SYNTHETICS AND SIMULANTS

Synthetics are man-made gem products.

Synthetics can be *exact copies* of natural gems, or they can be *unique materials* which are <u>not</u> found in Nature (these are called artificial products).

SYNTHETICS AND SIMULANTS

Examples include the synthetic rubies and emeralds. Such creations have virtually the same optical, chemical and physical properties as their natural counterparts.

SYNTHETICS

The Federal Trade Commission is quite specific in forbidding the use of the term "gem" or "gemstone" (or any recognized species or variety thereof), unless that product is solely and exclusively the work of Nature.

All other products offered for sale must be clearly identified with a readily understood adjective that indicates their synthetic status. Acceptable terminology for synthetics is variable, but would include product labels similar to the following: "synthetic gemstone", "laboratory-grown ruby", "cultured pearl", "created emerald", "man-made sapphire", "reconstituted turquoise".

[Synthetic, Chatham brand, emerald crystal cluster set as a pendant]

Artificial Gemstones

Man-made wholly "artificial" gemstones with no natural counterparts at all, include:

- **Cubic zirconia (CZ)**
- **YAG (yttrium aluminum garnet) and**
- **Artificial garnet GGG (Gadolinium Gallium Garnet).**

YAG, a popular synthetic widely used in industry and as a gem, can be made in a variety of colors from white to pink to green, and has no analogue in Nature

natural pearl and synthetic ruby ring

NON-GEM USES OF SYNTHETICS

- **Outside their use as synthetic or simulant gems, physicists and chemists make large quantities of both copies of natural gems, and totally artificial ones, for industrial and research purposes.**
- **At present over 90% of the diamond abrasives ("bort") for industry, used in everything from the saws that cut through pavement, to dentists' drills, are synthetics produced in a laboratory. Laser and electronic technologies depend strongly on the properties of laboratory created crystals. Even a cheap "quartz" watch has, at its heart, a synthetic quartz crystal. Lasers based on synthetic crystals are used in medicine in a wide variety of ways from surgery to removing tattoos to improving vision.**

Crystal Formation Processes

Both in Nature, and in the laboratory, there are three basic ways in which crystals form.

- ***Melt*** (a molten material solidifies)
- ***Solution*** (a solid is precipitated from a liquid in which it was dissolved)
- ***Vapor*** (a solid material condenses from a gas in which it was dissolved)

Crystal Formation Processes

We now will survey the most widely used gem crystallization processes, and the types of gems they produce:

<u>Melt Processes</u>:

- **Flame Fusion**
- **Czochralski "Pulling"**
- **"Skull" Melting**

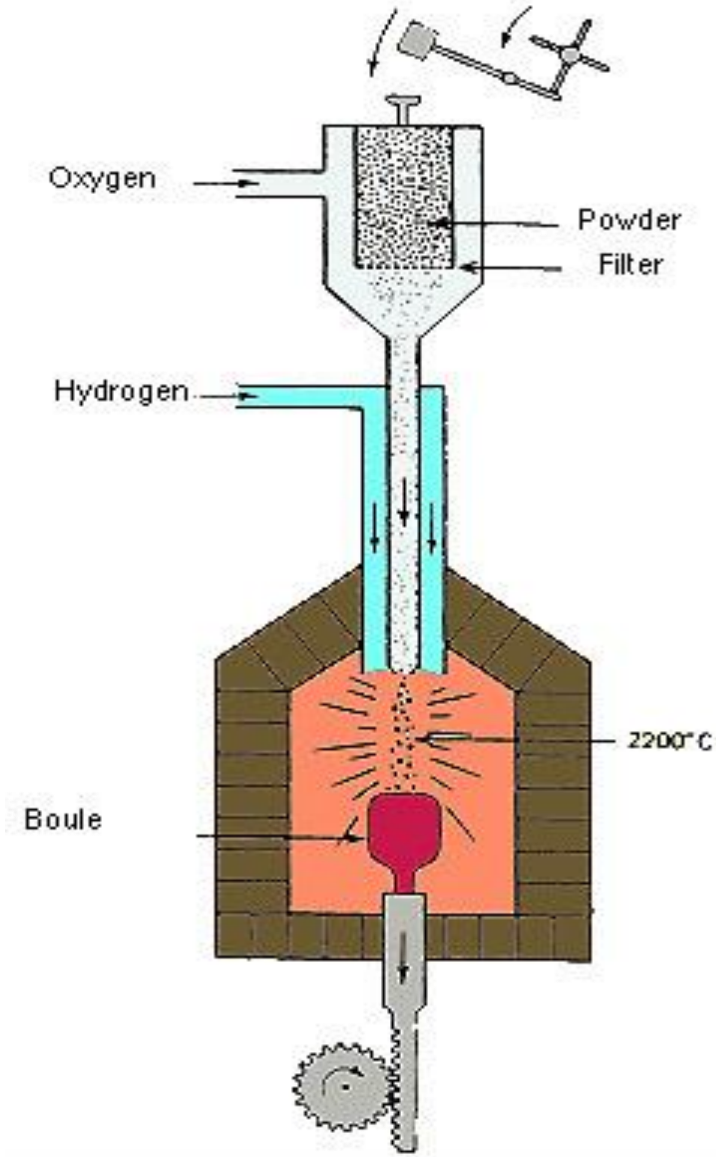
Melt processes

In each of the melt processes the powdered solid ingredients necessary to make the gem are brought to their melting point and then allowed to cool in such a way that a single large crystal or cluster of large crystals is formed. The three processes, each suitable for making different materials, differ primarily in the temperatures used, the type of container, the heat source and the nature of the surface on which crystallization occurs.

Melt processes

Flame Fusion

The process commercialized so successfully by Verneuil, is termed "flame fusion". It is simple in theory and in practice. Corundum is Al_2O_3, crystallized in the trigonal system. All that is necessary is to melt the raw material, aluminum oxide powder, and allow it to crystallize. If you want ruby, you just need to add a small amount of chromium oxide to the mix (Cr is the chromophore that creates red in ruby). Although the process has been scaled up for today's large factories, it is, in essence unchanged since Verneuil's time. Synthetics produced in this manner are the least expensive, and most commonly used types. So much so, that over one billion carats per year of flame fusion synthetic corundum, synthetic star corundum, and synthetic spinel are made.



The Verneuil "flame fusion" process for production of synthetic gems

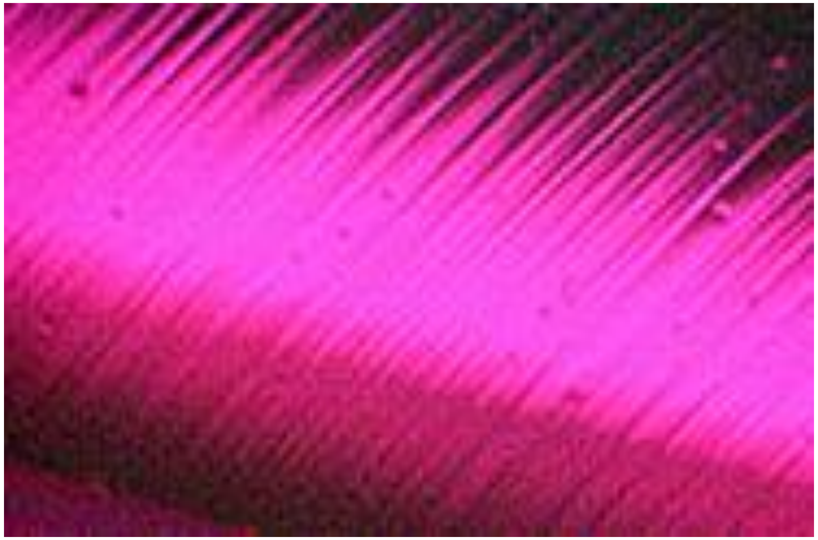
Verneuil "flame fusion" process

The powdered ingredients fall into a chamber heated to 2200 ^{0}C by an oxygen-hydrogen torch flame. As they fall they melt. Upon reaching a ceramic rod in the bottom, cooler, area of the chamber, they crystallize. Slowly the ceramic rod is turned and lowered creating from the melted corundum a carrot shaped crystal called a "boule". The shape of the boule is characteristic, and is *not* one that is found in Nature.

Synthetic ruby: split boule, faceted stone, star stone]

Flame fusion

Flame fusion synthetics are among the easiest types to identify. Their most characteristic feature is curved growth rings (called curved striae) that can be seen under magnification with appropriate lighting. In addition, sometimes coloring is uneven and follows the growth, making for curved color zoning. ***In the single crystal gems made by Nature, <u>there are never any curved growth features or curved color zoning, so their presence is a dead give away. The presence of bubbles is also occasionally a tell-tale sign.</u>***



Curved striae seen in a cut synthetic ruby at 25X, under diffused lighting

Czochralski "pulling process"

It was the needs of science and industry, rather than those of the jewelry trade, which prompted the development of the Czochralski "pulling" melt process. Emerging laser technology demanded larger diameter, strain-free, higher clarity crystals than could be produced by the flame fusion process. Only later did the jewelry market begin to eagerly absorb some of the production.

Czochralski "pulling process”

In this process, the gem source materials are melted in a metallic (usually platinum) crucible using radio frequency energy. A thin, flat, seed crystal (either natural or synthetic) is lowered to just touch the surface of the melt, then slowly rotated and withdrawn ("pulled"). The slower the rate of pulling, the larger the diameter of the resulting crystal boule.

Czochralski "pulling process”

The seed gives the solidifying materials both a surface on which to crystallize, and an atomic scale "pattern" to follow.

Czochralski "pulling process"

Although many exotic materials (like gallium arsenide) are made for exclusively for industry, YAG, corundum, Alexandrite, and cat's eye Alexandrite are the major gem materials produced by this method.

Production expenses are much higher than those of the simple flame fusion process, so the products are more costly as well.

Czochralski "pulling process”

YAG: a simulant for emerald and Tsavorite garnet, and a durable, brilliant material in its own right]

Pulled synthetics

Pulled synthetics are very difficult to identify microscopically as the crystal that forms on the seed is usually flawless, and the large diameter of the boule makes observing the curved striae difficult. ***<u>On occasion, they may contain triangular or hexagonal platinum crystals eroded from the walls of the crucible, which will conclusively identify the piece as synthetic.</u>***

"Skull" Melting

The commercial production of cubic zirconia, first accomplished by Russian scientists in the 1970s, required some ingenuity. The melting point of CZ is well over 2300 degrees C, which rules out the use of metal or ceramic crucibles. The problem was solved by using an externally cooled crucible filled with the powdered ingredients and then heating it with focused radio energy that melted only the center. The unmelted material formed its own insulation, or "skull". As the melt slowly cooled, large, usually flawless, crystals were formed.

"Skull" Melting

At present, CZ is the only material produced in this way, and costs are kept down by the large yields from each batch *(currently the retail price of CZ rough is about $0.05 per carat).* Various colors are produced, but for the great majority of CZ is sold in its colorless form as a diamond simulant.

"Skull" Melting

Although it is easy to identify by its optical and physical properties like density, thermal conductivity, and dispersion, microscopically, there are few signs of CZ's synthetic origin. Rarely, tell-tale bubbles can be seen

Solution Methods

The characteristic feature of these processes is that rather than being melted, the source materials are dissolved in a solvent (not always water), and put under high temperature and pressure. The supersaturated solution is slowly cooled, and the gem crystallizes onto a natural or synthetic crystal "seed"

Solution Methods

If the solvent is water, the process is termed *"hydrothermal",* if it is another substance, then the process is called *"flux".* Because of the high temperatures and pressures involved, strong sealed metal containers are used to hold the solutions.

Solution Methods

Some gems, like emerald and quartz, can <u>only</u> be made by solution methods. In other cases, such as with ruby and sapphire, solution methods are an alternative method of production.

Solution Methods
Hydrothermal

Hydrothermal: As the name indicates, this type of process uses water as the solvent. The vessel in which the gems form is lined with silver and referred to as a "bomb".

Solution Methods

Hydrothermal

Hydrothermal synthetics are relatively expensive, as the equipment used is pricey, and the yields are small and slow to form (weeks to months). Because this process so closely mimics what occurs naturally in the Earth's crust, the majority of inclusions in such gems are natural looking, making them hard to identify. Occasionally, cut gems will show part of the seed plate or a distinctive non-natural looking inclusion called a "nailhead spicule". *The primary gems produced by this method are emeralds, corundum (especially ruby) and quartzes in a variety of colors including blue.*

Hydrothermal synthetics: emeralds

Hydrothermal synthetics: rubies

Flux

In some cases the solvent in which the gem source materials are dissolved is not water, but another material like *lead fluoride or boron oxide,*

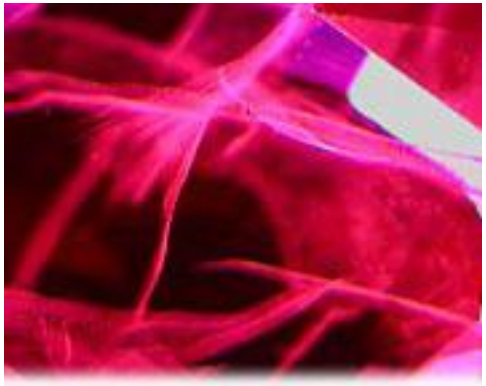
Flux

These materials have in common that they have a higher temperature of crystallization than the gem. As the temperature in the crucible is lowered, then, the gem crystallizes first, separating out of the still-liquid flux. The process is slow and expensive. The highly corrosive nature of the fluxes means that crucibles must be made of a very resistant metal like platinum, iridium or gold, and the process can take months.

Flux

Ruby, sapphire, quartz, emerald, Alexandrite, YAG and red spinel are the major gems produced in this way. Although expensive as synthetics go, the resultant gems have natural looking inclusions, the most notable of which are sometimes called "wispy veils".

Consisting of crystallized flux within minute cracks in the gem, they are so like natural fingerprint inclusions in their appearance that it takes a well-trained eye to discriminate them.



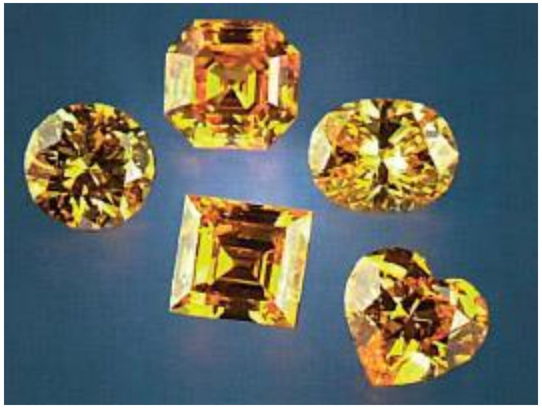
Flux rubies, magnified "wispy veil" inclusions in a flux grown synthetic ruby

Vapor Method

The third possible way to make gems synthetically is by vapor deposition. At present only diamonds have been made this way.

Diamond Synthesis

The first successful synthesis of diamond was accomplished in 1955 by scientists at General Electric Corporation. These were tiny, 0.15 mm. crystals meant for industrial use. By 1958 the cost of synthetic diamond "bort" was competitive with natural, and today industrially produced diamond abrasives dominate the market



Gemesis created fancy color diamonds

Chatham created fancy color diamonds

CVD, Chemical Vapor Deposition

The third of the possible gem synthesis processes (condensation from a vapor) has been pioneered, by Apollo Corporation, for the production of diamonds**. In this approach, a vacuum chamber (at .1 atm of pressure) containing a thin diamond seed crystal is filled with methane gas (CH_4) at 1000 degrees C. At that temperature and pressure regime, the carbon in the gas separates from the hydrogen, and crystallizes upon the diamond seed surface**

Simulants

Also known as imitation or faux gems, simulants *look like* what they imitate, but they don't have the chemical, physical and optical properties of the gem they mimic.

Some are man-made, and some are natural gems in their own right.

Natural Gems as Simulants

It is very common for one natural gem to be used to imitate another of similar appearance. For example serpentine, aventurine quartz and hydrogrossular garnet, all have long histories as jade simulants.

Likewise, bone is a common substitute for ivory, and white zircon has long been enjoyed as a natural diamond simulant. Red spinel commonly is substituted for ruby, sodalite for lapis lazuli, and copal for amber.

Man-made Simulants: Glass and Plastic

Glass: Although its historical roots go way back, glass is still one of the most popular gem simulants today. Glass, itself, is an amorphous material, but its main raw material, silica sand (quartz), is crystalline. In glass-making sand is mixed with certain other materials and melted; then it is cooled so quickly that crystallization doesn't occur.

Plastic

Most people would be surprised to learn how far back the manufacture of plastics goes. By the late 1800's the "plastic age" was well into its beginnings. The earliest plastics, like vulcanite, Bakelite, celluloid and lucite were used for a wide variety of purposes, including among them gem simulation.

Diamond Simulants

Synthetic diamond simulants entered the picture around 1910 when colorless sapphire was first produced by the flame fusion process. This was followed by the introduction of colorless synthetic spinel (1920), synthetic rutile (1948), strontium titanate (1955), YAG (1960), CZ (1976), and Moissanite (1996).


white zircon


synthetic rutile


strontium titanate


YAG


CZ


Moissanite

Diamond simulants natural and synthetic:,

Assembled Gems

Also known as <u>composite gems</u>, assembled gems are made of two or more pieces of gem material joined together. They can be used as to simulate (or fake) another gem, or just for their own sake, for example to make an artistic gem creation, or to make a particular gem material more durable or useable.

Doublets and triplets

Usually a doublet consists of a thin layer of some valuable, fragile, or rare gem material backed with a thicker layer of something sturdy, and less expensive. If the piece is unmounted, or set in prongs, it is usually very easy to see the demarcation line between the top and the bottom.

Sometimes the backing is simply used to provide contrast or create an artistic effect.

Doublets and triplets

A triplet is a doublet with a third, top, layer made of a tough transparent material like colorless quartz.