CHART OF COMMERCIALLY AVAILABLE GEM TREATMENTS

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This chart combines a comprehensive listing of the commercially available treatments for the most commonly used gem materials with an indication of the current status of their detectability. Designed as a supplement to "Gemstone Enhancement and Detection in the 1990s," from the Winter 2000 issue of *Gems & Gemology*, this chart makes the key information available in an easy-to-use reference tool.

For many centuries, a wide variety of techniques have been used to improve the appearance of gems. Early treatments typically involved changing the perceived color of stones through simple methods such as dyeing, painting, or backing them with a thin layer of foil. However, as time progressed, so did the sophistication of gem treatments. Today, there exist a vast array of methods to modify the appearance and/or properties of most gem materials (see figure 1), from rudimentary procedures such as dyeing to "high-tech" processes such as the high pressure/high temperature annealing of diamonds (Hall and Moses, 2001a,b).

Although many of the most common treatments can be identified with basic gemological training, experience, and equipment, more and more of the treatments entering the marketplace can only be detected with sophisticated analytical instruments and highly specialized expertise. It is also important that the gem and jewelry trade recognize that not all treatments are currently detectable. This is typically because of the nature of the treatment or the gem material, or a combination of the two. There are also treatments that are detectable in some cases and not in others.

This chart has been compiled to summarize the full range of treatments that may be encountered in the most common gem materials. Mentioned for each gem material are the changes that typically take place, as well as the treatment's current detectability.

A comprehensive discussion of the various treatments encountered in the gem and jewelry trade was provided in McClure and Smith (2000). This chart is intended to complement that original publication by condensing the information found therein into a more concise, easy-to-use reference tool. For more specific information regarding the detection or development of certain treatments, the reader is referred to that article. Note, however, that the chart also includes information relating to new treatments that have emerged in the last two years. References to these additional treatments, as discussed below, are provided at the end of this article. References listed in McClure and Smith (2000) will not be repeated here.

CHART CONTENTS

Although almost any gem material can be treated in some fashion, in general there are relatively few types of treatments. The following classifications, listed at the top of the chart, represent the most frequently encountered treatments in the gem and jewelry trade

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Figure 1. Many methods are now used to enhance gems. Illustrated here are, from left to right, starting at the top: (row 1) 5.66 ct clarity-enhanced emerald, 10.60 ct heated amber, 3.44 ct plastic-impregnated opal; (row 2) 4.48 ct "diffusion-treated" topaz, 2.51 ct irradiated pink tourmaline, 2.14 ct Ti-diffused sapphire; (row 3) 3.73 ct coated pink topaz, 0.92 ct thermally enhanced tanzanite, 1.29 ct Be-diffused yellow sapphire, 0.94 ct Be-diffused pink sapphire; (row 4) 1.03 ct clarity-enhanced diamond, 2.06 ct thermally enhanced ruby, 0.77 ct Be-diffused ruby. Photo © GIA and Harold & Erica Van Pelt.

today. Also addressed here and at the top of the chart are key methods of detecting these treatments.

Dyeing. This treatment consists of the introduction of a colored substance into gem materials that have either a porous structure (such as agate or turquoise) or surface-reaching fractures (such as quartz or corundum), to modify their color appearance.

Detection: In most gem materials, dyeing is readily detectable with magnification, sometimes in combination with a diffused light source. Concentrations of color are often present along surface-reaching fractures or within areas of a porous structure. In some instances, gems may be dyed to hues that do not exist in nature, which alone proves the presence of dye (such as with agate). However, in some gem materials that are structurally porous (such as coral, jade, or turquoise), dyeing may not always be detectable. For other gem materials (such as gray to black or "golden" pearls) more advanced analytical techniques such as energy-dispersive X-ray fluorescence (EDXRF), UV-Vis-NIR, or Raman spectrometry may be necessary (Elen, 2001, 2002). In addition, dyeing of some gem materials may be detectable with certain dyes and undetectable with others. For example, dyed green jadeite usually can be detected with a handheld spectroscope. However, most other colors of dyed jadeite, such as lavender, black, brown, and yellow, may not be detectable at all.

Chemical Bleaching. This treatment involves the use of chemicals to lighten or whiten the color of some gem materials, as well as to remove unwanted or uneven coloration.

Detection: Typically this form of enhancement is not detectable, even though it is commonly applied to several gem materials, such as coral, ivory, jade, and pearls. One exception to this general rule is jadeite, where the effects of the bleaching process on the granular structure of the jade may be detected with magnification.

Surface Coating. This treatment may have a variety of desired results, depending on the material that is applied. These include: (A) the application of a colored substance to all or part of the surface of a gem to induce or modify the color appearance; (B) the application of a metallic substance to produce iridescence on the surface; (C) coating with a wax or plastic to improve the surface luster or durability of the gem.

Detection: Surface coatings are most readily identified with magnification, by the presence of features such as scratches, areas at facet junctions where the coatings have been worn off, and tiny bubbles trapped in the coating. Metallic/iridescent coatings are readily recognized because the appearance they create does not occur naturally.

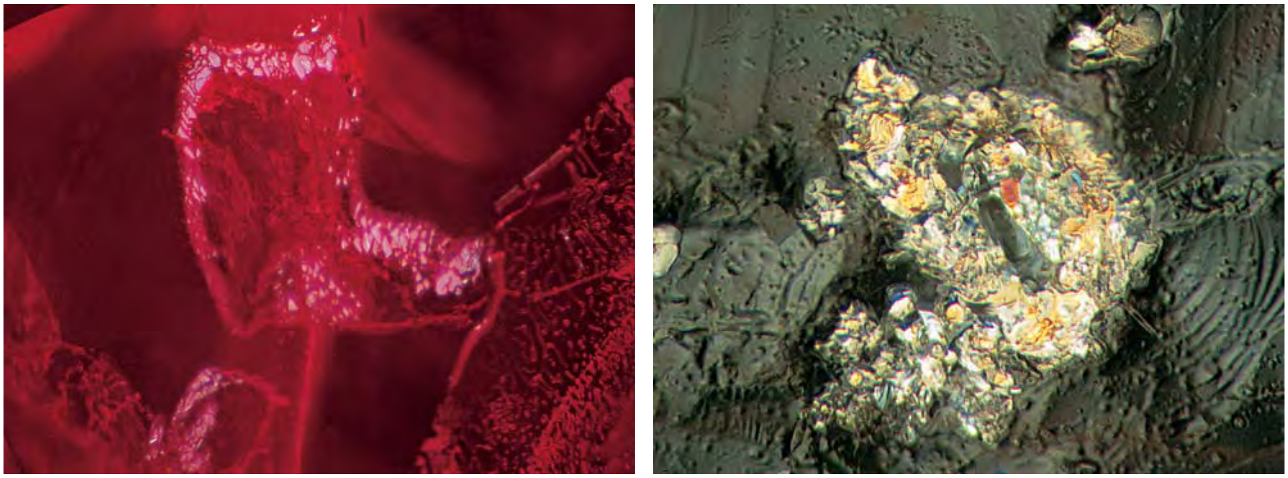

Figure 2. When rubies or sapphires are exposed to high temperatures, especially in the presence of a flux, synthetic corundum may be deposited on the surface of the gems. As shown on the left (magnified 33×), platelets of synthetic corundum have formed on the surface of a rough sapphire that has been treated by a Be-diffusion process. On the right (magnified 40×), small platelets of synthetic corundum can be seen lining the bottom of a glass-filled cavity in a Mong Hsu ruby. Photomicrographs by Shane F. McClure.

Impregnation. In this treatment, voids within a porous gem material are filled with a wax or polymer to improve the gem's durability, luster, transparency, or color appearance.

Detection: Typically, wax impregnation may be detected with the use of a "hot point" and magnification. Infrared or Raman spectrometry will readily identify polymer as well as wax impregnation.

Thermal Enhancement. Heat is applied to many gem materials to modify their color and/or clarity. Some gems may need only "low temperature" (e.g., less than 1,000°C) heating to achieve the desired results, while others require higher temperatures. In addition, some gem varieties (such as ruby and sapphire) may be exposed to either low- or high-temperature heating, and other gems (such as diamond) may be exposed to high pressure in conjunction with high temperature (HPHT).

For the vast majority of the gem materials treated in this manner, the application of heat is intended to improve their color. In the case of rubies and sapphires, heat is also applied to improve their transparency by dissolving rutile inclusions. In addition, corundum may be heated to facilitate the healing of fractures, either with or without chemical additives ("The Gübelin Gem Lab introduces . . . ," 2000). Another effect of exposing rubies or sapphires to high temperatures, particularly when a flux is used, is the deposition of synthetic corundum on the surface of the gems (McClure, 2002; "Further characterization . . . ," 2002; see figure 2). The heating process also often leads to the production of glass-like materials that can fill cavities and surface-reaching fractures in some rubies.

Detection: In corundum, heating is routinely detected by the presence of thermally altered inclusions (such as strongly altered crystals or healed fractures) or modified color concentrations (such as the spotty coloration of some heated blue sapphires), which are observed with magnification. For certain gems (such as some ruby, sapphire, or pink topaz), ultraviolet fluorescence may also provide an indication of thermal enhancement. However, there are still a number of gems (such as quartz, tourmaline, and tanzanite [zoisite]), where the color is modified homogeneously and there are few inclusion features present to indicate exposure to elevated temperatures. The heat treatment of such gems is typically undetectable or in some instances requires more advanced analytical techniques (such as UV-Vis-NIR or Raman spectrometry). Additionally, there are some gem species (such as corundum or diamond) where the detection of heating is possible in most cases, but not in all.

Diffusion Treatment. Today, we understand more fully that virtually all types of thermal enhancement involve some form of diffusion. The term *diffusion* refers to the movement of atoms or defects within the crystal lattice of a gem. The movement of pre-existing atoms is what makes thermal enhancement work (this phenomenon is referred to as *internal diffusion*). Diffusion *treatment* refers to the introduction of color-causing atoms from an outside source that then enter and move through the gem. When this movement is only at the surface, it is referred to as *surface diffusion*. If the movement is into the body of the stone, whether it is shallow or permeates the entire gem, it is properly called *bulk* or *lattice diffusion* (Emmett and Douthit, 2002b). It is important to note here that the historical use of the term *surface diffusion* in gemology is incorrect (Kizilyalli et al., 1999).

Many elements may be diffused into the lattice of a gem from an external source in order to produce color or create asterism. These include light elements such as beryllium (Be), or elements further down the periodic table such as titanium or chromium.

Detection: When heavier elements are diffused into a gemstone from an external source, the treatment is readily detected with magnification and immersion by the very shallow color penetration that results, as well as—with EDXRF or scanning electron microscopy–energy-dispersive spectrometry (SEM-EDS)—by the elevated concentrations of the diffused elements.

When light elements are used, the treatment may be less readily detectable, since the penetration of the diffused color may extend homogeneously throughout the stone and the color-causing elements may not be revealed by standard chemical analysis.

If the induced color does not permeate the entire stone, then the fact that it is surface related may be observable with magnification and immersion, providing a clear indication of diffusion treatment (Moses, 2002). Also, because the diffusion of some light elements into corundum requires extremely high temperatures, inclusions in stones subjected to this form of treatment show much greater damage than is seen in stones exposed to lower temperatures (figure 3).

Elevated concentrations of some color-causing elements lighter than the transitional elements, such as calcium, can be detected with routine chemical analysis (e.g., EDXRF); SEM-EDS can extend this capability down to boron. However, lighter elements such as Be or lithium can be detected only with more sensitive, less readily available analytical techniques such as laser ablation–inductively coupled plasma–mass spectrometry (LA-ICP-MS) or secondary ion mass spectrometry (SIMS), as described in McClure et al. (2002b).

Irradiation. The color of many gem materials can be altered by exposing them to various forms of radiation, such as electrons, gamma rays, or neutrons. The radiation can cause defects in the crystal lattice, called color centers. The resultant coloration may be shallow or extend throughout the gemstone, and in some cases it is unstable to heat and/or light (McClure et al., 2001).

Detection: This form of treatment is difficult or impossible to identify in most gems. In those situations where it can be detected, more advanced techniques (such as UV-Vis-NIR or Raman photoluminescence spectrometry) are usually required. However, this treatment can be detected in some gem materials without these advanced techniques, such as in diamonds that have colors not seen in natural stones, or that display characteristic color concentrations because they have been exposed to specific sources of radiation (fast electrons, radium salts, or a cyclotron reactor), as illustrated in figure 4.

Figure 3. The new Be-diffusion process exposes corundum to such high temperatures that extreme changes occur in the inclusions, such as: (left) partial recrystallization of melted inclusions, (center) completely melted inclusions that contain gas bubbles, and (right) large spherical blue halos around rutile crystals. Photomicrographs by Shane F. McClure (left and center, magnified 40×) and John I. Koivula (right, magnified 25×).

Figure 4. The color zoning characteristic of cyclotron irradiation in diamond follows the crown facets at a shallow depth below the surface of the stone. Photomicrograph by Robert E. Kane; magnified 40×.

Clarity Enhancement. This treatment involves introducing a liquid, semi-solid, or solid substance (such as oil, wax, resin, polymer, or glass) into surface-reaching fractures to reduce their visibility, thereby improving the apparent clarity of the gem. It is important to note that this treatment can be applied to almost any gem material; the chart lists only those gems in which this treatment is most commonly encountered.

Detection: Clarity enhancement usually is readily detectable with magnification and a little experience. However, when the refractive index of the filler is close to that of the host gem, and a large number of other types of inherent inclusions are present, detection may require closer scrutiny of the sample in a variety of viewing directions. In many instances, a "flash effect" is noted when the stone is viewed in a direction roughly parallel to a filled fracture. Gas bubbles trapped in an incompletely filled fracture or flow structures within the filler are also commonly observed.

Other Treatments. There are some treatments that are more or less individualized for certain gems. Examples include: "reconstructed" amber, in which smaller pieces of amber are combined to form larger pieces; laser drilling of diamonds, whereby a laser is used to create a path from a black inclusion to the surface of the diamond, which then serves as a conduit for chemical bleaching to "whiten" the inclusion; and a proprietary treatment to reduce the porosity and sometimes enhance the color of turquoise, known as the "Zachery treatment."

In this chart, the term *staining* (as used with ivory) is applied to describe the introduction or augmentation of an artistic design, as opposed to *dyeing*, which is used when the "body color" of a gem material has been altered. It must also be kept in mind that two or more types of treatment may be combined to create a result different from that produced by any of the techniques used alone. One example is the use of irradiation followed by heating to further modify color in diamond and topaz.

CHART ORGANIZATION

As stated above, this chart details the commercially available treatments that are applied to the most common types of gem materials. The upper one-third summarizes the most frequently encountered treatment classifications, as described in the first part of this article, including general comments relating to their detection; three images accompany each treatment type, illustrating the treatment results or visible clues to its detection. In the lower two-thirds of the chart, the individual gem materials are organized in five columns alphabetically from the upper left to the lower right. Gems are presented under their species or group name, as opposed to the variety, because many treatments alter the variety classification. Also included are amber, Ammolite, coral, ivory, and pearl.

Listed for each gem material are the types of treatments most often applied, with a brief description of the purpose or result of the treatment. It is important to note that the same type of treatment may achieve a wide range of results. Therefore, the chart presents only the most typical results for a particular treatment type.

At the end of each description is a letter code that indicates the current detectability for the specific type of treatment:

(**D**) – Those treatments that are routinely *detectable* using visual observation and/or standard gemological instrumentation.

(**D+**) – Those treatments that are *detectable but require advanced analytical techniques* that typically are not available to most gemologists.

(**NAD**) – Those treatments that are *not always detectable*. Depending on the type of gem material and the recorded properties, it is not always possible to detect some treatments in all cases.

(**ND**) – Those treatments that currently are *not detectable*.

In most cases, treatment types vary in terms of their detectability, both from one gem material to another and even among varieties within a gem material. Depending on the intended results, certain treatments may be more readily detected than others. For this reason, more than one detection code may be noted under an individual gem material and/or treatment type. One such example is Diamond/Irradiation, where three detection codes are indicated. This is because, depending on the type of radiation used, irradiated diamonds may be readily detectable (**D**), detectable but only with more advanced analytical techniques (**D+**), or even currently not detectable (**ND**). The identification of a treatment depends heavily on the gem material being treated, the type of treatment applied, and the properties that result after treatment.

Macro photographs, including some "before-and-after" treatment images, and photomicrographs of identifying features accompany most entries. These images are designated by letters for the top section and numbers for the bottom section. They are referenced by these letters and numbers to the specific treatment or gem material to which they apply.

This chart does not present all treatments or treatment results that are possible for any particular gem material. There are some gem materials that have been treated experimentally by a variety of means, but are not commercially available. There are also instances where the end result of a commercially available treatment may be atypical and rarely seen (see, e.g., figure 5). Although some basic guidelines concerning the identification of the most readily detectable types of treatments are provided, this chart is not intended to summarize *all* the criteria that are currently applied to detect *all* the various gem materials and accompanying treatments described herein. For further information on the identification of such treatments and the instrumentation used, the reader is referred to McClure and Smith (2000), as well as (for the newer treatments) to the references given in this article.

COMMENTS ON DISCLOSURE

Although this article is not intended to delve into the many aspects of proper disclosure of gem treatments, it is prudent that a few comments be made. Gems that have been manipulated in one fashion or another to modify or enhance their appearance are now a permanent part of our industry. In some cases, treatment has become so commonplace that the enhanced gem is more available in the marketplace than its nonenhanced equivalent (e.g., tanzanite, aquamarine, and citrine). Additionally, in some instances it was only through the application of a particular treatment that generally "more attractive" gems became available to the trade and consumers than would have been possible without the treatment (e.g., rubies and emeralds).

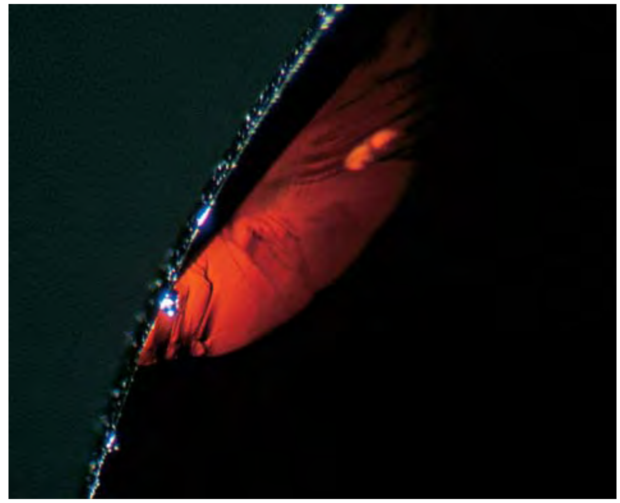

Figure 5. Irradiated black diamonds typically appear very dark green with a strong light source. However, we have on occasion seen treated black diamonds that were actually very dark orange, resulting from the annealing of irradiated, very dark green stones. Photomicrograph by Shane F. McClure; magnified 40×.

We also do not intend to suggest which treatments should be considered "acceptable" or "not acceptable." We believe that every type of gem material, untreated as well as treated, has a place in the gem and jewelry market. However, it is absolutely essential that all parties within the producing, wholesale, and retail sectors of the jewelry trade recognize that disclosure is vital to the welfare of the industry. Therefore, they must continually educate themselves on the availability, results, and identification of such treatments so that they can in turn properly inform their customers.

CONCLUSION

The topic of gemstone treatments, and their detection and disclosure, continues to be one of the most important issues facing our industry. Indeed, since our summary of gemstone treatments of the 1990s was published in the Winter 2000 issue, two major new treatment techniques with far-reaching implications for the gem and jewelry industry reached the market: new developments in the laser treatment of diamonds (Cracco and Kaban, 2002), and diffusion of beryllium into sapphire (McClure et al., 2002a, b; "Orange-pink sapphire…," 2002; Emmett and Douthit, 2002a,b). Other new treatments continue to emerge, such as synthetic ruby overgrowth on natural corundum (Smith, 2002). Before gem dealers or jewelry retailers can adopt a policy of proper disclosure, they must first educate themselves about the multitude of gem materials and treatments that are currently commercially available. This chart was specifically designed to summarize this information for those in our trade.

One of the key features of this chart is that it provides, for the first time, a detailed listing of the current state of detectability of certain treatments in specific gems. Most importantly, this includes the many instances where treatments are currently not detectable or not always detectable, or where they can only be determined with advanced instrumentation.

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