NOTES · AND · NEW TECHNIQUES

THE DISTINCTION OF NATURAL FROM SYNTHETIC ALEXANDRITE BY INFRARED SPECTROSCOPY

By Carol M. Stockton and Robert E. Kane

Infrared spectroscopy provides a means to distinguish natural from synthetic alexandrites in the range 2000–4200 cm^{-1}, as determined by a study of spectra obtained from 15 natural and 28 synthetic alexandrites from a variety of sources. The technique is nondestructive and, with Fourier transform instrumentation, extremely rapid. It is especially useful for identifying stones that contain no distinguishing inclusions.

The recent discovery of fine-quality alexandrite in Brazil (Koivula, 1987; Proctor, 1988) and the continued production of synthetic alexandrite (Nassau, 1980; Trossarelli, 1986; Guo et al., 1987; Kane, 1987) prompted an examination of the infrared spectra of these gem materials as additional means to distinguish the natural gems from the synthetic products (figure 1). The possibility had already been explored and found promising in a survey study of infrared spectra of various gem materials including alexandrite (Leung et al., 1983).

In most instances, characteristic inclusions serve to distinguish between natural and synthetic alexandrites (see references above). The natural gemstones usually contain distinctive natural-appearing inclusions such as: ultra-fine parallel growth tubes or needles; solid crystal inclusions of actinolite, quartz, mica, apatite, and other minerals; two- and three-phase fluid inclusions; and various internal growth features (Gübelin and Koivula, 1986). Flux-grown synthetic alexandrite—for example, that produced by Creative Crystals (Cline and Patterson, 1975)—is differentiated by inclusions of flux and platinum platelets. Alexandrite synthesized by melt methods—including the commercially available Czochralski-pulled products from Allied Signal (Morris and Cline, 1976) and Kyocera (Machida and Yoshihara, 1980; Uji and Nakata, 1986), and floating-zone material from Seiko (Koivula, 1984)—may show gas bubbles and identifiable curved, irregular, and/or swirled growth features. In addition, some synthetic alexandrites may show unusual features such as the weak chalky yellow short-wave fluorescence confined near the surface of the Inamori synthetic cat's-eye alexandrites (Kane, 1987).

In the absence of such distinctive features, however, there may be no other standard gemological properties that can conclusively identify the natural or synthetic origin of an alexandrite. Thus, laboratory identification techniques such as infra-

ABOUT THE AUTHORS

Ms. Stockton is senior research gemologist in the Research Department of the Gemological Institute of America, Santa Monica, California. Mr. Kane is senior staff gemologist in the Gem Identification Department of the GIA Gem Trade Laboratory, Inc., Los Angeles, California.

Acknowledgments: The authors thank the following for loaning material for this study: Prof.-Dr. Hermann Bank (Mineralogisch-Petrographisches Institüt der Universität Heidelberg), Gerhard Becker (Friedrich-August Becker), Robert Middleton (Los Angeles County Museum of Natural History), Judith Osmer (J. O. Crystal Co.), Jane Smith (Jewelers'-Circular Keystone), MSB Industries, and Ken Takada (Inamori Jewelry Division of Kyocera International, Inc.).

red spectroscopy are of some significance, especially considering the appreciable differences in market value involved.

MATERIALS AND METHODS

The current study examined 15 natural and 28 synthetic alexandrites from a variety of sources (see table 1). Spectra were obtained with a Nicolet 60SXB FTIR spectrometer (see Fritsch and Stockton, 1987) in the range 400–5000 cm^{-1}. However, only the range 2000–4200 cm^{-1} is of interest here since total absorption occurs below 2000 cm^{-1} (due to the presence of SiO_2), and no features were observed between 4200 and 5000 cm^{-1}. Although the spectra vary considerably according to crystallographic orientation (a property that is difficult to control with faceted gemstones), key distinguishing features can, nevertheless, be easily identified (see figure 2).

RESULTS

Table 2 shows clearly how distinct the spectra of natural and synthetic alexandrites are. Most notably, the natural alexandrites examined invariably exhibit absorption features centered at about 2160, 2403, 4045, and 4150 cm^{-1} that were not observed in any of the synthetics. In fact, features present in the synthetic alexandrites generally were limited to the range 2800–3300 cm^{-1}, regardless of orientation, with a few specimens showing bands between 2500 and 2700 cm^{-1}, and some with features between 3300 and 3700 cm^{-1}. In addition, the absorption features between 2800 and 3300 cm^{-1} are always stronger in the natural stones (again, see figure 2). This is probably due to the lack of water in the synthetics, which are manufactured by flux, floating zone, or Czochralski-pulling techniques (see Kane, 1987, for a summary), while the natural gems invariably incorporate H_2O and OH during their growth (Aines and Rossman, 1984).

Hydrothermal synthetic alexandrites have reportedly been manufactured (Trossarelli, 1986) and, should they become commercially available at some future date, further study will be necessary. However, the distinguishable infrared spectra of natural and synthetic hydrothermal emeralds

Figure 1. New sources of natural alexandrite, including Tanzania (crystal, top left, 51.81 ct) and Brazil (four faceted stones on left, ranging from 0.95 ct to 2.49 ct) are producing enough fine material to create increased demand for this unusual gemstone. In addition, the manufacture of flux synthetic alexandrite (on the right; the crystal is 36.18 ct and the faceted stones range from 0.72 ct to 3.88 ct.) by companies such as Creative Crystals and Inamori has raised the importance of being able to distinguish between the natural and man-made materials. Faceted natural alexandrites courtesy of Krementz & Co. Photo © Tino Hammid.

TABLE 1. Origin and number of samples of natural and synthetic alexandrites examined by means of Fourier transform infrared spectroscopy.

Origin	No. of samples
Natural	
Brazil	8
Sri Lanka	2
Tanzania	3
USSR	2
Synthetic	
Czochralski pulled	
Allied Signal	2
Inamori/Kyocera	9
Unknown	2
Floating zone	
Seiko	1
Flux-grown	
Creative Crystals	13
Unknown	1

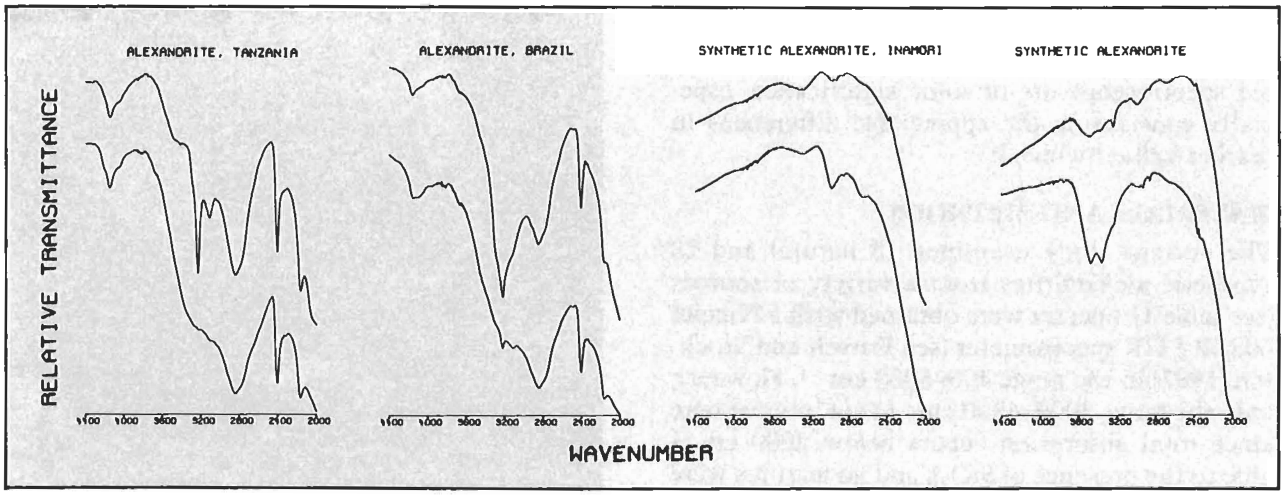

Figure 2. These infrared spectra illustrate both the variety of features within each category as well as the obvious differences between the spectra of natural and synthetic alexandrites in this wavenumber range. Spectra for two different orientations of each gem are illustrated.

(Stockton, 1987) suggest that similar distinctions will be possible for alexandrite should the need arise. In the meantime, separation of natural and synthetic alexandrite by infrared spectroscopy is straightforward.

TABLE 2. Major and distinguishing infrared features (in cm^{-1}) of natural and synthetic alexandrites, with ranges of observed band locations.

Natural	Synthetic
2159–2165***	
2401–2404***	
2415*	
2480–2487**	
	2509–2512*
	2601*
	2620–2680**
2775**	
2829–2850***	2848–2853**
	2971–2975*
2913–2917*	2917–2924**
	2927–2931*
2951–2954*	2952–2983**
3033–3038*	
	2078–3082*
3102–3109*	
3115–3135*	
3212–3230***	3224–3229*
	3250–3258*
4044–4050***	
4140–4155***	

**Sometimes present. **Usually present. ***Always present.*

REFERENCES

Aines R.D., Rossman G.R. (1984) Water in minerals? A peak in the infrared. *Journal of Geophysical Research*, Vol. 89, No. B6, pp. 4059–4071.

Cline C.F., Patterson D.A. (1975) Synthetic crystal and method of making same. United States patent 3,912,521, filed April 30, 1973, issued October 14, 1975.

Fritsch E., Stockton C.M. (1987) Infrared spectroscopy in gem identification. *Gems & Gemology*, Vol. 23, No. 1, pp. 18–26.

Gübelin E.J., Koivula J.I. (1986) *Photoatlas of Inclusions in Gemstones*. ABC Edition, Zurich.

Guo X., Chen M., Li N., Qin Q., Huang M., Fei J., Wen S., Li Z., Qin Y. (1987) Czochralski growth of alexandrite crystals and investigation of their defects. *Journal of Crystal Growth*, Vol. 83, pp. 311–318.

Kane R.E. (1987) Inamori synthetic cat's-eye alexandrite. *Gems & Gemology*, Vol. 23, No. 3, pp. 158–162.

Koivula J.I. (1984) Gem news: Synthetics. *Gems & Gemology*, Vol. 20, No. 1, p. 60.

Koivula J.I. (1987) Gem news: Brazilian alexandrites. *Gems & Gemology*, Vol. 23, No. 2, p. 123.

Leung C.S., Merigoux H., Poirot J-P., Zecchini P. (1983) Sur l'identification des pierres fines et de synthèse par spectroscopie infrarouge. *Revue de Gemmologie a.f.g.*, No. 75, pp. 14–15.

Machida H., Yoshihara Y. (1980) Synthetic single crystal for alexandrite gem. United States patent 4,240,834, filed September 14, 1979, issued December 23, 1980.

Morris R.E., Cline C.F. (1976) Chromium doped beryllium aluminate lasers. United States patent 3,997,853, filed November 29, 1974, issued December 14, 1976.

Nassau K. (1980) *Gems Made by Man*. Chilton Book Co., Radnor, PA.

Proctor K (1988) Chrysoberyl and alexandrite from the pegmatite districts of Minas Gerais, Brazil. *Gems & Gemology*, Vol. 24, No. 1, pp. 16–32.

Stockton C.M. (1987) The separation of natural from synthetic emeralds by infrared spectroscopy. *Gems & Gemology*, Vol. 23, No. 2, pp. 96–99.

Trossarelli C. (1986) Synthetic alexandrite from the USSR. *La Gemmologia*, Vol. 4, pp. 6–22.

Uji M.I., Nakata R. (1986) Chrysoberyl cat's-eye synthetic single crystal. United States patent 4,621,065, filed September 21, 1984, issued November 4, 1986.