Synthetic gemstone growth techniques

Three basic groups of growth techniques are used for almost all synthetic gemstone productions. Crystals can be grown from a melt, from a solution, or by vapor deposition.

Melt techniques

Verneuil flame fusion

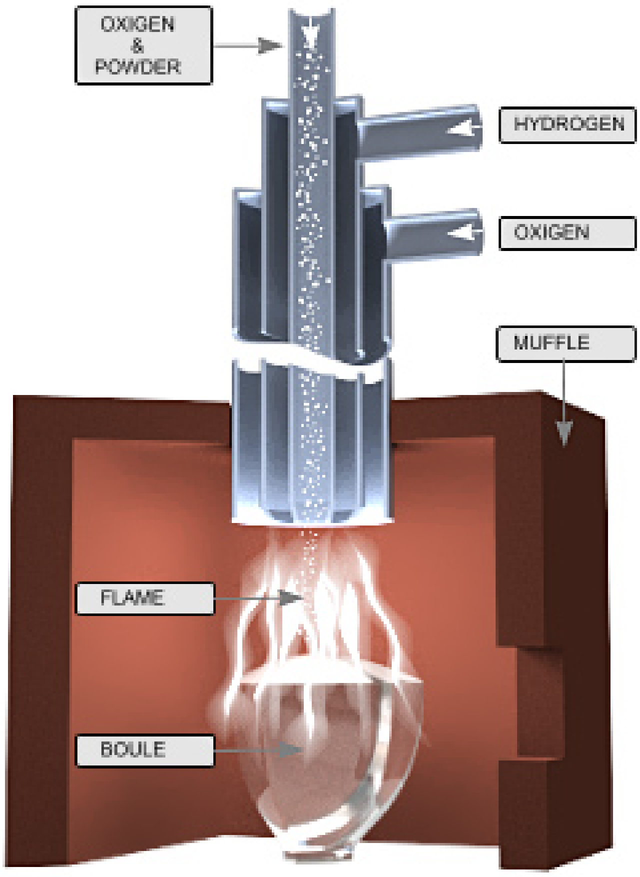

Fig. 24.: Verneuil's technique method where melting occurs in the hottest part of the flame and the melt solidifies on the boul

In the melt techniques, the starting point is a mixture of chemical elements or compounds, which will provide the composition of the substance to be crystallized. The mixture is melted and then cooled in a controlled fashion so that large single crystals grow upon solidification (freezing).

See Alexandrite Tsarstone collectors guide, Synthetic gemstone growth techniques, http://www.alexandrite.net/viewpage.html?id=ALXS-002-00012 (Information about melt, solution growth and vapour deposition techniques used for synthetic gemstones manufacturing) (as of).

The growth of ice crystals at the edge of a roof or ice cubes in a freezer are the most familiar examples of this kind of growth.

The major melt techniques include the Verneuil flame fusion method and Czochralski's pulling technique. Ruby, sapphire, spinel, YAG, GGG, rutile, alexandrite, strontium titanate and cubic zirconia can be produced by melt processes. The choice of a particular method depends on the properties of the melt, the melting temperature, the size requirements and the cost of the vessel, especially when platinum or iridium containers are involved. The so-called "skull" melting technique has been used only in the case of cubic zirconia, because of the very high melting temperature of the ZrO2.

Originally developed for growing large ruby boules, the Verneuil flame fusion technique was the first to produce synthetic gemstones. It has been used to produce sapphire, spinel, rutile, and strontium titanate. This technique still produces the bulk of today's synthetic corundum and spinel and used for growing sapphire of different colors, ruby, star sapphire and star ruby.

Czochralski´s pulling technique has been used to produce many kinds of synthetic stones including rubies, YAG, and Alexandrite. Pulled crystals are typically much larger and cleaner than crystals produced by the Verneil process. The skull melting process is used to produce cubic zirconia.

Solution growth

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Hydrothermal technique

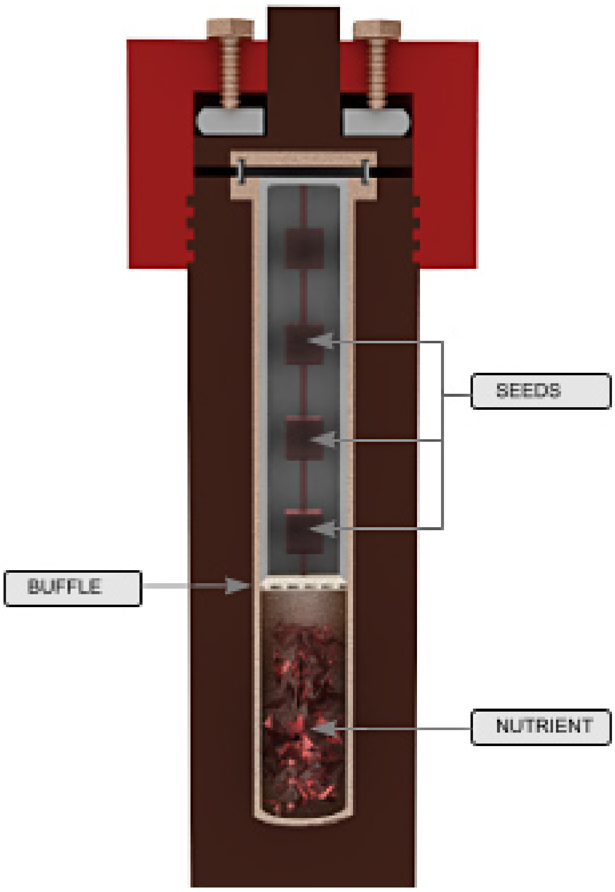

Fig. 25.: High pressure, high temperature autoclave used for hydrothermal synthesis of quartz crystals.

Although melt growth techniques provide for rapid growth and are basically simpler and easier to control than techniques starting from solution, there are certain materials where melt techniques cannot be used. In the case of quartz where the melt is too viscous, or in the case emeralds where the melt is immiscible, solution growth in one of its variants is more suitable.

One type of solution growth from water at high temperatures and pressure is known as the hydrothermal technique. Growth from solution is achieved by an increase in saturation. Like adding increasing amounts of sugar to water, the sugar will dissolve until the solution is saturated and can absorb no more and then it will begin to re-crystallize. With cooling, crystallization will increase and with heating it will decrease. A seed crystal is often employed to initiate the crystallization and to provide a point for the deposition to begin. Crystal growth rates are a function of time, temperature, and concentration. Hydrothermal techniques are used to make emeralds, quartz, rock crystal and amethyst.

In the hydrothermal process, powdered or crystalline nutrient is placed at one end of a pressure-resistant tube. A seed crystal is mounted on a wire frame near the other end and a water-based solution is added to the tube which is then sealed shut. The tube is placed in a furnace chamber with the nutrient-containing end of the tube resting on a heating element. As the floor of the furnace is heated, the bottom end of the tube becomes hotter than the top and dissolved nutrient material migrates toward the seed and crystallizes on its cooler surface.

Another type of solution growth is the flux technique where crystals are grown directly from the molten solvent. This process utilizes powdered chemicals of the correct composition and adds a liquid solution to dissolve the compound before super heating. The dissolved solution is known as a flux. As the solvent evaporates and the flux begins to slowly cool and crystallize. This process has been used to grow emeralds, rubies, sapphires, spinel, YAG, GGG, and alexandrite.

Solution growth may also be used to grow diamonds by a process known as HPHT (high pressure high temperature). HPHT also begins with a tiny diamond seed. In washing-machine-sized diamond growth chambers, each seed is bathed in a solution of graphite and a metal-based catalyst at very high temperatures and pressures. Under highly controlled conditions, the small diamond seed begins to grow, molecule by molecule, layer by layer, emulating nature´s process.

Vapor deposition

Chemical vapor deposition, (CVD) is the most recently discovered technique for crystal growth. Variations have been used to produce rubies, sapphires, and diamonds. Here, the material to be crystalized is vaporized at high temperatures. As it is cooled, it is deposited upon a seed crystal. In a typical CVD process the substrate is exposed to one or more volatile precursors, which react and/or decompose on the substrate surface to produce the desired deposit. CVD research is still in its infancy. For diamonds, the CVD process will be most interesting not only because gem-quality diamonds can be grown so quickly, but because the sizes and the impurities can also be controlled. The only limiting factors in size will be the size of the seed crystals and the growing time. Diamonds with the right properties will be produced to meet specific requirements for industrial or electronic applications. New applications for diamonds that had previously been either too expensive or too difficult to implement will become economically viable.

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