GEOLOGIJA. 2008. Vol. 50. No. 4(64). P. 227–236
DOI: 10.2478/v10056-008-0048-8

A review of current challenges for the identification of gemstones

James E. Shigley

Shigley J. E. A review of current challenges for the identification of gemstones. *Geologija*. Vilnius. 2008. Vol. 50. No. 4(64). P. 227–236. ISSN 1392-110X

A variety of treated and synthetic gem materials are encountered today in the jewelry marketplace in increasing quantities. Although normally entering into the market with correct information, in some cases these materials are sold with incorrect or inaccurate information on their identity. In some cases, they exhibit appearances that correspond closely to those of valuable untreated, natural gemstones. Although they can display certain distinctive gemological characteristics, some treated and synthetic gem materials can be difficult for jewelers to recognize, especially when these individuals lack gemological training and access to standard gem-testing methods and equipment. In such instances, testing by a professional gemological laboratory may be required. Accurate gem identification and complete information disclosure are essential in the jewelry trade to maintain both the commercial value of natural gemstones and the confidence among consumers who are considering gemstone purchases. The goal of most current gemological research is to provide practical means of gem identification for jewelers and gemologists to help insure integrity in the international gemstone trade. To support this goal, research on gem materials increasingly relies upon characterization with modern analytical tools such as chemical analysis, various spectroscopy methods, and other scientific techniques.

Key words: gemstones, treatment, synthesis, gem identification, equipment and methods

Received 27 August 2008, accepted 29 September 2008

James E. Shigley. GIA Research, Gemological Institute of America, 5345 Armada Drive, Carlsbad, California, USA. E-mail: jshigley@gia.edu

INTRODUCTION

Natural gemstones have been objects of desire and admiration in almost all cultures throughout human history. Diamond, ruby, sapphire, and emerald continue to have significant monetary value, and along with other gemstones, they have attained this status by possessing the desirable attributes of beauty, rarity, durability, and portability as well as the transient appeal of fashion. These attributes have contributed to the popularity of gemstones since ancient times.

Although new occurrences of natural gemstones are found from time to time in many parts of the world (Shigley et al., 2000), these localities combined with historically important gem deposits have not always provided the best quality material in sufficient amounts to meet the current demand for gemstones among consumers. Besides the relatively small amount of high-quality gem material typically produced at a given mining locality, there is also recovered a much larger percentage of lower-quality material (for example, with poorer size, color or clarity) that has little market value. Therefore, individuals continue to strive to develop methods to treat this lower-quality material in the laboratory to enhance its appearance and thereby its marketability for gem purposes.

The limited availability and high cost of high-quality natural gemstones mean that their potential use for other applications, such as in high technology, is also restricted. Thus, by taking advantage of current increasing knowledge of crystal-growth methods, efforts continue to be made by scientists to produce a variety of synthetic gem materials for both industrial and jewelry use. Except for natural gemstones of complex chemical composition (such as topaz and tourmaline), the synthetic counterparts of most important gemstones (diamond, corundum [ruby and sapphire], beryl [emerald and synthetic beryls of other colors], spinel, opal, chrysoberyl [alexandrite], and quartz [rock crystal, amethyst and citrine]) have been produced by various techniques and in significant quantities beginning with the synthesis of ruby a century ago.

In this article, the important gem treatment and synthesis methods will be summarized, along with some examples of particular challenges for the identification of treated and synthetic gem materials.

GEM TREATMENT

The treatment of natural gemstones by various means to improve their color or appearance extends in some cases back for

Table 1. **Treatment methods and treated gem materials (and relative abundance in the marketplace)**
1 lentelė. **Apdorojimo metodai, apdoroti brangieji ir juvelyriniai mineralai (ir santykinė jų gausa rinkoje)**

	Diamond	Beryl (Emerald, Aquamarine)	Chrysoberyl (Alexandrite)	Corundum (Ruby, Sapphire)	Jade (Jadeite, Nephrite)	Opal	Quartz (Rock crystal, Amethyst, Citrine)	Topaz	Tourmaline	Pearl (Cultured)
Methods to change color										
Irradiation	Occasional	Rare		Occasional			Common	Common	Rare	Rare
Heating	Occasional	Common		Common			Common	Common	Rare	Rare
Chemical bleaching					Common					Common
Surface coating	Rare	Rare		Rare	Common		Occasional	Occasional		Occasional
Dyeing		Rare		Rare	Occasional	Occasional	Occasional	Rare		Occasional
Color diffusion				Occasional				Occasional		
Heating at high pressure	Occasional									
Methods to change clarity										
Filling cracks or cavities	Occasional	Common	Rare	Occasional			Rare		Rare	
Remove inclusions	Occasional			Rare						
Quench crackling				Rare			Rare			
Impregnation					Common	Occasional				

thousands of years (see Overton and Shigley, 2008). Prior to modern times, the availability of treated gem materials was more restricted, and knowledge about them was not widespread. Correct information on all gemstones was quite limited, and what was available was often based in folklore. Accurate knowledge about gemology and natural gemstones accompanied the development of the science of mineralogy starting in the 1800s. The past century witnessed the expansion of gem treatments in terms of new and sometimes sophisticated techniques that were utilized on a widening range of gem materials. In some cases the use of these treatments is quite widespread, while other methods are more restricted. Some methods have been used for many years, and are considered by many in the jewelry trade as being traditional treatments that are more accepted as treatment practices. A good example is the heating of blue-green beryl to create aquamarine. Other methods such as the diffusion of foreign chemical elements into a gemstone like corundum (ruby and sapphire) to produce a color change are much less accepted and are considered by some to be more fraudulent (Emmett et al., 2003).

Table 1 lists the gem treatment methods that are currently used for several important gemstones. As shown in this table, these methods can be grouped into two general categories to change the color and the clarity of the material. Not all treatment methods are appropriate for every gemstone, and some gems are treated today by more than one method. The costs of the starting material and the treatment method itself versus the value of the treated material are important factors in determining whether a particular treatment method can be used. An assessment of the relative abundance in the jewelry trade of treated diamonds and colored gemstones is included in this table (i. e. relatively common, occasionally used, or rarely encountered). This assessment is based on published information, conversations with individuals involved with treating gems, and upon our experience at GIA with what is seen in the marketplace. McClure and Smith (2000) and Smith and McClure (2002) summarized the current treated gem materials of all kinds and their detection.

In general, the most widespread treatment methods, especially for colored gemstones, involve a change in color (to either darken or lighten an existing color, or to change the hue of the color). Two techniques in this category – exposure to heat and / or radiation – are similar to natural processes that can affect gem minerals in the earth; as a result, these treatments can sometimes produce similar colors as one could encounter in natural gemstones. This similarity between natural processes and certain laboratory treatments greatly complicates the problem for gemologists to distinguish natural-color and treated-color gemstones. For example, both heat-treated corundum (blue sapphire treated from pale-colored "geuda" corundum, and heated ruby from lower quality ruby) and heat-treated beryl (blue aquamarine) are routinely encountered in the jewelry trade. Radiation exposure is used to produce treated-color blue-to-green diamonds (which can be further changed to yellow-to-orange colors by heating to several hundred degrees Centigrade), blue topaz (from colorless or brown starting material), and to a lesser extent pink-to-red tourmaline (from pale-colored tourmaline) (Fig. 1). In the case of treated blue sapphire, topaz, and aquamarine, the widespread extent of the treatment and the ab-

Fig. 1. These gemstones were all treated by radiation exposure in the laboratory to improve their color. The group includes two examples of irradiated blue topaz (33.75 and 9.12 ct.), an irradiated red tourmaline (6.97 ct.), and three irradiated colored diamonds (0.50–0.80 ct.). Photo by Robert Weldon, copyright GIA
1 pav. Švitinti brangieji ir juvelyriniai mineralai

sence of distinctive identifying features means that gemologists often just assume that these materials are all treated unless they have specific information that they are natural-color.

Other color treatments for gemstones that are less often encountered include surface color coatings, dyeing and diffusion. The facet surfaces of diamond, quartz, topaz and recently zoisite (tanzanite) are sometimes coated with foreign materials to either change their color or to darken an existing color (Shen et al., 2007). Some fractured or porous gem materials (beryl [emerald] or turquoise) are dyed to improve their color, while opal is sometimes dyed or filled with plastic to improve its appearance. In the past decade, there has been widespread use of diffusion of chemical elements into pale-colored corundum (sapphire and ruby) during heat treatment to change or enhance the color. The degree of penetration of the diffused elements into corundum varies from quite shallow to deep depending on the element used and the heating conditions (Emmett et al., 2003). Another important example is treated jade (either jadeite or actinolite [nephrite]). When manufactured for jewelry use, jadeite jade is often chemically bleached to remove unattractive brownish staining or other surface contaminants, and the resulting material is then coated with wax or other materials to fill surface cracks and cavities (Fritsch et al., 1992). Some jade is also dyed to improve its color.

Some gemstones must be treated to improve their clarity to increase the possibility of their sale. Lower-clarity polished diamonds can be treated with special, high refractive index glasses to fill surface-reaching fractures to make the latter much less visible and to thereby improve the apparent clarity of the diamond (McClure, Kammerling, 1995). Prior to jewelry repair situations, recognition of these glass-filled diamonds is important since they can be damaged by heat from a jeweler's torch. Some diamonds contain dark-colored mineral inclusions (typically graphite or sulfide minerals) that distract from their appearance. To improve these diamonds, a laser is used to burn a straight, narrow channel from the surface down to the inclusion so that acids can be forced down the channel to dissolve the inclusion or lighten its color. In some cases in recent years, one or more lasers are focused within the diamond to extend a pre-existing fracture (or create a new one) from the inclusion to the diamond's surface, and then acids are introduced through the open fracture to dissolve the inclusion (McClure et al., 2000).

Due to the conditions of their formation in the earth, many emeralds contain surface-reaching fractures that can make them look less attractive when they are fashioned as gemstones. The number of fractures can vary from few to numerous (see McClure et al., 1999). Such emeralds are routinely treated to fill the open fractures with various liquids or melted solids (i. e. oils, resins, and on occasion green dyes) to minimize the visibility of the fractures (Johnson et al., 1999). Some poor-quality, highly fractured, translucent rubies are filled with a high refractive index glasses to significantly improve their clarity (McClure et al., 2006). Unfortunately, the materials used to fill open fractures in emeralds and other treated colored gemstones are not always stable or durable to normal conditions of gemstone use and jewelry repair, and the filled gemstones can be damaged unless proper precautions are taken.

GEM SYNTHESIS

After a few earlier efforts, successful gem synthesis began in the late 1800s with the growth of synthetic ruby by the flame-fusion (or Verneuil) method. The need of high-quality crystals for a range of industrial applications (i. e. optics components, laser crystals and other uses), the frequent lack of suitable natural crystals and the increased knowledge of different crystal growth mechanisms have since combined to yield the production of a wide variety of crystals by several methods, such of which are laboratory counterparts of natural gemstones (see Koivula et al., 2000). A synthetic gem material has essentially the same chemical composition, physical properties, and crystal structure as the more valuable natural gem mineral and, therefore, has many similar gemological properties. In contrast, a gem simulant or imitation has the appearance of a faceted natural gemstone, but has a different chemical composition, physical properties, and crystal structure. Both synthetic and imitation gem materials almost always possess gemological properties that allow them to be distinguished by a trained gemologist from the corresponding natural gemstones. Fig. 2 shows a variety of synthetic gem materials that can be found today in the jewelry marketplace.

Table 2 lists the current methods that are used for gem synthesis, which again fall into several categories – crystallization from a fluid of different chemical composition (such as a flux or aqueous hydrothermal solution), crystallization from a melt of roughly the same chemical composition, and direct crystallization from a vapor phase (or chemical vapor deposition used

Table 2. **Synthesis methods and synthetic gem materials (and relative abundance in the marketplace)**
Table 2. **Sintezės metodai, sintetiniai juvelyriniai mineralai (ir santykinė jų gausa rinkoje)**

	Diamond	**Beryl (Emerald)**	**Chrysoberyl (Alexandrite)**	**Corundum (Ruby, Sapphire)**	**Opal**	**Quartz (Rock crystal, Amethyst, Citrine)**	**Spinel**
Solution methods							
Aqueous					Common		
Hydrothermal		Common		Occasional		Common	Occasional
Flux	Rare	Common	Rare	Occasional			Occasional
Melt methods							
Solidification				Rare			
Crystal pulling			Rare	Occasional			
Flame fusion				Common			Common
Zone growth			Rare	Rare			
Other methods							
Vapor deposition	Rare						

Fig. 2. A variety of synthetic gem materials can be found today in the jewelry marketplace. From left to right starting at the top row, these include synthetic red spinel, synthetic blue sapphire, synthetic citrine, synthetic red beryl, synthetic emerald, synthetic blue spinel, two synthetic opals, synthetic amethyst, synthetic moissanite, synthetic ruby, synthetic alexandrite, and a synthetic diamond. The items weight from 0.43 to 1.81 carats. Photo by Maha Tannous, copyright GIA
2 pav. Sintetiniai juvelyriniai mineralai

to produce synthetic diamond). A seed crystal is often used to initiate crystal growth, with it either being suspended in the fluid or melt, or placed at the base of the growth chamber on a substrate.

Synthetic diamonds, grown from a metal flux at high temperatures and pressures, have evoked concerns in the jewelry trade about their identification ever since they were first produced in small gem-quality crystals in the early 1970s. However, due to the growth conditions involved, as well as the expense and restricted availability of the special growth equipment used, the actual number of synthetic diamonds suitable for jewelry use is limited. Most cuboctahedral crystals are yellow, yellow-orange to yellow-brown in color (some are blue or, on rare occasions, colorless), and they weigh up to 2 carats (1 carat = 0.2 gram), which can yield faceted pieces up to 1 carat in size. This material can be treated to change it to pink, red, or green colors. Colorless or colored (orange-pink, blue, or brown) tabular synthetic diamond crystals are also produced on a very limited basis by the chemical vapor deposition (or CVD) technique which involves crystallization of diamond at high temperatures in a vacuum chamber (Martineau et al., 2004).

In contrast to synthetic diamonds, colorless diamond imitation materials are much more abundant in the jewelry marketplace. Over the years, a number of less expensive natural gem minerals and synthetic materials have been used to imitate the appearance of colorless polished diamonds. Because these imitations differ in chemical composition and crystal structure from diamond, they display very different physical properties (hardness, specific gravity, refractive index, etc.) by which they can be distinguished by a jeweler. Today, the most important imitations are cubic zirconium oxide (cubic zirconia, or CZ) and synthetic silicon carbide (moissanite). With the exception of the latter, all other imitations can readily be distinguished from diamond on the basis of a difference in heat conduction; this difference can be detected with a simple gemological test instrument. Synthetic moissanite displays heat conduction similar to that of diamond and thus, unfortunately, can be mistaken for the latter when tested in this way. However, because of its hexagonal crystal structure, synthetic moissanite displays optical anisotropy, which can be seen visually as an apparent doubling of facet junctions when the material is viewed along the optic axis (this axis is normally oriented perpendicular to the large "table" facet at the top of the gemstone; see Nassau et al., 1997).

Among colored gemstones, the most important synthetic gem materials are synthetic corundum (ruby and sapphire), synthetic emerald, synthetic spinel, and synthetic quartz (both amethyst and citrine). They are produced by either solution or melt techniques, or both. In the marketplace, flame-fusion and crystal-pulled materials (synthetic corundum and synthetic spinel) are relatively less expensive and hence are more abundant than flux or hydrothermal synthetic gem materials. Synthetic amethyst grown by solution methods also falls in the less expensive category because of existing large-scale production facilities for synthetic quartz for use in the electronics industry. In contrast, hydrothermal- and flux-grown synthetic ruby, synthetic sapphire and synthetic emerald are more difficult to produce and therefore command higher prices in the market.

Certain synthesis processes, such as hydrothermal solution growth, are similar in ways to mineral formation in nature, and these processes can produce material with some rather similar growth features and inclusions to what is seen in the crystals of corresponding natural gem minerals. However, in many cases synthetic gem materials are more chemically pure, and they represent the products of more perfect crystal growth conditions than what is encountered among natural gemstones; these features can provide important clues to their laboratory origin.

GEM IDENTIFICATION EQUIPMENT AND METHODS

Jewelers with gemological training are taught to utilize a variety of standard gem testing instruments and techniques to identify diamonds and colored gemstones. These basic instruments, along with the scientific equipment now commonly found in major gem-testing laboratories, are listed in Table 3 with the kind of information that each provides (see Lu, Shigley, 2000).

Table 3. **Instruments and methods used for gem identification**
3 lentelė. **Brangakmenių identifikavimo metodai ir priemonės**

Instruments and methods	Observations	Measurements
Standard equipment		
10 × loupe	Color, appearance (luster and transparency), optical phenomena, crystal morphology, inclusions, growth features, surface features, gemstone cut proportions	
Binocular microscope with various lighting configurations (brightfield, darkfield, diffused, reflected, polarized, shadowed, fiber-optic illumination), and occasional use of immersion fluids	Color, appearance, optical phenomena, crystal morphology, internal features (inclusions, twinning, strain patterns, growth zoning), surface features, gemstone cut proportions	
Polariscope	Strain, twinning, optic character, pleochroism	
Refractometer	Optic character and optic sign	Refractive index, birefringence
Dichroscope	Pleochroism (dichroism)	
Spectroscope (prism or diffraction grating)	Visible absorption spectrum pattern	Spectra features
Color filter	Color appearance	
Electronic balance		Weight
Hydrostatic balance or heavy liquids		Specific gravity
Thermal conductivity meter		Thermal conductivity
Electrical conductivity meter	Electroluminescence	Electrical conductivity
Ultraviolet lamps (long- and short-wave)	Fluorescence, phosphorescence	
Thermal reaction tester	Effects of high temperature	
Advanced equipment		
Visible spectroscopy	Visible absorption or reflectance spectrum pattern	Spectra features
Infrared spectroscopy	Infrared absorption or reflectance spectrum pattern	Spectra features
Micro-Raman spectroscopy	Raman spectrum pattern	Spectra features characteristic of a particular gem material or mineral inclusion
Luminescence spectroscopy	Luminescence spectrum pattern	Luminescence excitation and emission spectra features
Cathodoluminescence spectroscopy	Luminescence colors and distribution patterns	Luminescence emission spectra features
Ultraviolet imaging	Luminescence colors and distribution patterns	
Scanning electron microscopy (SEM)	Structural features seen at high magnification	
X-ray fluorescence (XRF)	Luminescence colors and distribution patterns, or XRF spectrum pattern	Qualitative chemical analysis (major and minor elements)
Laser-ablation inductively-coupled-plasma mass-spectrometry (LA-ICP-MS)		Quantitative chemical analysis (minor and trace elements)
Electron microprobe	Chemical element distribution patterns	Quantitative chemical analysis (major, minor and trace elements)
Laser-induced breakdown spectroscopy (LIBS)		Quantitative chemical analysis (major, minor and trace elements)
X-ray radiography	Patterns of X-ray transparency differences	
X-ray diffraction (XRD)	Diffraction pattern	Crystal structure and unit-cell dimensions
X-ray topography		Lattice imperfections (dislocations, twinning)
Colorimetry		Color measurement

Diagnostic properties of all natural, treated and synthetic gem materials are published in several standard gemological textbooks (for example, Webster, 1994); this information is supplemented by reports on new gem materials in gemological journals and jewelry trade publications. With access to this information and familiarity with the equipment shown in Table 3, jewelers and gemologists are in a good position to identify many gem materials they encounter, or to recognize when they need the assistance of a gem-testing laboratory.

The most important of the basic gemological instruments is the binocular microscope. Used in combination with various lighting techniques, the microscope allows the gemologist to examine a gemstone for inclusions, growth features, color zoning and other features that provide important clues regarding a gemstone's identity. Measurement of the refractive index (RI) by means of a refractometer is also very important for the gemologist, since RI values and other optical properties are distinctive for many gemstones. Use of a prism or diffraction-grating spectroscopy allows the gemologist to relate a gemstone's color to its visible absorption spectrum, and indirectly to its chemical composition; these absorption spectra can also be quite diagnostic for gem identification purposes. Thermal and electrical conductometers, as well as reflectometers, are used to distinguish colorless diamond from imitation materials.

When basic gem testing does not yield a conclusive answer on a gem's identity, or further information is desired to support a preliminary conclusion, jewelers often turn to a gem-testing laboratory for assistance with gem identification problems. These facilities offer the availability of advanced analytical instrumentation along with more experienced gemologists who deal with identification problems on a daily basis. Such laboratory capabilities are essential today to detect some treated and synthetic gem materials. The advanced techniques must involve little or no physical damage of any kind to the gemstone, since original crystals are not always available for gemological study.

In general, the advanced analytical instrumentation listed in Table 3 falls into several categories. Spectroscopy techniques allow the study of how light and other electromagnetic radiation interacts with a gemstone to produce its color and other diagnostic spectral features. Faceted gemstones have been fashioned in styles to control the transmission of light (i. e. to optimize the amount of incident light that exits the gemstone through the upper "crown" facets). Therefore, it can be difficult to position a faceted gemstone (or a gemstone set in a piece of jewelry) in a spectroscopy instrument in such a way that allows sufficient light to pass from the instrument light source through the gemstone to the detector so that spectra can be recorded. Whenever possible, it is important to position the gemstone so that light can pass directly through parallel facets on opposite sides of the material to help maximize light throughput. Special optical components may also be necessary in the instrument to concentrate sufficient incident light on a small gemstone to record spectra. In addition, a translation stage holding the gemstone in the sample compartment can be of great help by allowing slight position adjustments to increase light transmission through the material. Recording the visible absorption spectra of highly colored or highly included gemstones can present problems, as can the effort to record spectra from gemstones faceted in unusual shapes that lack opposing parallel facets. The actual path length of light traveling through a faceted gemstone cannot be measured with accuracy because of the uncertainty in the number of internal reflections in that light path, so the recorded intensities for spectral absorption features are not directly related to this path length. Visible absorption spectra can provide important information on the causes of gemstone color and evidence for laboratory treatment. To determine the cause of color of a gem material, it is important to record spectra with polarizing filters oriented parallel and then perpendicular to the optic axis of optically anisotropic gem materials (a spectrum recorded in any orientation of the crystal is acceptable for optically isotropic materials). These visible spectra can also be used to calculate information on the color of a gemstone. Infrared spectra are often used to check for the presence of a foreign material in a treated gemstone, such as oils or resins in the open fractures of a treated emerald, and plastic used to improve the appearance of a treated opal. Because of the ability to position the incident laser light using an optical microscope on particular portions of a gemstone, the resulting Raman spectra can sometimes establish the identity not only of a gem material, but also of its mineral inclusions that in turn can provide information on the host gemstone (Fig. 3). Photoluminescence spectra provide valuable clues on whether a diamond might be treated or synthetic. Two other related methods are cathodoluminescence, which can provide information on the spatial distribution of different optical defects in a material as well as spectra of the emitted light, and ultraviolet luminescence spectra of either the excitation or emission features related to the fluorescence of a gem material.

Another group of analytical instruments includes those for chemical analysis. Most gemological laboratories utilize an energy-dispersive X-ray fluorescence (EDXRF) system for qualitatively analyzing polished gemstones for the presence of elements between magnesium and uranium on the Periodic Table. When exposed to the incident X-ray beam, the sample emits X-rays that are characteristic of the major and minor elements that are present (in amounts greater than ~0.1 weight percent). If suitable analytical standards of known chemical composition are available, comparison of the results of the analysis of both the standards and the unknown sample can provide semiquantitative chemical composition data on the latter. The EDXRF method is rapid, and it requires no sample preparation other than the requirement of a flat surface for analysis that is representative of the entire sample. The electron microprobe is a more expensive instrument that offers the ability to quantitatively analyze small areas on a sample; the sample must possess a polished flat surface that must be carbon coated for the analysis, and the results of the unknown must be compared to results from analytical standards of similar nature that are prepared for each element of interest.

Some gemological laboratories currently use laser-induced breakdown spectroscopy (LIBS) as an alternative method of quantitative chemical analysis of gem materials. Another important, very sensitive method is laser-ablation inductively-coupled-plasma mass-spectrometry (LAICPMS) (Fig. 4). Using this technique, tiny amounts of material are ablated from the surface of the gemstone by a focused laser beam, and the resulting particles are transported by flowing argon gas into the inductively-coupled-plasma ion source. The positively charged

Fig. 3. This Renishaw 1000 InVia Raman microscope allows the collection of both Raman spectra as well as photoluminescence spectra of a gem material. The equipment is set up to use several lasers with different excitation wavelengths (488.0, 514, 633 and 830 nm). Photo by Kevin Schumacher, copyright GIA

3 pav. Raman spektroskopijos sistema

Fig. 4. The need for accurate chemical composition data for minor and trace elements in gem materials has resulted in major gemological laboratories acquiring equipment capable of analyzing materials using the laser ablation – inductively coupled plasma – mass spectrometry (LA-ICP-MS) technique. Shown here are a Thermo X Series II ICP mass spectrometer on the left, and a New Wave UP-213 laser ablation system on the right. Photo by Kevin Schumacher, copyright GIA

4 pav. LAICPMS sistema

ions are extracted from the plasma through an interface into the high vacuum of the mass spectrometer, and are separated according to their mass / charge ratio and energy / charge ratio and detected by a secondary electron multiplier. This technique provides for the simultaneous analysis of all elements of the Periodic Table (except the noble gases) in concentrations down to parts-per-million levels by comparative analysis of standard reference materials.

The final instruments shown in Table 3 are mainly X-ray diffraction and X-ray imaging techniques. The former provides information on the crystal structure of a gem material by means of a diffraction pattern, but it requires either a small powdered sample for analysis, or a polished surface of the material that can be rotated in the X-ray beam to allow the beam to interact with different orientations of the crystal lattice. The latter equipment produces photographic or real-time digital images of a material that can reveal differences in X-ray transparency.

In contrast to the publication of basic gemological properties on gemstones in a number of standard reference books, information on gemstones derived from the advanced analytical techniques (such as spectral features and chemical composition data) is usually scattered in the scientific and gemological literature and, therefore, is not easily accessible. It is necessary for the staff of a gem-testing laboratory to compile their own information database on the gemstones they examine in order to help identify them. When building this database, an important goal, whenever possible, is to study known natural, treated, or synthetic gem materials because the resulting data have greater validity. The database can then be used to establish multiple criteria for gem identification. One of the best ways for developing means of detecting treated gem materials is provided when gem samples can be documented before and then after a known treatment process, since changes in the color or appearance of the sample can then be directly related to the treatment.

INFORMATION DISCLOSURE AND LABORATORY CERTIFICATION

Customers considering the purchase of a gemstone may have little knowledge about the gemstones and their values, and often these purchases are made for important occasions and at some expense to the individual. Therefore, they rely on trained jewelers for this product information and assurance about the purchase. In many countries, jewelers are required to disclose accurate information on the gemstones they sell to consumers, and they desire to do so to maintain consumer confidence. However, this information disclosure assumes that the jeweler knows if the item is a treated or synthetic gem material. If jewelers have gemological training and possess the necessary standard equipment, they can correctly identify many of the gem materials they encounter, or if some uncertainty exists, they can request help from a gem-testing laboratory. The latter case is increasingly necessary considering the increasing sophistication and proliferation of certain gem treatment and synthesis processes. Jewelers often now require some type of certification on the identity of a gemstone from the source from whom the item was purchased, or they obtain a laboratory identification report on the item. In spite of the availability of such reports, jewelers continue to face challenges with accurate gem identification and with disclosure of correct identity information on gemstones to consumers.

Individual important gemstones possess sufficient value to warrant their careful examination by the trained staff of a gemological laboratory. Most current gemological research is directed at solving these challenges of gem identification. However, such laboratory examination may not be possible for less expensive gemstones which are bought and sold in large quantities (such as pale aquamarine, amethyst, citrine and other colors of quartz, garnet, topaz, tourmaline, and almost all gemstones in small sizes). In such instances, testing for treated and synthetic material is only practical when carried out on representative samples of the group.

As mentioned earlier, the use of some gem treatments extends back several centuries. These methods are sometimes considered as accepted practices in the jewelry trade. When such methods are widely used, it is often assumed by jewelers that all samples of a particular kind of gemstone are treated. Even in such instances, correct identity information on the material should be disclosed to consumers.

CURRENT GEM IDENTIFICATION CHALLENGES

Jewelers and gemologists currently face challenges with recognizing particular treated and synthetic gem materials. Some examples are as follows:

1. Diamonds that are treated to change or improve their color by radiation exposure and / or high-pressure high-temperature annealing. While there might be some visual evidence of treatment that a trained gemologist can look for, in general, colored diamonds must be examined by a gem-testing laboratory to detect evidence of these laboratory treatments. Wang et al. (2005) described some colored diamonds treated by multiple processes, and Shigley (2008) provided a general overview of color and clarity treatments of diamond.

2. Synthetic colored and colorless diamonds may display gemological properties that would allow them to be recognized by gemologists, but considering the high market value of diamonds, they too are often best recognized by gemological laboratories (see Shigley et al., 2004; Martineau et al., 2004; Shigley, 2005).

3. Colored gemstones such as emerald, tourmaline, topaz and ruby that are clarity-enhanced by the filling of surface-reaching fractures with a liquid or a glass. Examination with a binocular microscope can often provide visual evidence of filled fractures, but the extent of the filling process and the filling material used require the item to be sent to a gemological laboratory.

4. While some synthetic gem materials (such as synthetic ruby, sapphire, emerald and spinel) display growth features and inclusions that can be seen with a binocular microscope, those that are free of such features cannot always be positively recognized by a gemologist and require advanced laboratory testing.

5. Radiation exposure is used to improve the color of gemstones such as beryl, chrysoberyl, diamond, spodumene, topaz, and tourmaline, but it is often difficult to prove this exposure as the result of laboratory treatment, since gem minerals can be exposed to natural radioactivity in the earth. In addition, irradiation treatment can leave some gem materials slightly radioactive for a period of time depending on the kinds of radionuclides that are present. While it is illegal to possess radioactive gem material, detecting this low-level radioactivity requires additional equipment and methods that are not typically found in gem-testing laboratories.

6. The heat and / or diffusion treatment of ruby and sapphire is widespread in the jewelry trade. In some instances, these treatments can be detected by examination with the binocular microscope based on color zoning and the types of inclusions. However, the potential high market value requires that any important ruby or sapphire be tested by a gemological laboratory for possible treatments (Emmett et al., 2003).

7. Jadeite and nephrite jade are also valuable gem materials, and both are frequently subjected to treatments to improve their appearance. There may be some visual evidence of bleaching and impregnation treatments, but a more detailed study by a gemological laboratory is often required to detect the type of impregnation substance.

8. Colored and colorless coatings are being used on a variety of gem materials. While both kinds of coatings may exhibit evidence of imperfections or damage to the coating when viewed with magnification, advanced laboratory testing is often required to determine the exact nature of the coating material (see again Shen et al., 2007; Schmetzer, 2008).

9. The identification of all gem materials becomes more complicated when dealing with very small gemstones (~0.1 carat or less) that are sold in quantity or are mounted in pieces of jewelry (Kitawaki et al., 2008).

10. Some treatment methods are used to improve the appearance of gem minerals before they are manufactured as gemstones. This is often carried out for fraudulent purposes, so those purchasing gem crystals or fragments should be aware that it may be necessary for this material to be tested also by a gemological laboratory.

CONCLUSIONS

Besides natural gemstones, an extensive variety of treated and synthetic gem materials are available today in the marketplace and through the Internet, and this trend will continue. They offer consumers a wide choice of gem materials, colors, qualities and prices. They represent the products of conventional and more recently developed treatment and synthesis methods. While trained gemologists can recognize many of the gem materials they encounter, continual educational efforts are needed to keep them updated on new materials coming into the marketplace. Even with the use of advanced scientific equipment and methods by a gemological laboratory, the accurate identification of some treated and synthetic gem materials can be difficult to establish. Advances in technology are expected to produce new treatment and synthesis techniques, which in turn will require ongoing development of new methods and equipment for gem identification.

References

1. Emmett J. L., Scarratt K., McClure S. F., Moses T., Douthit T. R., Hughes R., Novak S., Shigley J. E., Wang W., Bordelon O., Kane R. E. 2003. Beryllium diffusion of ruby and sapphire. *Gems & Gemology*. ***39***(*2*). 84–135.
2. Fritsch E., Wu S. T. T., Moses T., McClure S. F., Moon M. 1992. Identification of bleached and polymer-impregnated jadeite. *Gems & Gemology*. ***28***(*3*). 176–187.
3. Johnson M. L., Elen S., Muhlmeister S. 1999. On the identification of various emerald filling substances. *Gems & Gemology*. ***35***(*2*). 82–107.
4. Kitawaki H., Abduriyim A., Okano M. 2008. Identification of melee-size synthetic yellow diamonds in jewelry. *Gems & Gemology*. ***44***(*3*). 202–213.
5. Koivula J. I., Tannous M., Schmetzer K. 2000. Synthetic gem materials and simulants in the 1990s. *Gems & Gemology*. ***36***(*4*). 360–379.
6. Lu T., Shigley J. E. 2000. Nondestructive testing for identifying natural, synthetic, treated and imitation gem materials. *Materials Evaluation*. ***58***(*10*). 1204–1208.
7. Martineau P. M., Lawson S. C., Taylor A. J., Quinn S. J., Evan D. J. F., Crowder M. J. 2004. Identification of synthetic diamond grown using chemical vapor deposition. *Gems & Gemology*. ***40***(*1*). 2–25.
8. McClure S. F., Kammerling R. C. 1995. A visual guide to the identification of filled diamonds. *Gems & Gemology*. ***31***(*2*). 114–119.
9. McClure S. F., King J. M., Koivula J. I., Moses T. M. 2000. A new lasering technique for diamonds. *Gems & Gemology*. ***36***(*2*). 138–146.
10. McClure S. F., Moses T. M., Tannous M., Koivula J. I. 1999. Classifying emerald clarity enhancement at the GIA Gem Trade Laboratory. *Gems & Gemology*. ***35***(*4*). 176–185.
11. McClure S. F., Smith C. P. 2000. Gemstone enhancement and detection in the 1990s. *Gems & Gemology*. ***36***(*4*). 336–359.
12. McClure S. F., Smith C. P., Wang W., Hall M. 2006. Identification and durability of lead glass-filled rubies. *Gems & Gemology*. ***42***(*1*). 22–34.
13. Nassau K., McClure S. F., Elen S., Shigley J. E. 1997. Synthetic moissanite: A new diamond substitute. *Gems & Gemology*. ***33***(*4*). 260–275.
14. Overton T. W., Shigley J. E. 2008. A history of diamond treatments. *Gems & Gemology*. ***44***(*1*). 32–55.
15. Schmetzer K. 2008. Surface treatments of gemstones, especially topaz – an update on recent patent literature. *Journal of Gemmology.* ***31***(*1/2*). 7–13.
16. Shen A. H., Wang W., Hall M. S., Novak S., McClure S. F., Shigley J. E., Moses T. M. 2007. Serenity coated colored diamonds: Detection and durability. *Gems & Gemology*. ***43***(*1*). 16–34.
17. Shigley J. E. (ed.). 2005. *Gems & Gemology in Review: Synthetic Diamonds*. Gemological Institute of America, Carlsbad, California. 294 p.
18. Shigley J. E. (ed.). 2008. *Gems & Gemology in Review: Treated Diamonds*. Gemological Institute of America, Carlsbad, California. 301 p.
19. Shigley J. E., Breeding C. M., Shen A. T. 2004. An updated chart on the characteristics of HPHT-grown synthetic diamonds. *Gems & Gemology*. ***40***(*4*). 303–313.
20. Shigley J. E., Dirlam D. M., Laurs B. M., Boehm E. W., Bosshart G., Larson W. F. 2000. Gem localities of the 1990s. *Gems & Gemology*. ***36***(*4*). 292–335.
21. Smith C. P., McClure S. F. 2002. A chart of currently available gem treatments. *Gems & Gemology*. ***38***(*4*). 294–300.
22. Wang W., Smith C. P., Hall M. S., Breeding C. M., Moses T. M. 2005. Treated-color pink-to-red diamonds from Lucent Diamonds Inc. *Gems & Gemology*. ***41***(*1*). 6–19.
23. Webster R. 1994. Gems – Their Sources, Descriptions and Identification (fifth ed., revised by P. G. Read). London: Butterworth-Heinemann. 1026 p.

James E. Shigley

ŠIUOLAIKINIŲ REIKALAVIMŲ BRANGIŲJŲ IR JUVELYRINIŲ MINERALŲ IDENTIFIKAVIMUI APŽVALGA

Santrauka

Šiandien juvelyrikos rinkoje pastebima nuolat auganti apdorotų ir sintetinių brangiųjų bei juvelyrinių mineralų įvairovė. Nors dažniausiai rinkai jie pateikti su teisinga identifikuojančia informacija, kai kada ji yra iškraipyta ar nepilna. Kartais brangakmeniai panašūs į vertingus nepaveiktus natūralius. Nors matomi tam tikri išskirtiniai gemologiniai požymiai, kai kuriuos apdorotus bei sintetinius brangiuosius ir juvelyrinius mineralus juvelyrams gana sudėtinga atpažinti, ypač jei trūksta gemologinių žinių ir patirties, taip pat nėra galimybės patikrinti šiuos mineralus įprastais identifikavimo metodais su specialia įranga. Tokiais atvejais brangakmenių identifikavimas specialioje gemologinėje laboratorijoje gali būti itin reikšmingas. Siekiant tinkamai nustatyti natūralių brangakmenių komercinę vertę, būtina tiksliai juos identifikuoti ir pateikti išsamią informaciją. Tai yra svarbu ir ugdant brangakmenių pirkėjų pasitikėjimą. Gemologinių tyrimų tikslas – juvelyrikos ir gemologijos specialistams suteikti praktinių žinių, kurios padėtų identifikuoti brangakmenius ir tuo užtikrintų sąžiningumą tarptautinėje brangakmenių prekyboje. Taigi brangiųjų ir juvelyrinių mineralų tyrimai tampa vis labiau priklausomi nuo modernių analitinių priemonių, kurios remiasi chemine analize, įvairiais spektroskopijos metodais ir kitomis mokslinėmis metodikomis.

Джеймс Е. Шиглей

СОВРЕМЕННЫЕ ТРЕБОВАНИЯ К ИДЕНТИФИКАЦИИ ДРАГОЦЕННЫХ И ЮВЕЛИРНЫХ МИНЕРАЛОВ

Резюме

В настоящее время на ювелирном рынке появляется все больше облагороженных и синтетических драгоценных (ювелирных) минералов. Обычно на рынок попадают минералы с точной информацией, но драгоценные камни в отдельных случаях продаются с неверной и неточной идентификационной информацией. Иногда по внешнему виду они похожи на необлагороженные драгоценные камни. Некоторые облагороженные и синтетические драгоценные (ювелирные) камни внешне могут соответствовать их естественным геммологическим свойствам. Их идентификация ювелиром может быть затруднена. Особенно при недостаточных знаниях и опыте последнего, а также при ограниченной доступности тестации стандартными методами с использованием специальных приборов для драгоценных камней. В таких случаях необходима тестация в профессиональных геммологических лабораториях. Точная идентификация и предоставление информации о драгоценных камнях обязательна на ювелирном рынке для поддержания коммерческой стоимости натуральных драгоценных камней и доверия потенциальных покупателей. Главной целью современных геммологических исследований является обеспечение ювелиров и геммологов практическими предметами для идентификации драгоценных камней, гарантирующими добросовестность на интернациональном рынке драгоценных камней. Поэтому исследование драгоценных и ювелирных минералов все больше зависит от современных аналитических средств, которые основываются на химическом анализе, на разных спектроскопических методах, а также на других научных технологиях.