SYNTHETICS AND SIMULANTS

- ***The jewelry industry uses special terms for manufactured and look-alike gemstones: synthetic and simulant. The differences between them are subtle, but very important.***

- Synthetic refers to a manmade material with essentially the same chemical composition, crystal structure, and optical and physical properties as the natural gem material (e.g. synthetic emerald, ruby, sapphire, diamond…)

- ***There are also materials that simply look like natural gems. These products are called simulants or imitations, and can be either natural or manmade. Substitute is an older term for the same thing.***

Synthetic gems

- A synthetic gem material is one that is made in a laboratory, but which shares virtually all chemical, optical, and physical characteristics of its natural mineral counterpart, though in some cases, namely synthetic turquoise and synthetic opal, additional compounds can be present.

- Synthetic gem crystals have been manufactured since the late 1800s, and their production is often marked by a need for them in industrial applications outside of the jewelry industry. The first success was in producing synthetic ruby of faceting quality. ***Synthetic crystals are used in communications and laser technology, microelectronics, and abrasives.*** Because synthetics for jewelry applications can be “made to order” [i.e. consistent color and crystal shape] given the right ingredients, time, and the facilities to grow them, they are likely to be much less rare than natural gems of equal size, clarity, and saturation of color. Because of this, and because it is possible to confuse them with gems that are naturally occurring, there are strict guidelines regarding how they are marketed and sold.

- In the United States, the Federal Trade Commission requires that any gem material produced in a laboratory be described in a way that leaves no doubt that it was not produced naturally. It is considered to be a deceptive practice if a synthetic gem material's origin is not clearly disclosed throughout the distribution channel at the time of sale, from the manufacturer to the consumer.

- There are also a number of industry organizations such as the American Gem Trade Association (AGTA), the International Colored Gemstone Association (ICA), and the World Jewellery Confederation (CIBJO) that have formulated specific guidelines for their members regarding the disclosure of synthetic gems at the time of sale

Processes

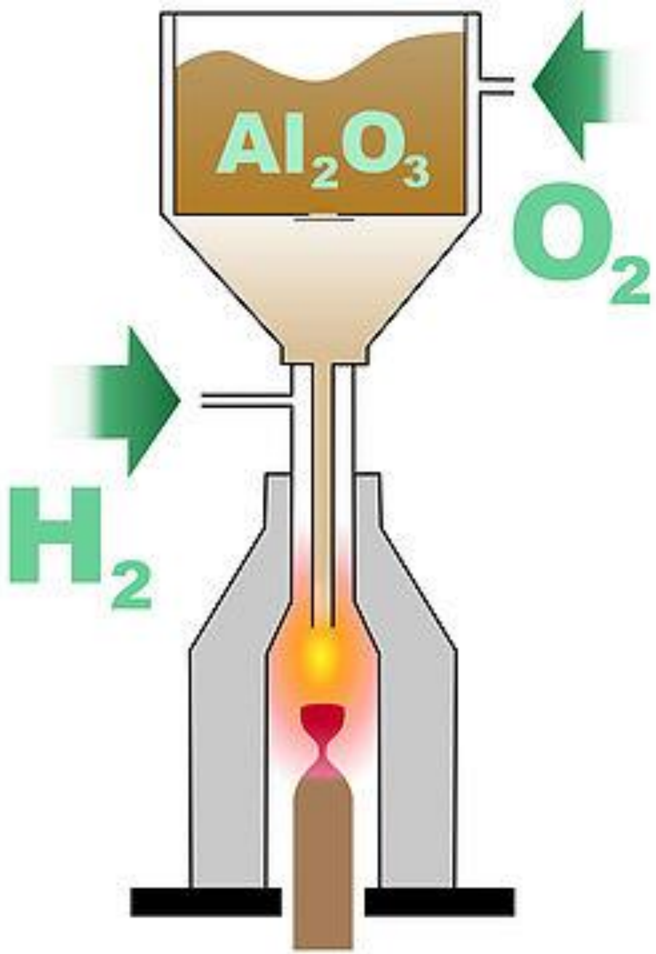
During the last century, researchers have developed a number of different ways to create these synthetic gem materials in the laboratory. Most of these methods fall into two major categories ***– melt or solution***

Flame Fusion or Verneuil process (melt process)

The first commercially successful synthetic gems were created by the flame fusion process. This process involves dropping powdered chemicals through a high-temperature flame, where it melts and falls onto a rotating pedestal to produce a synthetic crystal. Today it remains the least expensive and most common way to make gems such as synthetic corundum and spinel.

Crystal Pulling or Czochralski process (melt process)

Pulling emerged in the early 1900s. **Czochralski Process (Cz). CZ** is also known as "crystal pulling" or "pulling from the melt." In this process, silicon is first melted and then allowed to freeze into a crystalline state in a controlled manner. The advantage of this method is that it is fast and highly controllable. The industrial cultivation of high-purity monocrystalline silicon crystals using the Cz process has become well established primarily for the solar and semiconductor industries (in the computer industry for integrated circuits and in microsystem technology). Gems synthesized by pulling include synthetic alexandrite, chrysoberyl, corundum, and garnet.



Verneuil process (melt process)

Flux growth (solution process)

Today some synthetic gems, such as emerald, ruby, sapphire, alexandrite, and spinel can be created through a flux-growth process. Flux is a solid material that, when melted, dissolves other materials in the same way that water dissolves sugar. As the dissolved chemical solution gradually cools, synthetic crystals form. Growing a synthetic gem by the flux method requires patience and significant investment. ***Crystal growth can take up to a year, and the equipment is very expensive. But the results, especially when it comes to emerald, are well worth the time and effort.***

Hydrothermal growth (solution process)

Like the flux process, the hydrothermal growth process is slow and expensive. But it's the only method for successfully growing synthetic quartz. This process requires heat and pressure and imitates the conditions deep in the earth that result in the formation of natural gems. Nutrients are dissolved in a water solution, and then synthetic crystals form as the solution cools. While the following list encompasses the commonly seen synthetics, over the years there have also been experimental synthetic gems. These include malachite, color change synthetic spinel and others. But because nature produces these products more readily, they are not often seen today.

Some of the synthetic gems that are more frequently encountered include:

Synthetic diamond (this is not frequently encountered)

These diamonds, grown in a laboratory, share most of the characteristics of their natural counterparts: they are essentially carbon.

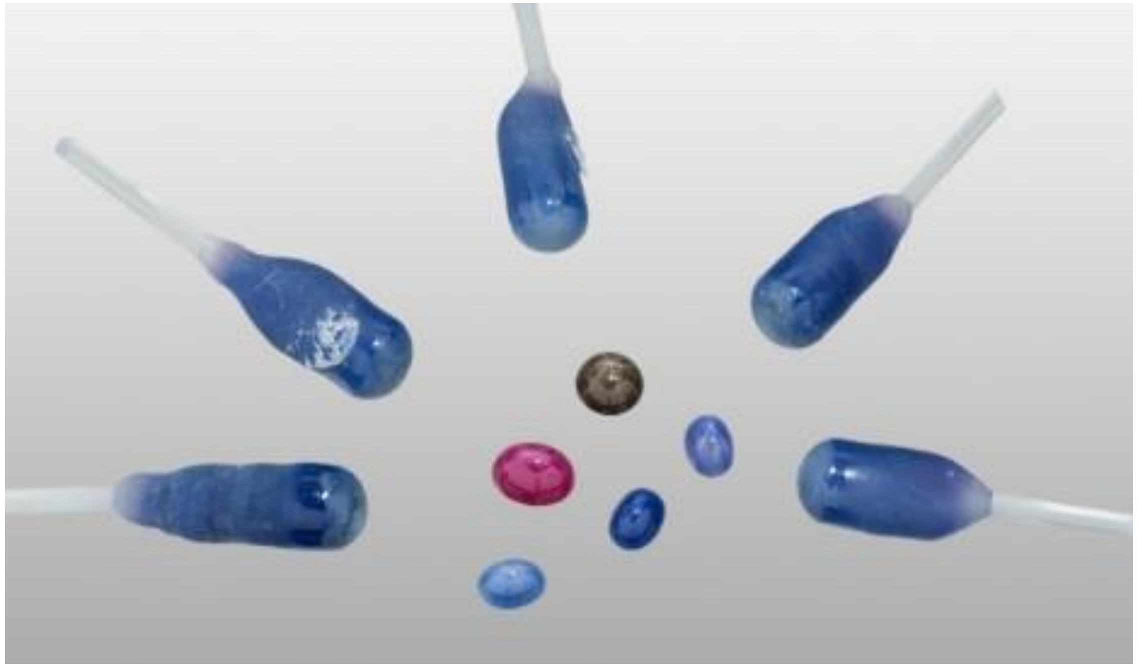
Chemical vapor deposition (CVD) – diamond growth in a vacuum chamber due to a chemical reaction which releases carbon atoms that precipitate on diamond seed plates.

Synthetic corundum (widely available)

Synthetic corundum, which includes ruby and sapphire, can be made by the greatest number of processes. Because of this, synthetic corundum is available at many price levels, from very affordable to very expensive.

Ruby – in the late 1800s, ruby became the first gem to be created in a laboratory by Auguste Verneuil. In 1902, he announced the development of his flame-fusion process for synthesizing this beautiful gem.

Sapphire –Many synthetic sapphires are still made by flame fusion, but flux-grown sapphires have been available since the 1960s. Flux-grown, pulled and hydrothermal synthetic sapphires can be very convincing substitutes for the natural gem. Color change synthetic sapphire, made to imitate alexandrite, has been popular since the early 1900s. Induced inclusions caused star effects in some synthetic ruby and sapphire.



Synthetic sapphires can be manufactured to show asterism (star effect), in cabochon cut stones, such as these.

Synthetic emerald (widely available) and other beryls (rare)

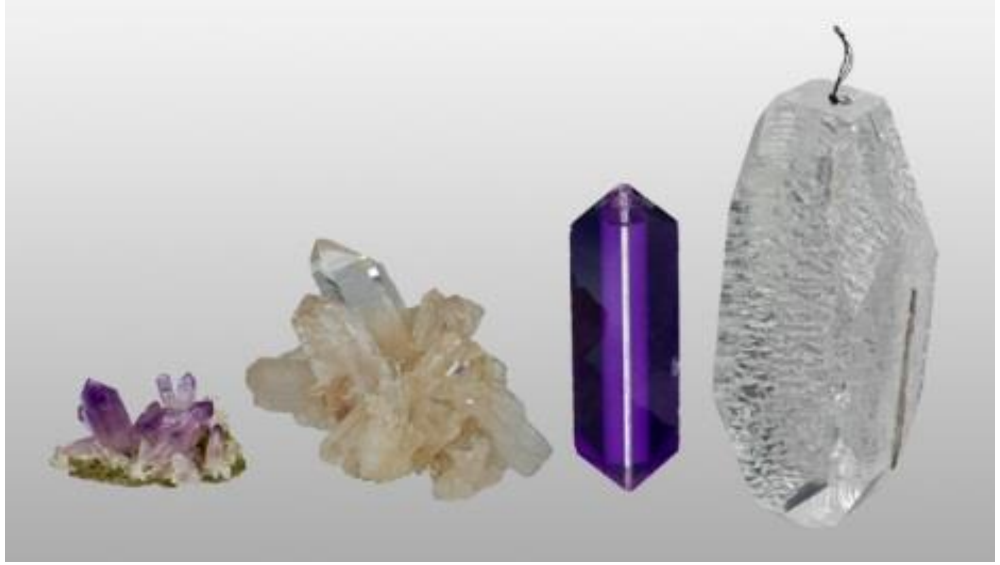
Synthetic beryl is available in many colors including yellow, red, blue (aquamarine) and green (emerald). In the late 1980s and 1990s, Russia became a significant producer of these synthetic gems and is still a major supplier of hydrothermally grown gemstones such as synthetic beryl and synthetic corundum, along with others like synthetic diamond and synthetic alexandrite.

These are examples of synthetic beryl crystals and cut stones (including the synthetic emerald variety—the green stones)

Synthetic quartzes (widely available)

Gem-quality quartz, such as citrine, rose quartz, smoky quartz, and amethyst, is attractive. But natural gem-quality quartz is plentiful so scarcity is not the reason that researchers went to the trouble of developing a way to synthesize gem-quality quartz. **The reason is that it plays a key role in technology**. It can generate an electric current when it's placed under pressure and can vibrate in precise response to alternating current. **These virtues are put to practical use in watches, clocks, communications equipment, filters, and oscillators.**

Amethyst: Lab-grown amethyst and other synthetic quartz varieties found their way into jewelry after being developed for industrial applications. The first hydrothermal quartz appeared in laboratories in the 1890s. It wasn't until World War II that synthetic quartz was widely available commercially.



Natural amethyst and rock crystal quartz crystals (left) and synthetic amethyst and synthetic rock crystal quartz crystal (right).

Man-made simulants

Synthetic spinel – synthetic spinel is often used as a simulant because it can mimic the look of many different natural gems (such as sapphire, zircon, aquamarine and peridot), depending on its color. Its accurate reproduction of a wide variety of colors makes it a common choice for imitation birthstone jewelry. Prevalence: common.

This group of synthetic spinel boules and cut stones illustrates how this manmade material can be made to look like other gemstones, such as ruby and various colors of sapphires

Strontium titanate – this colorless manmade material became a popular diamond simulant in the 1950s. ***However, its dispersion (the optical property that creates fire in a faceted gemstone) is over four times greater than diamond.*** Strontium titanate is most often produced by the flame-fusion method and can be made in colors, such as dark red and brown, by adding certain chemicals during the growth process. Prevalence: rare. **YAG and GGG** – several manmade materials have been used as diamond simulants over the years. In the 1960s, yttrium aluminum garnet (YAG) and its “cousin” gadolinium gallium garnet (GGG) joined classic simulants like glass, natural zircon, and colorless synthetic spinel. ***YAG and GGG are also available in a variety of colors. Prevalence: rare***

Yittrium aluminum garnet (or YAG) can be manufactured in a variety of colors such as those seen here. The colorless crystal is used as uncut material to fashion diamond simulants

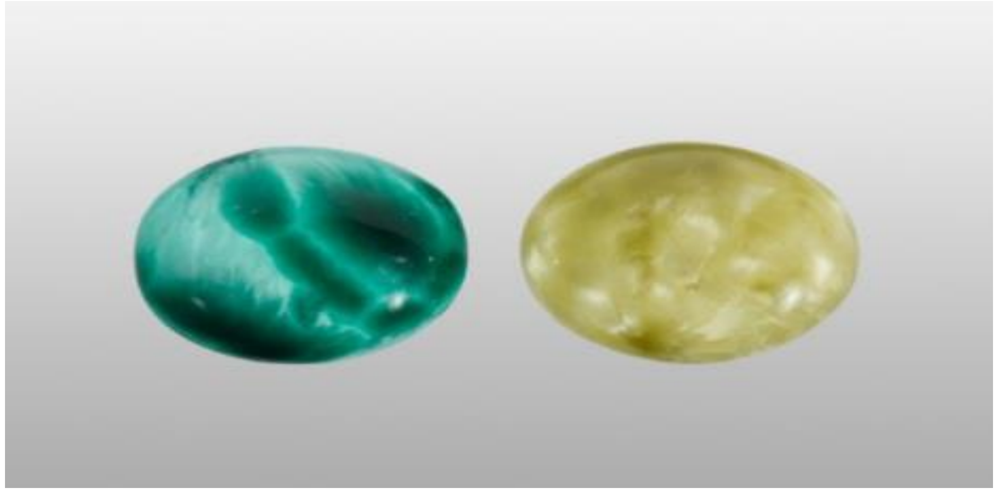
Synthetic cubic zirconia (CZ) – early diamond simulants have been almost entirely replaced in the past three decades by colorless CZ. It is made by a process called skull melting. As the material melts, the outer portion is kept cool to form a solid crust which then contains the melt. CZ can be produced in almost any color, and in darker hues, it is a convincing alternative for gems in purples, greens and other dark tones including black. Prevalence: common.

Cubic zirconia, (or CZ) is also manufactured in a variety of colors, though colorless CZ makes the most convincing colorless diamond simulant

Synthetic moissanite – colorless synthetic moissanite was introduced in the late 1990s as a diamond simulant. It is closer to diamond in overall appearance than any previous diamond imitation, but now it is most often sold as a gem in its own right. Prevalence: occasional.

Natural diamond (left), and (inner left to right), laboratory grown moissanite in the near colorless to greenish range

Glass – manufactured glass is an age-old gem imitation that is still used today. Since glass can be manufactured in virtually any color, this makes it a popular substitute for many gems. Although it is less brilliant, glass is used to imitate stones like amethyst, aquamarine, and peridot. It can also be made to look like natural phenomenal gems, like tiger's eye and opal, and fused layers of glass can imitate the look of agate, malachite, or tortoise shell. Prevalence: common

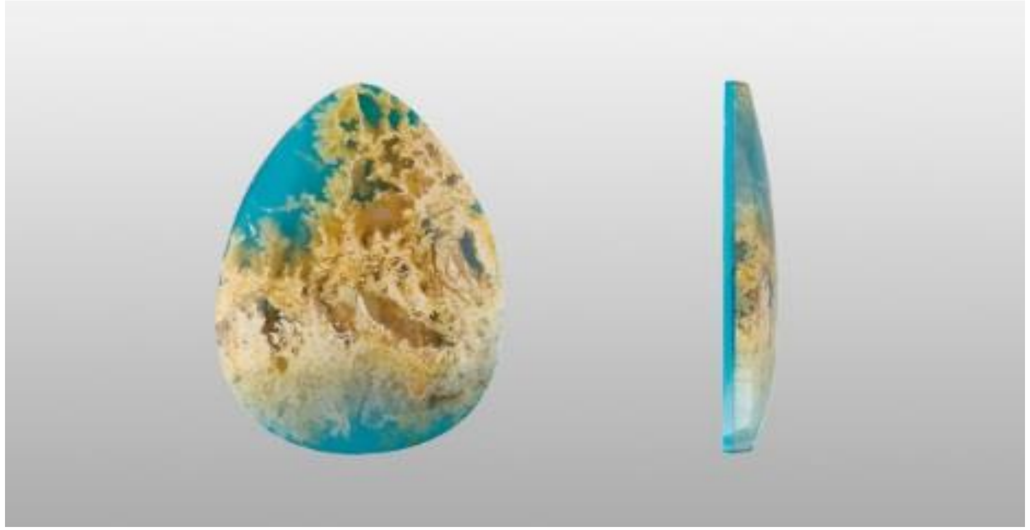


Glass, such as this material, can be made to look like a variety of gemstones; in this case glass makes a convincing substitute for malachite (left), and rutilated quartz (right

Assembled Stones:

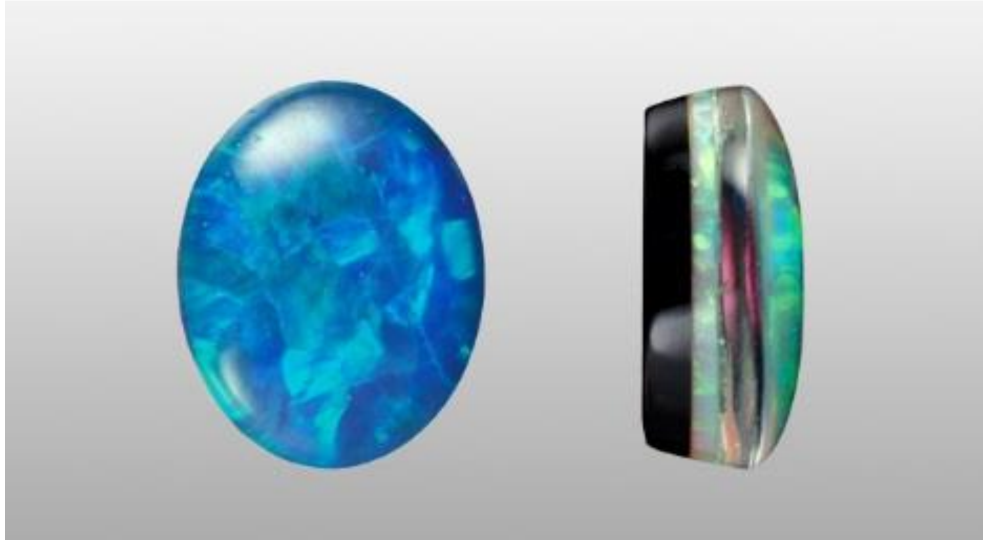
When manufacturers glue or fuse two or more separate pieces of material together in the form of a faceted gemstone, the result is called an assembled or composite stone. The separate pieces can be natural or manmade. The flat surfaces that are glued together are parallel to the large table facet of the gem so as to impart a more uniform face-up color

Doublet – a doublet consists of two joined segments. Prevalence: common



A doublet, such as this one, contains two joined portions of a gem that are held together by colorless glue, as a profile view of this material shows

Triplet – a triplet has three segments, or two segments separated by a layer of colored cement. Prevalence: common.



A triplet contains two or more segments of a gem, or different gems, that are joined by layers of glue. In a profile view, this image shows a thin seam of opal in the center that is backed by dyed black chalcedony, and is overlayed (the domed area) by a quartz cabochon

Plastic – plastic is often used to imitate gemstones in inexpensive fashion jewelry. However, this modern manmade substance has also been manipulated into convincing imitations of organic gems like amber, pearl, and coral, or aggregate materials like jade, turquoise and lapis.

Plastic is not a durable imitation, so special care must be taken to prevent damage.
Prevalence: common.

What are Gemstone Enhancements?

GEMSTONE TREATMENT AND ENHANCEMENT METHODS

The term **enhancement** is defined as any treatment or process other than cutting and polishing that improves the appearance (color/clarity/phenomena), durability, value or availability of a gemstone. In today's gem marketplace, many gemstones have been enhanced by a variety of methods. Such processes may range from simple heating (such as with tanzanite) to high-tech irradiation (such as blue topaz).

Some gemstone enhancements are less stable than others, meaning that the appearance of a gem may change with time.

A gemstone enhancement is considered stable as long as the gem does not change in appearance (color and/or clarity) under normal wear, cutting, cleaning, repair or display conditions.

Gemstones can be divided into three basic enhancement categories.

Symbols for Specific Forms of Enhancement (based on AGTA: The American Gem Trade Association)

- **B = Bleaching:** The use of heat, light and/or chemicals or other agents to lighten or remove a gemstone's color. This is often accompanied by subsequent dying and/or impregnation. Example: bleached cultured pearl; bleached/impregnated jadeite (‘B-jade’)
- **C = Coating:** The use of such surface enhancements as lacquering, enameling, inking, foiling, or sputtering of films to improve appearance, provide color or add other special effects. Example: coated diamond
- **D = Dyeing (staining**): The introduction of coloring matter into a gemstone to give it new color, intensify existing color or improve color uniformity. Example: dyed green jadeite
- **F = Filling**: The filling of surface-breaking cavities or fissures with colorless glass, plastic, or some similar substance. This process will improve durability, appearance and/or add weight. Example: ruby
- **Fh = Flux healing:** During heat enhancement, fluxes (or heat alone) may be used to heal fractures/fissures which were formerly open. The process dissolves the walls of the fractures and redeposits the molten gem material, healing the fractures closed. Example: ruby (particularly that from Möng Hsu, Burma)
- **H = Heating**: The use of heat to alter color, clarity, and/or phenomena. Example: Ruby, sapphire, tanzanite, aquamarine, demantoid garnet
- **I = Impregnation:** The impregnation of a porous gemstone with a colorless agent (usually plastic) to give it durability and improve appearance. Example: Stabilized turquoise

- **L = Lasering:** The use of a laser and chemicals to reach and alter inclusions. Example: diamond
- **O = Oiling/Resin Infusion:** The filling of surface-breaking fissures with a colorless oil, wax, resin or other colorless substances, except glass or plastic, to improve the gemstone's appearance. Example: emerald
- **R = Irradiation:** The use of neutrons, gamma, ultraviolet and/or electron bombardment to alter a gemstone's color. The irradiation may be followed by a heating process. Example: blue topaz
- **U = Lattice ('bulk' or 'surface') Diffusion:** Outside-in diffusion of coloring chemicals via high-temperature heat treatment to produce color and/or asterism. Example: lattice diffusion-treated sapphire
- **W = Waxing/Oiling:** The impregnation of a colorless wax, paraffin and/or oil in porous gemstones to improve appearance. Example: jadeite

Two Important Organizations with an Interest in Gem Enhancement:

FTC: The Federal Trade Commission regulates many *basic* aspects of marketing, advertising and commerce in general. For gems and jewelry, the pertinent regulations regard certain aspects of advertising and describing gems, as well as issues of gem weights and measurements.

AGTA: The American Gem Trade Association is an industry organization of carefully screened colored gemstone dealers who are based in the USA. Attaining membership in this organization involves a lengthy and rigorous vetting process meant to assure that only dealers who ascribe to the highest standards of ethical business practices can belong. This organization has had extreme influence, world-wide, primarily by developing and publicizing standards of ethical business practices for colored stone dealers, especially as regards disclosure of enhancements.

AGTA guidelines for gem advertising and marketing go well beyond the generalized and generic ones found in the FTC regulations. Because more and more countries are adopting the AGTA guidelines and their coding system, or patterning their own after it.

Natural Gemstone Enhancement Chart (based on the AGTA Source Directory 2000–2001)

Natural Gemstone	Enhancement Symbol	Description Used	Frequency Encountered	Stability	Care Requirements
Agate	D	–	Usually	Excellent to good	Normal
Fire Agate	N	–	–	–	Normal
Alexandrite	N	–	–	–	Normal
Amber	E or H	–	Usually	Very good to good	*Special
	D	–	Rarely	Variable	Special
Amethyst	E or H	–	Occasionally	Excellent	*Special
Ametrine	N	–	–	–	Normal
Andalusite	N	–	–	–	Normal
Aquamarine	E or H	–	Usually	Excellent	Normal
Beryl	R	Maxixe	Always	Poor	X-Special
	R	Yellow	Usually	Variable	Special
	N	Yellow-green	–	–	Normal
	E or O	Red	Commonly	Very good to fair	Special
Chalcedony	D	Black	Always	Excellent to good	Normal
	D	Banded	Usually	Excellent	Normal
	D	Green	Usually	Good to fair	Special
	D	Blue	Commonly	Good to fair	Special
	E or H	Carnelian	Usually	Excellent	Normal
	D	Carnelian	Occasionally	Excellent to good	*Special
	D	Jasper	Occasionally	Excellent	Normal
	N	Chrysoprase	–	–	Normal

Chrysoberyl	N	Transparent	–	–	Normal
	R	Cat’s eye	Occasionally	Excellent	Normal
Citrine	E or H	–	Usually	Excellent	Normal
Coral	N	Black	–	–	*Special
	E or B	White	Commonly	Good	Special
	E or W	Pink	Commonly	Good	Special
	I	Orange	Commonly	Good	Special
	B	Gold	Usually	Very good	Special
	D	Red	Occasionally	Variable	X-Special
Natural Gemstone	Enhancement Symbol	Description Used	Frequency Encountered	Stability	Care Requirements
Diamond	L	–	Occasionally	Very good	Normal
	C	–	Rarely	Very good to poor	Special
	F	–	Occasionally	Very good	Special
	HP	–	Rarely	Unknown	Special
Diamond – Fancy	R	–	Occasionally	Excellent to very good	Special
	L	–	Occasionally	Very good	Normal
	F	–	Rarely	Very good	Special
	C	–	Rarely	Fair to poor	Normal
	H	–	Rarely	Unknown	Normal
Diopside – Chrome	N	–	–	–	*Special
Emerald	E or O	–	Usually	Very good to fair	Special
	D	–	Occasionally	Variable	Special
Garnet	N	All varieties	–	–	*Special
	E or H	Some demantoid	Commonly	Very good	*Special

Hematite	N	–	–	–	Normal
Iolite	N	–	–	–	Normal
Jade – Jadeite	E or W	–	Commonly	Fair	Special
	B and I	Green/purple/white	Commonly	Very good to good	Special
	D	–	Occasionally	Variable	Special
	B and W	–	Rarely	Poor	Special
Jade – Nephrite	D	–	Rarely	Unknown	Special
Kunzite	E or H	–	Commonly	Fair	Special
	R	–	Commonly	Fair	Special
Natural Gemstone	Enhancement Symbol	Description Used	Frequency Encountered	Stability	Care Requirements
Lapis lazuli	E or W	–	Commonly	Fair	Special
	D	–	Commonly	Variable	Special
Moonstone	N	–	–	–	Normal
Morganite	E or H	–	Commonly	Excellent	Normal
Opal	O	White/black	Rarely	Fair	Special
	I	–	Rarely	Good	Special
	O	Boulder	Usually	Good	Special
	D	Matrix	Commonly	Good	Special
	N	Fire opal	–	–	*Special
	I	Cat’s eye	Usually	Good	Special
	I/O/D	Hydrophane	Commonly	Good to fair	Special
Pearl – Natural	E or B	White	Usually	Very good	Special
	D	–	Rarely	Very good to good	Special
Pearl – Cultured	E or B	White	Usually	Excellent	Special
	D	Many colors	Usually	Variable	Special

Peridot	E or O	–	Rarely	Good to fair	Special
	F	–	Rarely	Good	Special
Ruby	E or H	–	Usually	Excellent	Normal
	Fh	–	Commonly	Excellent	Normal
	O	–	Occasionally	Good to fair	Special
	D	–	Rarely	Poor	Special
	R	–	Rarely	Unknown	Normal
	F	–	Commonly	Very good to fair	Special
	U	–	Rarely	Good	Special
Natural Gemstone	Enhancement Symbol	Description Used	Frequency Encountered	Stability	Care Requirements
Sapphire	E or H	–	Usually	Excellent	Normal
	U	–	Occasionally	Good to fair	Special
	O	–	Occasionally	Good to fair	Special
Sapphire – Fancy	E or H	–	Usually	Excellent	Normal
	R	Yellow/orange	Occasionally	Very poor	X-Special
	O	–	Occasionally	Good to fair	Special
	U	–	Occasionally	Good to fair	Special
Serpentine	D	Various colors	Commonly	Good to fair	Special
	E or W	–	Commonly	Very good to good	Special
Spinel	N	–	–	–	Normal

	O	–	Occasionally	Good to fair	Special
Sugelite	N	–	–	–	Normal
Sunstone	N	–	–	–	Normal
Tanzanite	E or H	–	Usually	Excellent	*Special
Topaz	R	Blue	Usually	Excellent	Normal
	R	Yellow/orange	Occasionally	Variable	Special
	R	Green	Occasionally	Poor	X-Special
	U	Green	Usually	Good	Special
	N	Brown	–	–	*Special
	E or H	Red/pink	Usually	Excellent	Normal
Natural Gemstone	Enhancement Symbol	Description Used	Frequency Encountered	Stability	Care Requirements
Tourmaline	N	Chrome green	–	–	Normal
	N	Cat's Eye	–	–	Normal
	E or H	Yellow/orange	Rarely	Excellent	Normal
	R	Yellow/orange	Rarely	Very good	Normal
	E or H	Green/blue	Commonly	Excellent	Normal
	O	Any color	Occasionally	Good to fair	Special
	E or H	Pink/red/purple	Occasionally	Excellent	Normal
	R	Pink/red/purple	Commonly	Good	Normal
	D	Pink/red/purple	Occasionally	Fair to poor	Special

Turquoise	W	–	Commonly	Fair to poor	Special
	D	–	Rarely	Poor	X-Special
	I	–	Commonly	Good	Special
Zircon	N	Green/brown	–	–	*Special
	E or H	Blue/colorless	Always	Fair to poor	Special
	E or H	Yellow	Rarely	Good	Special
	E or H	Red	Commonly	Fair to poor	Special

Notes:

- The “N” symbol is used only for gemstones that are guaranteed to have not been enhanced.
- All jewelry (with or without stones) requires special care; some jewelry requires extra-special (X-Special) care.
- * Indicates a gemstone that generally requires special or extra-special care (although the need for care is not necessarily related to the enhancement).

Heating: (AGTA Code = H)

The most versatile and widely used treatment for gems is heating. Depending on the gem and the desired effect, temperatures used vary from those provided by placing the gems in direct intense sunlight, to near melting point temperatures of 2000 degrees C; periods of heating range from minutes to several days, and oxygen may be present or excluded from the heating atmosphere

To heat most kinds of colored gemstones is a standard procedure between mining and cutting of the gem. It became more and more sophisticated as the knowledge about it was passed over from generation to generation. Methods vary from simply burning the rough minerals in an open fire to highly elaborate techniques under regulated temperatures.

The atmosphere in which the gem is "baked" is important, as it will influence whether its ions gain or lose electrons. That is, it will determine if a chromophore ion will be changing from Fe^{3+} to Fe^{2+} or vice versa. A "reducing" atmosphere (one without oxygen) which can either be supplied via a high tech furnace, or simply by placing the gems to be treated in a closed container with charcoal), causes the number to go down (+3 to +2 for example).

In an "oxidizing" atmosphere (oxygen present) the number goes up.

Why are gemstones heated?

The rough gems are heated to improve their quality. Through burning, as the heating is also called, hues become stronger, colors are revealed or even changed by the process, inclusions become less prominent or vanish at all, and the durability of the stone is improving. For example, if a darkish Tourmaline is heated, its color will brighten. Heating can lead to astonishing outcomes, and otherwise unimposing minerals are turned into beautiful sparkling treasures.

Does heating affect the price of a gemstone?

Good quality gemstones are by far less common than comparable enhanced ones, and this can be reflected in the price. Unheated Red Ruby and unheated Blue Sapphire are in permanent demand, and those natural wonders are traded with a premium.

Top quality unheated Red Ruby and Blue Sapphire are absolutely rare, hard to find even in the world's most famous deposits and therefore extremely expensive. On the other hand, many kinds of gemstones would not exist without heat treatment, e.g. tanzanite or prasiolith.

In today markets, you will find that Aquamarine, Amethyst, Citrine, Kunzite, Tanzanite, Topaz, Tourmaline, Zircon as well as Ruby and Sapphire are enhanced with heat in most cases.

Heating

The treatment is permanent and accepted within the gem community. Heating does not change the chemical structure of the gem

Heating amber: **Amber is heated for three main purposes: to darken it, to clarify it, and to *deliberately* add stress fracture inclusions.**

When heated at low temperatures the surface of amber gradually darkens over time. Much of the clear amber found in nature is a light yellow to gold color, but shades from tan to gold to orange to dark brown can be obtained by heating. The color is usually confined to a surface layer and so is often done <u>after</u> the gems have been fashioned. If desired, the surface layer can then be partially polished or carved away to provide contrast or create a design. (Similar low temperature heating of ivory has been used, by unethical antique dealers, to darken its surface and create the <u>illusion</u> of great age). Low temperatures *must* be used on these gems as due to their organic nature, they will char, melt or burn!

Heating beryl: **Two species of beryl gems are commonly heat treated. Aquamarine and Morganite occur naturally in shades of slightly greenish blue, and slightly yellowish pink, respectively, but the "market preferred" colors are *pure* shades of blues and pinks. Heat is used to obtain these preferred colors.**

(The temperatures necessary to accomplish the removal of yellow tones by changing one iron ion to another using a reducing atmosphere, are low, and therefore, generally leave no obvious signs.)

Therefore, aqua and Morganite of pure blue or pink color should be *assumed* to have been heated, unless otherwise stated.

Heating chalcedony: Of the many forms of chalcedony, carnelian is the only one which is likely to be heated.

The orangey brown color of carnelian comes from its iron oxide content, which, when unheated, is hydrated (chemically, it has loosely attached water molecules bound to it). This form of iron oxide is known as limonite and is yellow to orange to brown in color. The amount of limonite which stains the chalecdony will differ, making carnelian naturally highly variable in tone and hue. Heat removes the bound water from the limonite and converts it to the unhydrated form, hematite, which, as its name suggests, is blood red in color.

Due to the low temperatures involved (the Ancients simply put it in the sun to bake) it is not possible to discriminate natural heating which might occur underground during, or after, gem formation, from that which is man-made. Therefore, if the color is significantly on the red side, assuming it to be heated, is erring on the side of caution.

Heating corundum: **Virtually all corundum gems (sapphires and rubies) have been heated. Many different outcomes from the heating processes are possible depending on the temperature, atmosphere, and the particular chemistry of the material being treated. Interestingly, in corundum, heat: 1) can either increase or decrease color intensity, 2) it can dissolve rutile to clarify a piece, or 3) exsolve it to create or emphasize chatoyance or asterism. 4) It can be used to partially heal fractures improving clarity, and 5) it can diminish the tell-tale appearance of "curved striae" in synthetics by paritally melting these layers into each other.**

We learned that heating can <u>remove</u> yellow tones in aqua, but by changing the conditions, it can <u>emphasize</u> them in sapphire. By using high heat and an oxidizing atmosphere, a pale yellow sapphire can acquire a deeper, richer color.

Blue tones in corundum can be increased *or* decreased: which way it goes is controlled by altering heating and atmospheric conditions. High temperature and rapid cooling under reducing conditions can change the ions of iron and titanium in pale blue sapphires to a form which results in a stronger blue color, for example.

On the other hand, some corundum suffers from too much blue color --> like certain quite purplish rubies and those "midnight" sapphires, so dark they virtually look black. Some of these gems are susceptible to conditions (oxidizing at high temperature) which removes some of the blue, making them much more attractive and saleable.

Corundum is also heated to change its clarity status. This is accomplished in two ways. Rutile is a mineral which, depending on conditions under which the gem was formed, may be dissolved within the corundum, and therefore not visible to the eye, or may have crystallized within the corundum as discrete needles affecting clarity and the chatoyance phenomenon. "Silky" corundum can be heated and cooled under precise conditions which will cause the rutile needles to dissolve into the corundum thereby greatly clarifying the gem; or conversely, gems with significant dissolved rutile can be subjected to heat and temperature regimes which encourage the dissolved rutile to "exsolve" into solid needles.

Heating diamond: **After diamonds have first been irradiated to green and blue green, they are often heated (a process termed "annealing") to further alter their color. Generally, such stones change to yellow or brown, but, rarely, some pieces with slightly different chemistry or crystallography, heat to highly desirable pink, purple or red colors.**

Not all diamonds react to this treatment, but when they do the results are stunning and the value of the stone jumps significantly. About 5% of diamonds can be made colorless, and a larger percentage can be made into "fancies". The fancy colors, are more subdued and natural-looking than those produced by irradiation, and unlike the case with irradiated stones, there are no obvious signs to help identify them as enhanced, so laboratory analysis is required.

Heating quartz: As with corundum, heating quartz can have various effects. Gentle heating of dark or muddy amethyst lightens the purple, and can reduce unattractive grey and smokey tones. At higher temperatures amethyst converts to yellow or orange citrine or, rarely, to yellow-green prasiolite. (Chemical or physical factors present in amethyst mined in only a few sites are of the sort that create prasiolite when heated, so it is much rarer than citrine.

Citrine <u>does</u> occur naturally, in which case Nature has already supplied the heat, but in general, natural color stones are notably lighter in tone than those produced with human help.

Smokey quartz when heated can turn yellow, also making citrine although this is less commonly done than heating amethyst. Tiger'seye which is usually a golden yellow color will become red upon heating.

Heating topaz: Two types of topaz are routinely heated. 1) White topaz, as a first step in its color enhancement, is irradiated to brown, and it must then be heated to create a *stable* blue color. 2) Much natural ("precious") topaz of a yellow or orange color, some with subtle pink overtones, is unattractively muddied with brown, which can usually be removed or reduced by heating, a process traditionally referred to as "pinking"

Both processes use relatively low temperatures, so there is little evidence left behind. Once again, it is prudent to assume that any blue or precious topaz has been heated unless it can be proven otherwise. Natural blue topaz is very rare, and when found it is generally quite pale, and pinking of precious topaz rough is standard practice virtually everywhere that it is mined.

Heating tourmaline: Heating can be useful in lightening the color of some dark blue and green tourmalines that without such treatment, look almost black. Unfortunately, not all dark stones respond to the heating. In some cases, as with amethyst, muddy tones also can be lightened or removed.

For these reasons, the majority of blue and green tourmaline rough is heated, so it is prudent to assume it. Some red tourmalines (rubellites) can be improved in color by heating, and though not common practice, it is occasionally done.

Heating zircon: Zircon which occurs naturally in orangey brown shades, has both a long history of use as a gem, and a long and creative history of enhancement by heating.

In the first step of treatment, rough zircon is exposed to temperatures of around 1000 degrees C, in a reducing atmosphere where many brown stones turn blue, some turn white and others don't change.

Those which do not respond may then be re-treated at slightly lower temperatures of about 900 degrees C, in an oxidizing environment. Results can vary from yellow to white to red.

Heating zoisite: When a transparent variety of zoisite was first found in Tanzania, Africa, there was little excitement due to its dull, brownish yellow color. Experiments with heating, though, soon yielded gems of a beautiful blue-violet color. As it turns out, heating was turning one of the color axes of this naturally trichroic gem from yellow-green to colorless, and allowing the less dominant blue and violet colors to be clearly seen. "Tanzanite" was born.

As is so commonly true of gem rough, some *individual pieces* have a typical chemistry or crystallography, and react differently to treatment than most. In the case of this type of zoisite a very small percentage of the gems heat to an attractive green to blue green color. Dubbed "Green Tanzanite" (a misnomer, but one that stuck), such specimens have high value as collector stones, and are quite beautiful in their own right.

Beryllium Heating

Beryllium heating is most commonly used to reveal yellow and orange colors in sapphires. Sapphire is often found in gem gravels together with Spinel, Tourmaline and Chrysoberyl. Latter has an influence to the color of the Sapphires if heated together: To sort out the different specimen before the traditional burning process is sometimes too difficult.

Heated together, the Chrysoberyl ($BeAl_2O_4$) volatilizes very little quantities of Beryllium (Be). This is probably a catalyst causing a thermo-chemical reaction in the Corundum's atomic structure. Once this coherence was found, it was made a point to produce Yellow and Orange Sapphire. The exact coloring process in this reaction is still unknown. The method is relatively new, hence it is also frequently called “new heating” or “heat treatment with additives”. Beryllium heating cannot be detected by standard gemological analyzing methods, only by two sophisticated and expensive tests which both are destructive.

Oiling

This method has been used for more than 600 years, mostly on fissured and porous gemstones - especially Emerald. This treatment reduces brittle fractures and may provide a better clarity. Besides colorless oils various fillers are used, e.g. wax and natural or synthetic resins. Oiling is not a permanent treatment and in some cases requires reapplication every few years, but it is generally accepted. Special care should be exercised when mounting, repairing and cleaning oiled gems. Under no circumstances oil-dissolving chemicals should be used for cleaning

Diffusion

Diffusion or “surface diffusion” is an enhancement method in which certain elements such as iron and titanium are added during the heating of the gemstone. Commonly used on Corundum, the added elements create a diffusion layer. This layer can be a colored coating or contain asterism producing inclusions, or both. This treatment is quite stable, but surface Diffused Star Sapphires or Diffused Sapphires should be handled with special care because the effect bearing subsurface is only about 0.1mm in depth. A diffused gem may lose its beauty if scratched, polished, re-cut, or otherwise damaged.

Irradiation

Hidden in the depth of Earth for millions of years, gems are undergone to natural radiation that can impinge on the colors or clarity of gemstones. If exposed to artificial gamma or electron irradiation, this effect can be used to enhance the gems. Within hours, a gemstone's color can be altered and the clarity improved. Irradiated gems do not require special care and the treatment is considered permanent, but the colors may fade with time or regress towards its previous hue in some cases (Yellow Beryl, Kunzite, Blue Topaz).

Doublet and Triplet

Doublet

Two pieces of gem material, fused together by heat or cemented with a very thin layer of colorless glue.

Triplet

A colored layer of cement joins two colorless pieces of gem material, or three pieces of gem material are joined with colorless and black cement (opal triplets).

Irradiation: (AGTA Code = R) After heating, the most commonly used treatment for gem enhancement is irradiation. With some important exceptions (like diamonds), treated stones are usually not distinguishable from untreated ones, as gems are often subject to similar, but natural, irradiaton effects during, and after, their formation.

Although the bombardment with neutrons and, to a greater extent, with electrons, can leave some residual radioactivity, its duration is relatively short. Government agencies in the USA, and other gem irradiating nations, have strict regulations for the holding and testing of irradiated gems to assure that they are not released to the public until they are safe to handle and wear.

Irradiating beryl: Colorless beryl (variety = Goshenite) can be irradiated to stable shades of yellow to gold (variety = golden beryl or heliodor). Unenhanced golden beryl is also common, and it is essentially impossible, outside of a large gemological laboratory, to tell whether it was man or Nature that supplied the color producing irradiation.

Irradiating diamonds: As presented in the section on heating gems, diamonds irradiate to green or blue green. Another color which is commonly produced via irradiation is "black". Well, actually, it is not black but a very, very, dark green, and the visual impression is definitely black.

Virtually all the black diamonds used in jewerly today are the irradiated type.

Irradiating pearls: One of the many possible enhancement processes that are used to change color in cultured pearls, the use of gamma irradiation has different effects on fresh and saltwater cultured pearls.

Irradiating quartz: Colorless quartz, rock crystal, is irradiated to produce smokey quartz in shades from light to very dark brown or grey-brown. The smokey quartz found before modern irradiation techniques were developed, and a proportion of that mined and sold today, comes pre-irradiated by Mother Nature.

Once again, with smokey quartz, we have a case where it is difficult to impossible to determine the origin of its color, and it is best to assume it has been irradiated by man, in the absence of proof to the contrary.

Irradiating tourmaline: The world's supply of attractively colored pink to red tourmaline has recently been greatly increased by new discoveries. Some Brazilian tourmalines, formerly rejected due to poor color, and the majority of the large new deposits being found in Africa, are irradiated to diminish brownish tones.

Irradiating topaz: In terms of sheer carat weight, and probably also in terms of economic value, blue topaz is the most important irradiated gem. Colorless topaz is plentiful and inexpensive, but not all of it will irradiate successfully. Treaters generally screen the rough with an inexpensive gamma ray treatment which identifies the rough which will benefit from further irradiation, before proceeding with more costly and time consuming treatments.

Waxing: (AGTA Code = W) When the surface of a gem is coated with colorless wax, (or oil) the process is termed waxing. Generally, this treatment is used with stones with a vulnerable, porous surface, or those with microscopic surface imperfections whose polish luster can be boosted with it.

Porous materials like turquoise that have been waxed, are thereby, at least partially, protected from absorbing skin oils and other environmental contaminants.

(Paraffin and beeswax are the traditional materials used, and re-doing a gem can be as simple as painting on melted wax and buffing off the excess).
Most of the world's highest grades of turquoise and jadeite can be assumed to have been given this treatment. It is also occasionally used with lapis lazuli, rhodocrosite, serpentine, variscite and Amazonite.

Dyeing: (AGTA Code = D) Dyeing is relatively easily accomplished with porous gems and those crystalline gems which are aggregates. The pores and the spaces between the microcrystals allow the dye to be taken up. Single crystal gems, however, are not good candidates for dyeing as they will only take up dye where they have surface reaching fractures.

There is really only *one case* in which dyeing is an "accepted industry standard", and has no effect on the value of the gem: black onyx. All other instances of dyeing (when disclosed) negatively affect the value of the gem, in some cases, dramatically.
Examples of porous and aggregate gems which are frequently dyed are chalcedony, jade, coral, pearls, and howlite.

Bleaching: (AGTA Code = B) Probably the most routinely bleached gem, is pearl. Historically, long before cultured pearls were invented in the early 20th century, pearl fisherman would spread their treasures out in the bright sunshine, carefully rotating them over a period of time, which tended to lighten and even the color, and diminish some unsightly dark spots.

Light is still used in some pearl processing facilities. (Anyone whose hair gets lighter in with long exposure to sunshine, or whose window drapes have faded over time, will realize how effective a bleach light can be.

In addition to light, chemicals such as hydrogen peroxide (Lady Clairol, anyone?) and chlorine (as in Clorox bleach), speed up the process, but on delicate organic gems like pearl and coral, must be used at low strength and with care.

Impregnation (aka "stabilization"): (AGTA Code = I)

When a colorless, hardened, resin is suffused *throughout* a porous stone to make it more durable or improve its appearance, it has been impregnated. A common market term for such gems is "stabilized". There is only one imporant type of gem for which this treatment is essential--> without impregnation, ammolite is too fragile to withstand fashioning or wear. Unenhanced specimens, exist, but are suitable only for display.

Other gems like jade or turquoise are commonly treated in this manner. Low grades of highly porous turquoise that may have nice color, but are excessively fragile, or near impossible to polish, can be greatly improved by resin impregnation. "B" and "C" jades, after being acid bleached have resin infused into the resulting cavities (if the resin is colored, then the piece is considered dyed, "C" jade).

Oiling: (AGTA Code = O) and Filling: (AGTA Code = F) Both of these types of treatments involve the filling of surface reaching fractures or cavities with colorless oils, resins, or glass. They are done for the same reason: to clarify a gem, by decreasing the relief of the fracture or cavity. The difference between them hinges on whether the filling material is essentially a liquid (oil or unhardened resin) or solid (hardened resin or glass).

Of the two, oiled gems are more accepted in the gem marketplace and do not depress value greatly. Even though the oil treatment is temporary, the favorable viewpoint comes both from the long standing and widespread use of gem oils, and the fact that it can be successfully be re-done if necessary. Virtually all emeralds are oiled, some as rough at the mine site, others only after they are cut. Certified unoiled emeralds bring a 10% - 20% price premium. If the oil is colored, then the emerald is considered to be dyed, and its price is much more severely affected

Filled gems are another matter. Although it can be argued that the filling, being hardened, is less likely to evaporate or be dislodged by cleaning and wear, several factors create a generally negative impression that translates to a drastic effect on gem prices.

The solid resins can discolor and become more opaque with age, and since they cannot be removed, will then permanently degrade the gem's appearance. Fairly large areas can be filled with solids, which are less durable than the host gem and can become scratched, chipped or dulled with wear.

This process is primarily used with rubies and diamonds, both very valuable gems, so it must not be forgotten that these chunks of glass or plastic resin are adding weight to the gem. That is, adding weight of a material which is <u>not</u> valuable, but which the customer is paying for.

Gems which are properly disclosed as oiled or filled, should include appropriate care instructions. For example, oiled emeralds should not be steam or ultrasonically cleaned. Jewelry containing filled rubies and diamonds should not be repaired or resized without removing the gems from the settings, as heat from a torch or immersion in metal cleaning solutions can cause melting or etching of the filler.

Laser drilling: (AGTA Code = L) Thus far, this treatment, a type of clarity enhancement, has been seen only in diamonds, and is virtually always combined with acid "bleaching" and fracture filling. The purpose of the tunnel created by the laser is to provide a channel for the acid and glass, or resin, to enter.

Diffusion: (AGTA Code = U) When gems are diffused, they are heated to very high temperatures, just to the verge of their melting points. This heating is done in the presence of a material which contains chromophores such as titanium, chromium or other atoms, which are then able to diffuse into the stone's surface or interior to change color or create phenomena. Two such processes are currently in use: 1) surface diffusion, and 2) bulk or "lattice" diffusion.

Surface diffusion has been around for decades and, until recently, was pretty much confined to use on blue sapphires and the occasional ruby. By packing already faceted, light colored stones into a container with powdered titanium and iron, and heating to very high temperatures, a thin surface layer rich in these chromophore elements is formed, which through selective absorption, greatly darkened the apparent blue color.

Bulk or lattice diffusion was discovered to be occuring in 2003 when stones that began appearing the market in 2002 were critically examined. The gems were sapphires of an extremely rare and valuable color called "padparashah" (orangey pink). The inexplicably large numbers of fine colored stones suddenly available, raised questions that led to a fervor of activity among the staff gemologists in organizations such as AGTA and GIA.

Athough the treaters were freely acknowledging that the gems had been heated, they insisted that that was the end of the story. Adding to the confusion, the stones did not fit the profile of diffused gems as the color penetrated well into the interior--> in many causes completely throughout the stone.

Coating: (AGTA Code = C) Coated gems are those that have been treated with surface enhancements such as laquering, inking, painting, foiling, or sputtering of a film to enhance color, improve appearance or add phenomena.

Coating has a long history: from use of gold foils in antiquity, to the painted back Rhinestones of the 19th century, to today's iridescent metallic coatings. Coatings are usually fairly easy to detect, but can escape notice if they are applied only to back of the gem (as in a "foilback") and the gem's setting is fully closed. The coatings of foilbacks range from crude and obvious, to sophisticated and well hidden

Gemstone enhancements are procedures applied to gems to improve their appearance and wearability. There are many kinds of treatments. Some have been used for centuries, while others are recent. People in the gem industry choose treatments based on the gem type and the desired effect. Although some gemstone enhancements are commonplace, the gem-buying public remains relatively unaware of these practices.

Common Gemstone Enhancements

Heat Treating

The most common form of enhancement is heating. For example, jewelers should inform their customers that rubies and sapphires are “probably heat treated,” since heating is so common for corundum gems. Heating enhancement so closely resembles what happens in nature that you can’t always tell if gems have been treated after mining. Sometimes, microscopic examinations can reveal evidence of heating. Otherwise, there is no way to tell if the heating was done before or after mining.

Radiation

Yes, radiation. (Now you know why some in the gem industry are nervous about full disclosure). Radiation is a scary word. Revealing that a gem was irradiated will likely drive away customers. But just as with heating, radiation enhancements duplicate what happens in nature. During their formation, radioactive elements affect many gem crystals. That doesn’t mean these gems are radioactive or otherwise harmful.

Most blue topaz gems are colorized in a two-step enhancement process. First, radiation modifies electron sharing between certain atoms in the crystal structure of colorless topaz. This turns the topaz brown. Next, heating creates a stable blue color.

Oiling

Some gems, notably emeralds, have internal fractures. Light reflection off their surfaces seriously affects the clarity and brilliance of these stones. Simply filling these fractures with a substance with similar optical properties makes these tiny cavities transparent. The difference in the appearance of the finished gem can often be startling!

Unlike heat and radiation, oiling gemstones doesn't mimic a process that occurs in nature. To gem cutters, oiling poses a serious problem, because those tiny fractures represent structural weaknesses. They must consider these areas in the cutting process. Oil-masked fractures increase the risk of damaging a gem during cutting. To gem owners, oiling is well worthwhile. The oil filler isn't visible. It simply allows the natural beauty of the stone to shine. For them, gemstone enhancements like oiling increase both the emotional and monetary value of the gem.

Jewelers should tell buyers that oiled gems need special care. For example, frequently washing dishes while wearing such a stone can make it less brilliant. Vigorous cleaning methods, like using heat or an ultrasonic system, can be disastrous.

Dyeing and Sealing

Gemstone enhancements can be applied to less expensive gems, too. Dyes are common treatments for stones such black onyx. Jewelers often seal porous materials like turquoise with surface coatings, such as paraffin wax, so body oils won't cause discoloration.

Filling

Diamonds, rubies, and sapphires can be filled with lead glass to improve their clarity.