrostatic method applies to Archimedes principle and can be used for all but very small gemstones.

Archimedes principle:
An object totally immersed in a fluid experience an upward force equal to the weight of the fluid it displaces (Read, 1999).