ADVANCED GEM CHARACTERIZATION

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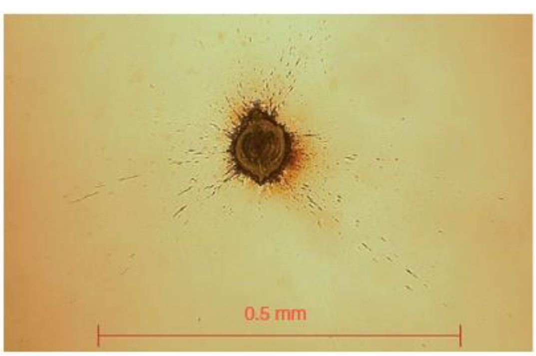
As clever minds combine an ever-increasing menu of high-tech methods in the quest to enhance the properties of both natural and synthetic gems, the challenges of gem characterization continue to grow rapidly. Gemology has adopted new methods to keep pace.

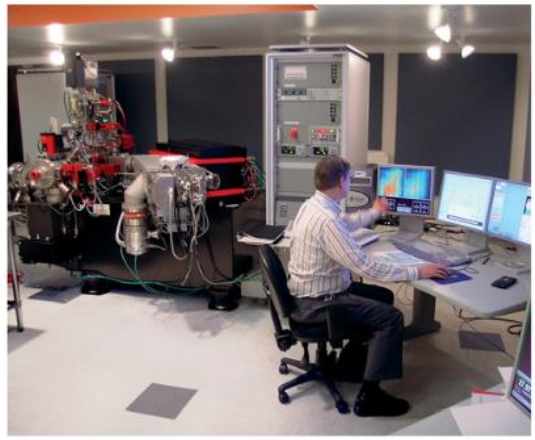
Techniques considered advanced a decade ago—such as infrared, Raman, X-ray fluorescence, and photoluminescence spectroscopy, as well as LA-ICP-MS—are now routine analytical tools in well-equipped gemological laboratories. Trace-element analyses at the parts per million level are now at the forefront of determining locality of origin and treatments. New methods now being used in academic and industrial laboratories will become increasingly important in gemological labs as the technology applied to gem treatments rapidly advances.

Established tools remain important, though. Infrared spectra can be used to identify phases (including X-ray amorphous phases), detect the presence of organic oils and resins in stones, classify diamond type, and identify certain minor and trace constituents of minerals that may reveal clues to their origin or treatments. Raman spectra are also used for phase identification. Because the beam can be focused as small as a micrometer in diameter in laboratory-grade instruments, Raman spectroscopy has become the method of choice to identify small inclusions in stones. The availability of large libraries of spectra makes this a powerful technique for nondestructive phase identification (even of organic components).

Visible-range spectroscopy remains a primary tool for studying color in minerals. Combined with chemical analysis, it can determine which metals cause color, in which oxidation states the metals occur, and even the site in the crystal where they occur. Such information can assist in geographic origin studies.

This minute crater on the surface of a pink sapphire was produced by LIBS analysis. Photo by G. R. Rossman.





A nanoSIMS is a powerful analytical instrument that can detect both trace elements such as beryllium diffused into corundum and the isotopic compositions of the stone. Photo by Brendan M. Laurs.

Luminescence reveals much about the growth history of minerals, and several of these methods have found important gemological applications as well. Luminescence helps identify certain treatments and is of particular use in separating natural and synthetic diamonds. Thermoluminescence testing responds to radiation damage induced either by nature or by laboratory treatment. Unfortunately, this test is destructive and will remove color from most samples.

Laser-ablation methods (LA-ICP-MS and LIBS) have opened up a whole new range of quantitative analyses of most elements in the periodic table. In addition to providing basic information about the chemical composition of a gem, these analyses are often of great use in establishing geographic origin, while leaving only a tiny crater on the gem's surface. Secondary-ion mass spectrometry (SIMS and nanoSIMS), an ion-beam method, provides highly sensitive chemical analysis of selected elements and also gives isotopic compositions (leaving craters of just 20 to 0.1 μm in diameter). This technique is also well-suited for obtaining chemical depth profiles of coatings.

X-ray methods have evolved from a primary method for phase identification to a tool for nondestructively detecting and analyzing a number of minor components, and now digital X-ray methods are used to obtain images of the internal structure of pearls.

This author anticipates that other new tools will become commonplace in the years ahead. Electron paramagnetic resonance (EPR) is a particularly sensitive analytical tool for detecting certain metals, color centers, and radiation damage centers at low concentrations. This could be particularly useful in the examination of color centers in diamond and the changes these centers undergo with heat and other treatments. Unlike thermoluminescence, EPR does not destroy radiation-induced color. Analysis of specific isotopes is now frequently applied in academic research, but has seen comparatively little use in gemology. Oxygen isotopes show a wide range of variation in geologic systems. Analysis of oxygen isotopes has already been established as a powerful method to distinguish emeralds and corundum from different geographic origins. Argon isotopes, meanwhile, have played a major role in proving that some samples of red andesine from Asia have been treated.

These methodologies have applications in determining gem provenance and detecting treatments and synthetics. Defect patterns in the form of color centers and luminescence centers in gems can be used to identify, for example, characteristic growth and chemical signatures. Differentiating between natural and treated color continues to challenge gemologists. Luminescence offers a powerful nondestructive methodology with great potential to assist in this endeavor.