SYNTHETIC GEM MATERIALS IN THE 1980s

By *Kurt Nassau*

Although the 1980s did not experience the emergence of several totally new synthetics that characterized the preceding decade, it was during this period that synthetics matured, with many new manufacturers and greater manufacturing capacity. The highlights of this decade include the introduction of a number of new synthetic sapphires, rubies, and emeralds, as well as the appearance of the first commercially available cuttable synthetic diamond. The 1980s also saw the influx into the market of literally tons of synthetic amethyst and thousands of tons of synthetic cubic zirconia. As new synthetic products emerged, so did the need for new detection techniques. Developments during this decade will provide major challenges in the years to come.

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Acknowledgments: The author is grateful to many of his colleagues for information provided, particularly to R. Crowningshield of the GIA Gem Trade Laboratory, New York, and J. Wenckus of Ceres Corp., North Billerica, Massachusetts.

Gems & Gemology, *Vol. 26, No. 1, pp. 50–63*

The 1980s followed a decade that experienced a peak in arrivals of new laboratory products. A series of synthetic gem materials were perfected during the 1970s, including synthetic alexandrite, cuttable-quality synthetic diamond, synthetic amethyst, and flux-grown synthetic sapphire. There were also two new diamond imitations, gadolinium gallium garnet (GGG) and synthetic cubic zirconia (CZ), as well as some near-synthetic imitations made of ceramic or glass: imitation turquoise, imitation lapis lazuli, "Opal-Essence," and imitation coral. Details of these materials are provided in Nassau (1980).

Although the only totally new synthetic material introduced during the 1980s is synthetic cat's-eye alexandrite, this is the decade when synthetics matured, with the first significant commercial availability of a variety of new products developed from earlier technologies including:

1. Chatham flux-grown synthetic orange sapphire and synthetic blue sapphire
2. Ramaura flux-grown synthetic ruby
3. Lechleitner synthetic overgrowth corundums
4. Knischka flux-grown synthetic ruby
5. Biron hydrothermal synthetic emerald
6. Russian hydrothermal synthetic emerald
7. Russian flux-grown synthetic emerald

Also during the 1980s, literally tons of synthetic amethyst "haunted" the gem and jewelry industry. In addition, the decade brought the first, if limited, *commercial* availability of synthetic diamonds (for industrial purposes) in a quality and size that could be suitable for use in jewelery. Each new product possessed a new set of characteristics, so that the gemologist was faced with the need in many cases for new "rules of identification" and even the development of new tests. Even though synthetics and imitations represented only about 5% of the total dollar value of the U.S. retail trade (estimated per Nassau, 1980), they continued to generate great concern through the industry.

Figure 1. Large amounts of relatively low-cost Verneuil synthetic ruby and sapphire were available during the 1980s and were even used, in conjunction with cubic zirconia, in reproductions of fine jewelry. Jewelry courtesy of Our Secret Creations, Beverly Hills, CA; photo by Shane F. McClure.

Synthetic materials may be separated into two groups. The term *luxury synthetics* refers to difficult-to-grow, high-cost materials, including some synthetic alexandrite, synthetic emerald, and flux-grown synthetic ruby and sapphire. *Lower-cost synthetics* encompasses materials such as synthetic star ruby and sapphire; synthetic opal; synthetic citrine, amethyst, and other varieties of quartz; as well as synthetic cubic zirconia and Verneuil-grown synthetic ruby, sapphire (figure 1), and spinel. While the decade of the '80s has seen a greater variety and quantity of luxury synthetics on the gem and jewelry market, it has experienced an explosion of lower-cost synthetics. By the end of the decade, production of cubic zirconia had increased about 20-fold over production in the late 1970s, to about 100 million carats per month (J. Wenckus, pers. comm., 1989).

This article examines the major developments in gem synthesis and production during the last decade. While most synthetics manufacturers do not divulge their processes, knowledge of crystal-growth techniques and examination of the product can usually provide identification of the process used, if not all the details of the specific procedure. This article will also consider those products (such as Ardon Associates' Kashan synthetic rubies and the Linde hydrothermal synthetic emeralds) that are no longer being manufactured, since old material or pre-existing stock is still likely to be seen by the gemologist. In addition, some of the discussion refers to products first made on an experimental

TABLE 1. Synthetic ruby products and producers, with references to the recent literature.[a]

Process	Name/current producer	References
Melt		
Verneuil flame fusion	Many[b]	Nassau, 1980
Float zone	Bijoreve/Seiko	Koivula, 1984
Czochralski pulling	Many	Nassau, 1980
	Inamori/Kyocera[b]	Koivula and Kammerling, 1988a; Schmetzer, 1986c
Flux[c]	Chatham	Nassau, 1980; Gübelin, 1983a,b; Schmetzer, 1987
	Gilson/Nakazumi	Schmetzer, 1986c
	Kashan/Ardon	Nassau, 1980; Gübelin, 1983a,b; Burch, 1984; Henn and Schrader, 1985
	Knischka	Gübelin, 1982, 1983a,b; Gunawardene, 1983; Galia, 1987
	Lechleitner "overgrowth"	Kane, 1985; Gunawardene, 1985a; Schmetzer and Bank, 1988
	Ramaura/J.O. Crystal	Kane, 1983; Bosshart, 1983; Gunawardene, 1984; Schmetzer, 1987

[a] *For general reference, also see Schmetzer (1986a,b).*

[b] *Asteriated material also produced.*

[c] *A number of these processes also employ synthetic overgrowth over a synthetic or a natural seed.*

basis some years ago (e.g., the General Electric synthetic jadeite), about which information was released only recently.

It is not possible to cover in detail the preparation techniques of all synthetic products, current as well as recent manufacturers. Since my book on the subject (Nassau, 1980) appeared exactly at the beginning of the decade, it can be used as a point of departure for this article, with the materials discussed in the same sequence as there used. For the most part, I have not included the identifying characteristics of these products and the methods by which they can be separated from their natural counterparts (as well as from each other, should it be required); this aspect alone would easily fill an entire issue of *Gems & Gemology.* Some individual items are discussed, however, when their nature is related to special manufacturing aspects or to important developments of the decade. As much as possible, the reader is referred to the published literature in this regard.

SYNTHETIC RUBY AND SAPPHIRES

Ruby was the first synthetic gem material to be produced commercially, with the Geneva and Verneuil flame-fusion products both appearing at the turn of the century. Verneuil's synthetic blue sapphire followed in 1911. A large Verneuil flame-fusion industry has risen over the decades, with bearings and cover "glasses" for watches the major products. Today, production exceeds 200 metric tons – or one billion carats – per year worldwide (J. Wenckus, pers. comm., 1989). The need for high optical-quality synthetic ruby for use in lasers has resulted in a variety of alternative melt-growth techniques; the products of some of these have also been faceted. Table 1 lists those products that are currently available in the gem trade, together with their manufacturers and recent publications where they (and, in some instances, their identifying characteristics) have been described; the discussion by Schmetzer (1986a) is particularly comprehensive.

Flux growth of synthetic ruby dates back only to the 1960s. Schmetzer (1986a) published the results

Figure 2. Large Knischka flux-grown synthetic crystals, like the one from which this 52.06-ct cushion cut was faceted, have been grown recently. Stone courtesy of P. O. Knischka; photo by Shane F. McClure.

Figure 3. One of the attractive synthetics to reach the gem market in the 1980s is the Ramaura flux-grown synthetic ruby. This 23.86-ct crystal, the largest Ramaura rhomobohedron grown to date, is courtesy of Ramaura Cultured Ruby, Judith Osmer; photo © Tino Hammid.

of his research into the nature of the fluxes used by different manufacturers, that is: Li_2O-MoO_3-PbX, where X is F_2 or O (Chatham, Gilson, Lechleitner); Na_3AlF_6 (Kashan); Li_2O-WO_3-PbX (Knishka); and Bi_2O_3-La_2O_3-PbX (Ramaura). The high cost of producing this luxury synthetic has kept demand, and therefore production, of this as well as of the analogous blue and orange flux-grown synthetic sapphires relatively low. Production of Kashan synthetic ruby was halted by bankruptcy proceedings in 1984. Continued research on the Knischka product, however, recently resulted in the growth of some extremely large crystals, such as the one from which the 52.06-ct cushion cut in figure 2 was faceted. For the experimental synthetic flux ruby overgrowth by Lechleitner, under way since 1983, both natural seeds (Schmetzer and Bank, 1988) as well as Verneuil synthetic seeds (Kane, 1985) have been reported.

It should be noted that the Ramaura synthetic ruby (figure 3) is reported to be tagged with a small amount of a rare-earth element to make it more readily identifiable by a yellowish orange fluorescence. This fluorescence is not always detectable using standard gemological methods, however, and it could easily be absent in a cut stone depending on how the stone was fashioned from the rough (Kane, 1983; Gunawardene, 1984).

A wide range of colored synthetic sapphires can be readily grown by the Verneuil technique (Nassau, 1980). Both synthetic blue sapphire as well as synthetic orange "padparadscha" sapphire have been grown using other methods as well: from the flux by Chatham (Kane, 1982; Gübelin, 1983b; Gunawardene, 1985b; figure 4) and by Lechleitner (including overgrowth); and with the Czochralski

Figure 4. In the early 1980s, Chatham Created Gems, known for its production of flux-grown synthetic emeralds, introduced flux-grown blue, orange, and pinkish orange synthetic sapphires to the market. The Chatham synthetic emerald shown here weighs 4.15 ct; the synthetic sapphires range in weight from 1.91 to 6.20 ct. Photo © Tino Hammid.

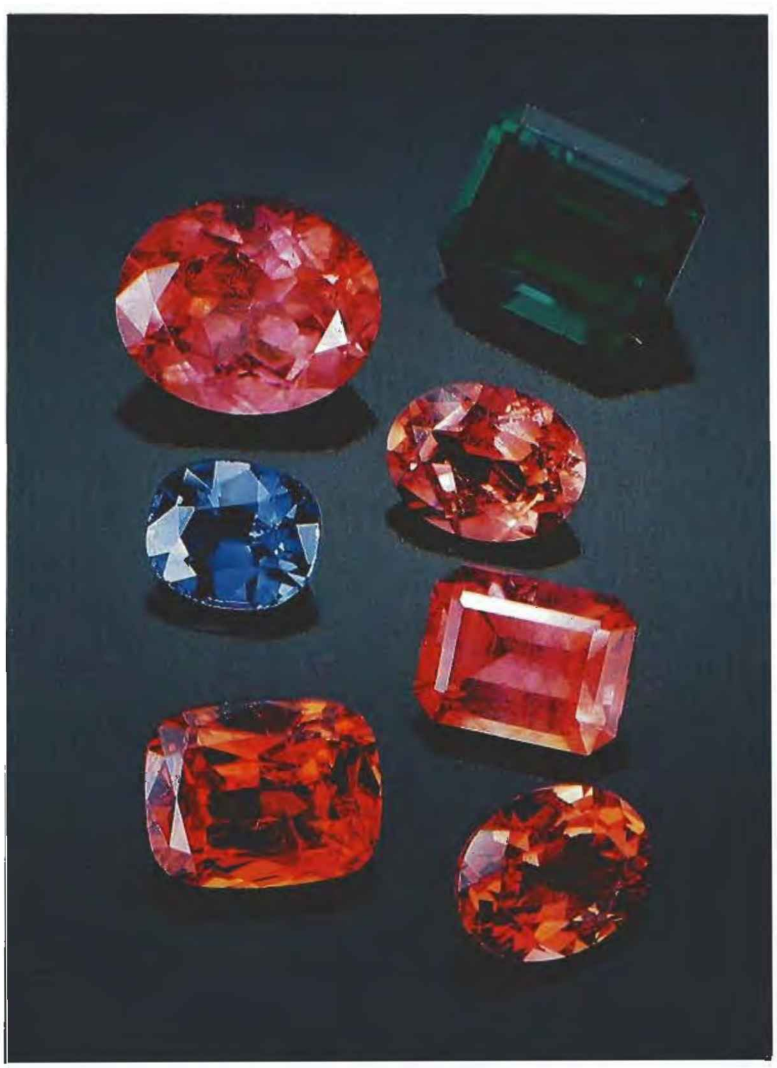
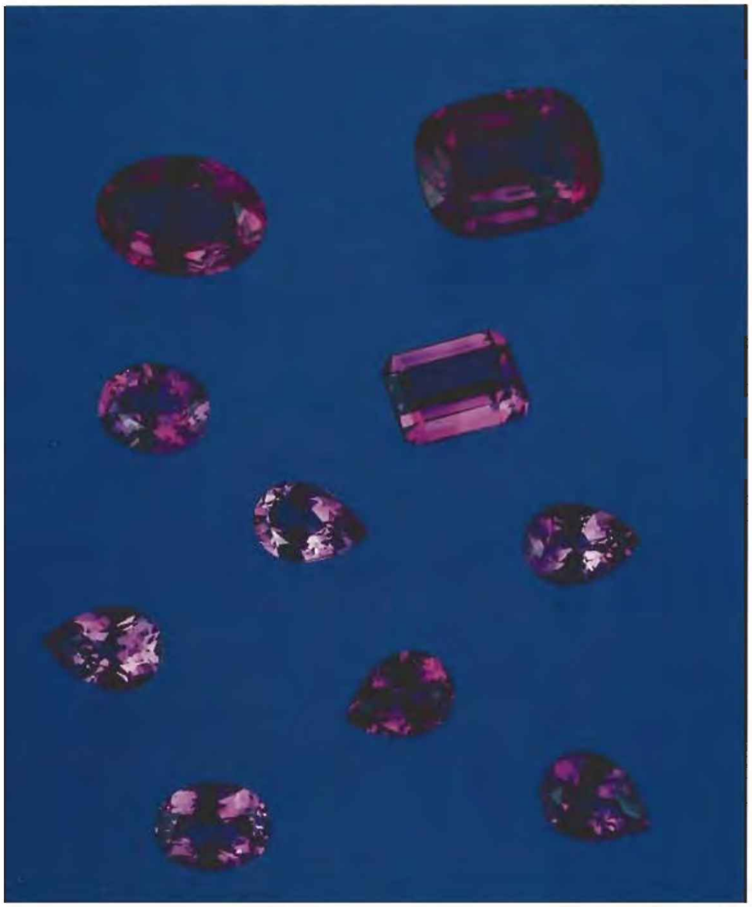


Figure 5. A flux healing process was used to induce this "fingerprint" in a Verneuil synthetic ruby. Also note the curved striae characteristic of the Verneuil flame-fusion process. Photomicrograph by John I. Koivula; magnified 45×.

and/or float-zone techniques by the Bijoreve division of Seiko and the Inamori division of Kyocera (Gunawardene, 1985b).

During the 1980s, two potentially misleading characteristics of flame-fusion synthetic ruby and sapphire were described: (1) natural-appearing fingerprint-like inclusions that can be induced after growth by a flux healing (Koivula, 1983; figure 5); (2) natural-appearing needle-like inclusions that were identified as the edges of twinning planes (Hargett, 1989).

Figure 6. Major amounts of synthetic amethyst (the largest here is 10.86 ct) entered the gem trade during the 1980s. Photo by Shane F. McClure.



SYNTHETIC QUARTZ

Giorgio Spezia accomplished the earliest successful growth of synthetic quartz by the hydrothermal method about 1905 in Italy (Nassau, 1980; Trossarelli, 1984). Colorless synthetic quartz was successfully commercialized about 1950 and, because of its piezoelectric properties, has been used in large quantities in a variety of communications devices since then. Today, some 1,000 metric tons are grown worldwide each year, although only a small part of this production, about 20 metric tons, or 100 million carats, is used in the gem trade, mostly as synthetic amethyst (figure 6) and citrine (B. Sawyer, pers. comm., 1990). Figure 7 shows one of several large modern Japanese synthetic quartz factories currently in operation.

Colorless synthetic quartz can be irradiated to produce a synthetic smoky quartz; since the same can be done with natural colorless quartz, which is plentiful, there should be no significant gem market for either the colorless or the smoky synthetic product, although the author has seen some in the trade. Both synthetic citrine and synthetic amethyst have been manufactured since the 1970s in the USSR (Nassau, 1980; Balitsky, 1980). This production was joined in the 1980s by a Japanese product (Lind and Schmetzer, 1987). A synthetic rose quartz has been produced experimentally by adding both iron and titanium (Hosaka et al., 1986).

The observation of inclusions, when present, to separate natural and synthetic amethyst and citrine was augmented in the 1980s by the examination of growth and twinning structures. An identification technique based on Brazil-law twinning, present in natural amethyst and absent in synthetic amethyst, was described by Schneider et al. (1983) and Schmetzer (1986c). The use of a simple polariscope to determine the presence or absence of twinning in amethyst/synthetic amethyst (figure 8) was subsequently proposed by Crowningshield et al. (1986) and has since been widely adopted. It is possible, however, that the twinning test could be negated if the manufacturers of synthetic amethyst were to use carefully chosen natural twinned seeds, as has already been done on an experimental basis (see, e.g., Koivula and Fritsch, 1989).

SYNTHETIC EMERALD AND OTHER BERYLS

Although work in this area started in France in the 19th century, the first commercially successful synthetic emerald was produced, by C. C. Chatham of San Francisco, only about 1940. P. Gilson of France introduced his product some 20 years later. Both of these manufacturers use a flux process, based on lithium di-molybdate, $Li_2Mo_2O_7$ (Nassau, 1980).

In the 1960s, J. Lechleitner of Austria introduced a hydrothermal technique to add a thin coat of synthetic emerald to the surface of a faceted pale natural beryl. By 1970, Linde Air Products Co. had created a hydrothermal synthetic emerald; this was originally released under the Quintessa name and subsequently reactivated as Regency synthetic emerald by Vacuum Ventures. Next, the Inamori Division of Kyocera, a Japanese firm, began marketing a synthetic flux-grown emerald under the name Crescent Vert.

A whole series of new manufacturers, using either flux or hydrothermal (figure 9) processes, have come on the scene in the 1980s, as shown in table 2. Perhaps the most interesting of these new products is associated with the names Biron and Pool (see, e.g., Hicks, 1988). The Biron hydrothermal synthetic emerald, which contains both chromium and vanadium as well as some chloride, was first produced in Western Australia early in the decade (Kane and Liddicoat, 1985; Kane, 1988; Bank et al., 1989). About 1988, the Emerald Pool Mining Company (Pty.) Ltd. of Perth, Australia,

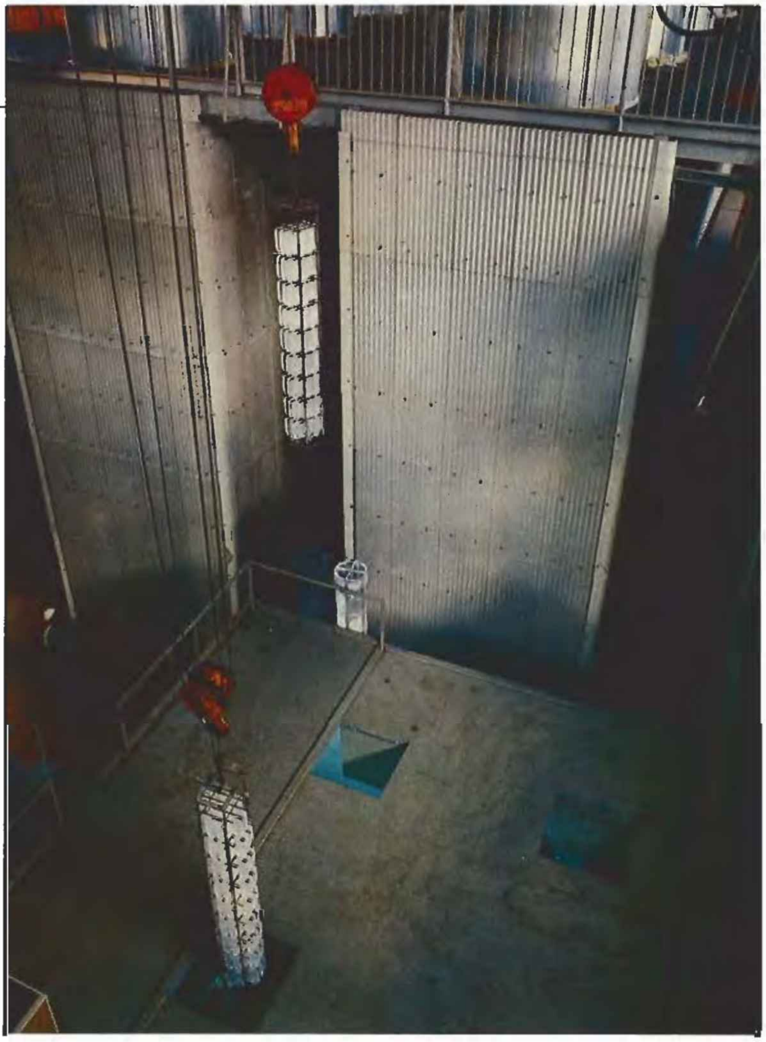


Figure 7. The growth of synthetic quartz is a major industry, as represented by this large quartz-growing facility of Daiwa Shinku Corp., the Ichikawa plant. Only about 2% of the annual production of synthetic quartz is used in the gem trade, primarily as synthetic amethyst. Photo courtesy of Daiwa Shinku Corp.

Figure 8. The difference between the twinned natural (left) and the untwinned synthetic (right) amethyst is clearly seen looking in the optic axis direction of each under crossed polarizers. Photos by Shane F. McClure.

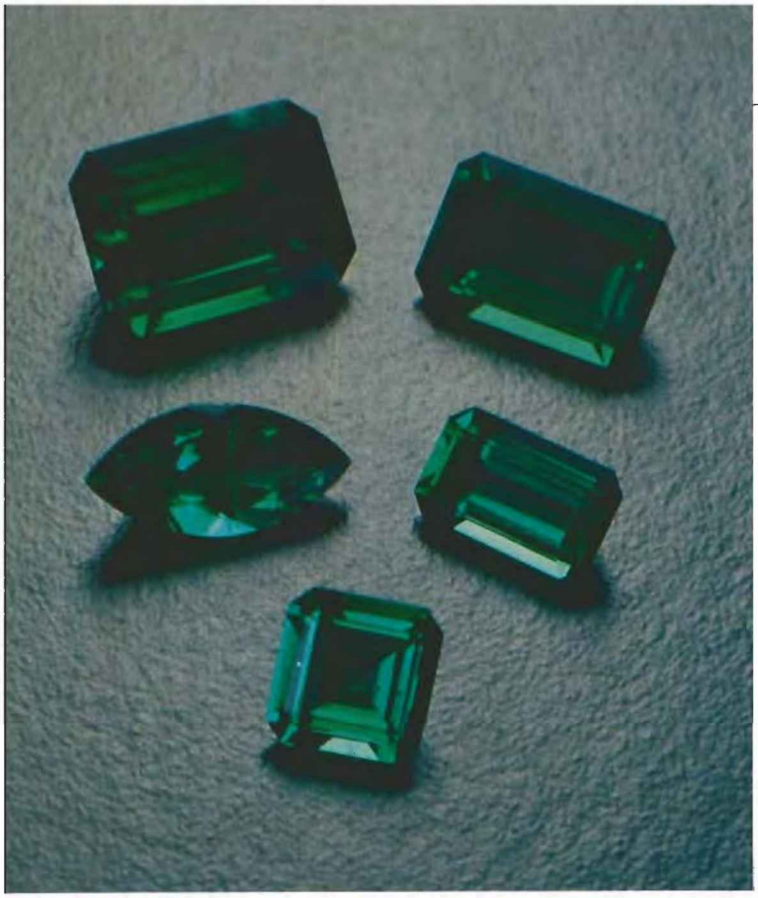


Figure 9. Russian hydrothermal synthetic emeralds were introduced to the gem market in the 1980s. Photo © Tino Hammid.

began an intense marketing campaign in which they implied that some of their product was natural emerald, claiming that a "unique and secret treatment process" was used to convert some of the lower-grade crystals from their mine into high-quality material. However, Brown and Snow (1988), found that all the Pool material they examined was Biron-type synthetic emerald.

In response to complaints that their advertising contravened the laws of many countries, Pool spokespeople merely asserted that natural emerald from their mine was "recrystallized" (Koivula and Kammerling, 1988b). Because the use of natural feed-stock with its attendant impurities makes growth much more difficult, I do not believe that any gem manufacturing technique can afford to use more than an insignificant trace of natural feed. It has been reported (J. Birkner, pers. comm., 1990) that following a reorganization, the name "Biron synthetic emerald" was reintroduced in October 1988.

In the past, Gilson has produced two types of flux-grown synthetic emerald, one with chromium as the colorant and another with iron added as well to reduce the intense red fluorescence (Nassau, 1980). More recently, they have also manufactured a flux-grown product with chromium and nickel present, giving a yellowish green color (Schmetzer, 1989). Also during the 1980s, the Gilson operation was acquired by the Japanese firm Nakazumi Earth Crystals Corp.

TABLE 2. Synthetic emerald and other beryls, products and producers, with references to the recent literature.

Process	Name/current producer	References
Synthetic Emerald		
Solution		
Flux	Bijoreve/Seiko	Kennedy, 1986
	Chatham	Nassau, 1980
	Gilson/Nakazumi[c]	Nassau, 1980; Schmetzer, 1989; Kelly and Brown, 1987
	Inamori/Kyocera	Nassau, 1980
	Lechleitner[a]	Schmetzer and Bank, 1982
	Lennix/Lens[b]	Graziani et al., 1987; Hodgkinson, 1988; Attanasio et al., 1989
	USSR[b,c]	Koivula and Keller, 1985
	Zerfass	Nassau, 1980
Solution		
Hydrothermal	Lechleitner "overgrowth"	Schmetzer et al., 1981
	Biron/Biron Minerals[b] (previously Pool)	Kane and Liddicoat, 1985; Kane, 1988; Bank et al., 1989
	Quintessa/Linde	Nassau, 1980
	Regency/Vacuum Ventures	Brown and Snow, 1983; Koivula, 1986
	USSR[c]	Schmetzer, 1986b; Brown et al., 1989
(Chemical vapor deposition?)	ANICS/Adachi Shin	Koivula and Misiorowski, 1986; Hiss and Shor, 1989
Other Synthetic Colored Beryls		
(Chemical vapor deposition?)	ANICS/ Adachi Shin	Koivula and Misiorowski, 1986; Hiss and Shor, 1989
Solution		
Hydrothermal	Regency/Vacuum Ventures	Bank and Becker, 1981; Nassau, 1989
	USSR	Koivula and Kammerling, 1988b

[a] Also overgrowth over pale natural beryl.
[b] Contains or may contain vanadium in addition to chromium.
[c] Contains or may contain iron in addition to chromium.

Considerable research was conducted during the last decade on the use of synthetic emerald for tunable lasers, for which large, high optical-quality hydrothermal synthetic emerald crystals are needed (Buchert and Alfano, 1983). A continuation of this work may in time provide the stimulus for yet larger and better-quality production.

It has long been known by crystal growers that the addition of chromium is responsible for the color of synthetic emerald and omitting it will give colorless beryl. The addition, then, of other impurities to colorless beryl should give other colors, such as those of iron in blue or green aquamarine and golden beryl, manganese in pink and red beryl, and so on. A number of manufacturers have experimented with such colors, as summarized in table 2. The specific colors that have been achieved in synthetic beryl are given in table 3, modified after Nassau (1980, p. 156) and reflecting the reports indicated in table 2. It is interesting to note that the Adachi Shin ANICS product has even been made in "watermelon" form, with a green synthetic emerald layer over a deep pink synthetic beryl core (Koivula and Misiorowski, 1986); the data provided by the manufacturer in that report and elsewhere (Hiss and Shor, 1989) suggest a chemical vapor deposition technique, but as given these data are not convincing to a crystal growth expert.

TABLE 3. Color varieties achievable in synthetic beryl.[a]

Impurity	Color (variety)	Producer[b]
None	Colorless (goshenite)	R
Cr, Cr+V	Deep green (emerald)	U, etc.
V	Deep green (emerald[c])	U
Fe	Pale blue to greenish (aquamarine)	A, U
	Yellow to greenish (heliodor)	A, U
Mn	Pink (morganite)	A, R, U
	Red	A, U
	Gray-green[d]	—
Mn+Cr	Purple[d]	U
Ni	Pale green[d]	A, U
Co	Pink to violet[d]	A, U
Cu	Blue[d]	A, U
Color center	Deep blue to green[e] (Maxixe and Maxixe type)	—

[a] *As modified from Nassau (1980), including current data from K. Schmetzer (pers. comm., 1990).*

[b] *See table 2: A is ANICS, R is Regency, U is USSR; see table 2 for others.*

[c] *Not universally accepted designation.*

[d] *Probably does not occur in nature.*

[e] *Irradiation caused, fades in light; opposite dichroism to aquamarine.*

SYNTHETIC DIAMOND

Although based largely on technology developed by General Electric in the 1970s and earlier, the gem-quality, single-crystal synthetic diamonds produced by Sumitomo Electric Industries in the 1980s represent the first commercial availability of such material. The most important developments have been the steady increase in the size, quality, and quantity of gem-quality material that can be grown affordably by the high-pressure technique (Shigley et al., 1986). As with so many advances in gemstone synthesis, this product was not developed for the jewelry industry but rather for high-technology applications: primarily as heat sinks for semiconductor devices. A later report (Shigley et al., 1987) revealed that De Beers has been conducting research in this area since the 1970s, and has accomplished the production of crystals as large as 11.14 ct.

The high-pressure product can be made in colorless, yellow, green, and blue. To date, however, only the yellow gem-quality synthetic diamonds (figure 10) have been released into the industrial market commercially. The working volume inside the belt apparatus is now quite large (about 10 cm in diameter and 15 cm high), and growth is as much as one-half carat per day on each crystal. Where a yellow color is acceptable, several crystals can be grown in each of several layers at one time by using the wide range of iron-based alloys as solvents. The much more limited range of aluminum-based alloys reduces the number of colorless or blue crystals that can be grown at one time.

A production rate is not available for present single-crystal growth, but the potential scale of operations can be gauged from that for synthetic diamond grit, estimated at about 300 million carats per year, representing about 90% of the diamond grit market for cutting, grinding, and polishing tools. The scale involved can be seen from figure 11, exterior and interior views of the De Beers synthetic diamond factory in Rand, South Africa; these are the first published photos showing close-up details of such a facility. The identification characteristics for recent Sumitomo and De Beers products have been published by Shigley et al. (1986, 1987).

To date, synthetic gem-size and gem-quality

Figure 10. For the first time in the 1980s, gem-quality synthetic diamonds were sold commercially, although not generally for gem use and only in various shades of yellow. These synthetic diamond crystals (0.63–1.07 ct), and the ones from which their faceted counterparts (0.16–0.24 ct) were cut, were obtained by GIA from Sumitomo Electric Industries. Photo © Tino Hammid.

diamond has not presented a problem to the jewelry trade. However, every large-scale synthetic diamond manufacturer (De Beers, Sumitomo, the Russians, and, no doubt by now, the Chinese) could aim part of their production at this market. Whether the result would make economic sense for the producer (luxury synthetics usually market at about one-tenth the price of the equivalent natural stones, while thus far the Sumitomo synthetics have been sold for prices comparable to similar-colored natural diamonds) remains to be seen.

Single-crystal synthetic diamond thin films have shown "promise" since early work by Derjaguin and Spitsin in the USSR about 1956 (Nassau, 1980). To this day, even when grown on single-crystal diamond, the new film grows to a thickness of just one or two microns (one micron is one-hundredth of a millimeter) and then stops being single crystal! Instead, there forms a polycrystalline, granular-type layer, which can be grown quite thick. Alternatively, thick layers can also be grown by incorporating hydrogen, thus forming a "diamond-like" hydrocarbon film, which definitely is *not* diamond and is significantly softer, although in some cases it may be harder than corundum (Nassau, 1989).

The idea of growing a thin, hard, synthetic diamond film on another material, perhaps on a faceted cubic zirconia, may seem exciting to the gemologist. As discussed elsewhere (Nassau, 1989), however, there have been problems of adhesion, transparency, and appearance (e.g., Koivula, 1987), of the temperatures required, and so on. For the immediate future, there should be no trade concerns on this matter.

SYNTHETIC CUBIC ZIRCONIA

Cubic zirconia (CZ) does occur rarely in nature (Stackelberg and Chudoba, 1937; Nassau, 1980), so this widely used diamond imitation is properly classified as a synthetic. As a diamond imitation, synthetic CZ is far superior to a sequence of synthetic products that has included colorless sapphire, spinel, rutile, strontium titanate, YAG (yttrium aluminum garnet), and GGG (gadolinium gallium garnet). It is, in fact, so close in appearance to diamond and produced at such a low price—just one to two cents per carat wholesale in large quantities, that it is unlikely that a more effective material (short of a very inexpensive synthetic diamond!) could ever compete with it.

By 1980, only four years after the first synthetic CZ was identified in the U.S. (Nassau, 1976), the production rate was already some 50 million carats per year (Nassau, 1980), while today it is over one billion carats per year, with the Ceres Corp. accounting for almost one-half of this total (J. Wenckus, pers. comm., 1989).

It is likely that the great production and availability of synthetic CZ in the 1980s was enabled by the events surrounding U.S. patent No. 4,153,469, issued May 8, 1979, to the USSR group of V. I. Alexandrov, V. V. Osiko, V. M. Tatarintsev, and V. T. Uovenchik for the growth of synthetic CZ. This was curious, since the material patented had been previously described in a 1969 French report (Nassau, 1980). When both the Ceres Corp. and their distributor, MSB Industries, ignored Russian demands that they purchase a license or cease production, the Russians brought suit. The U.S. district court found that the application and testimony on the basis of which the patent had originally been granted to the Russians contained misrepresentations and that "what was done could be characterized as fraud. . . ." The court concluded that the patent was unenforceable (Carter, 1983).

A variety of colors, including yellow, orange, red, purple, and a range of greens, have long been available in synthetic CZ (Nassau, 1981). Not until the 1980s, however, were good deep sapphire-blue and emerald-green colors introduced, accomplished with the use of a much larger amount of stabilizer than usual (figure 12). This product was called C-Ox by the original USSR manufacturer (Fryer, 1983a); these colors are also produced by Ceres Corp.

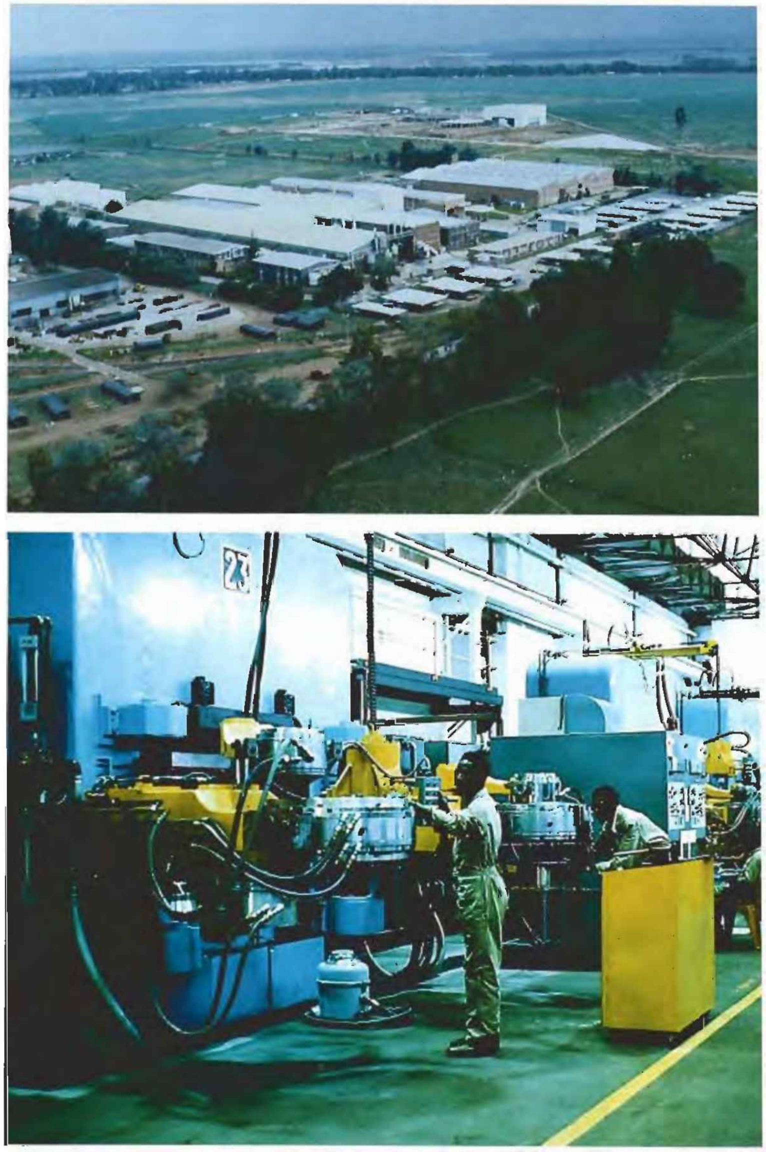


Figure 11. The potential scope of the gem synthetic diamond market is evident in these exterior and interior views of the De Beers synthetic diamond factory in Rand, South Africa. Courtesy of De Beers.

SYNTHETIC ALEXANDRITE

At the beginning of the 1980s, there were two types of synthetic alexandrites in the gem market: Creative Crystals' flux product (production was discontinued in 1985), and Czochralski-pulled material from Kyocera (Allied also pulled such mate-

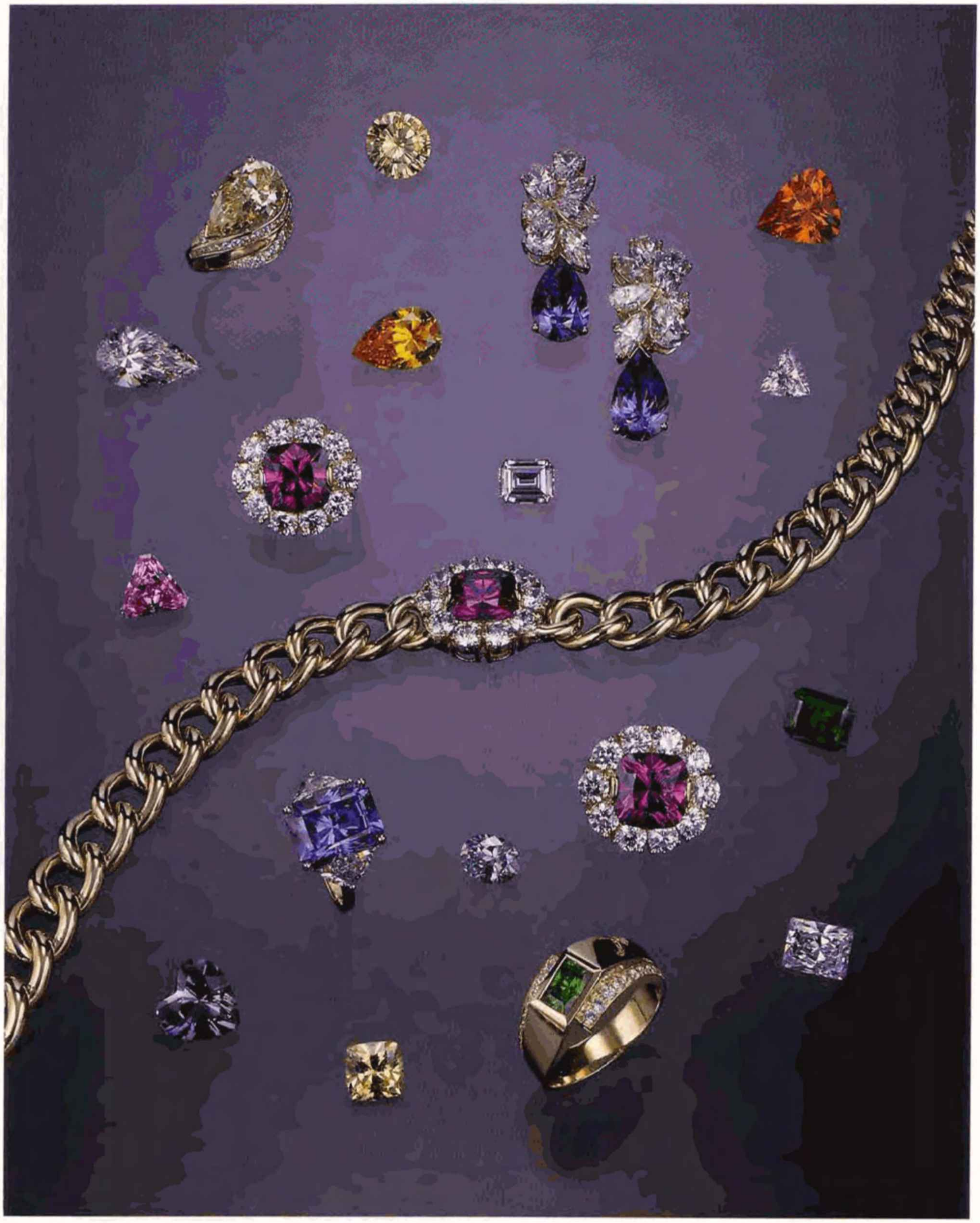


Figure 12. Synthetic cubic zirconia is purple when cobalt is present. With increased stabilizer concentration, the color becomes a deep blue and can also be changed to a dark green by a second yellow-producing addition. During the 1980s, large quantities of many different colors of synthetic cubic zirconia appeared in the jewelry trade, some in elaborate reproductions of fine jewelry, as illustrated here. Jewelry courtesy of Our Secret Creations, Beverly Hills, CA; photo by Shane F. McClure.

rial for use in laser research). Today, there are six synthetic alexandrite products that a gemologist might see (table 4). Float-zone growth, used by Seiko, is a melt-growth alternative to Czochralski pulling; the latter produces a product that is optically better, but the former can be more convenient in that it avoids the need for a crucible (although it is more difficult to control).

The two melt techniques listed in table 4 also lend themselves to making synthetic cat's-eye alexandrite. Chatoyancy is derived from the precipitation of a foreign phase by a heat treatment after growth, similar to the technique used in making synthetic star ruby and sapphires. With magnification, one can see minute particles oriented in parallel planes; these are quite different from the parallel growth tubes or needles present in the natural material (Kane, 1987).

SYNTHETIC OPAL, JADEITE, AND MALACHITE

Gilson made white and black synthetic opal by a chemical precipitation and settling process from about 1974 (Nassau, 1980). In 1983, his product was improved to appear much more natural (Fryer et al., 1983b; figure 13); shortly thereafter, a synthetic fire opal was also seen (Gunawardene and Mertens, 1984). The Gilson production has since been taken over by Nakazumi Earth Crystals. There is also a new synthetic opal from Kyocera that is marketed under the Inamori name (Fryer et. al., 1983c; Schmetzer and Henn, 1987). A synthetic opal manufactured in Australia has been reported recently as well (Downing, 1988).

Figure 13. During the 1980s, Gilson synthetic opal was improved to appear much more natural. Courtesy of J.O. Crystal Co., photo © Tino Hammid.

TABLE 4. Synthetic alexandrite products and producers, with references to the recent literature.

Process	Name/current producer	References
Synthetic Alexandrite		
Solution		
Flux	Alexandria/ Creative Crystals	Nassau, 1980
	USSR	Trossarelli, 1986; Henn et al., 1988
Melt		
Czochralski pulling	Allied Signal	Nassau, 1980
	Inamori/Kyocera	Nassau, 1980
	USSR	Trossarelli, 1986
Float zone	Bijoreve/Seiko	Koivula, 1984
Synthetic cat's-eye Alexandrite		
Melt		
(Czochralski?)	Sumitomo Cement	Dillon, 1983
(Float zone or Czochralski?)	Inamori/Kyocera	Kane, 1987

The jadeite form of jade has been synthesized on an experimental basis by General Electric in green and lavender by using a jadeite-composition glass crystallized at medium pressure (Nassau and Shigley, 1987). This material has not been produced commercially.

A Russian synthetic malachite was reported in 1987, said to be manufactured commercially in pieces up to 8 kg (Balitsky et al., 1987). So far, I know of no independent examinations of this material.

THE FUTURE OF SYNTHETICS

Modern technology has had a tremendous impact on the gem industry: Virtually all of the many synthetic gem materials that emerged over the last half century originated as spin-offs from technological research in other areas. Since the mid-1970s, however, there has been a strong worldwide contraction of exploratory materials research, which explains the scarcity of totally new synthetic gem materials in the 1980s. Since there is little likelihood of a reversal of this trend in the near future, the arrival of many new synthetics is, in my opinion, not to be expected. Only in synthetic diamond films is intense research continuing, based on U.S. government funding for the "Star Wars" Strategic Defense Initiative program. As discussed above, however, I do not believe that synthetic diamond – in either bulk or thin-film form – will be used widely in the gem trade in the foreseeable future.

A variety of other gem materials have been synthesized on an experimental basis over the years without ever reaching the marketplace. In addition, enough is known about the growth conditions of materials such as topaz and tourmaline that gem-size and gem-quality synthetics would be possible. It is undoubtedly the absence of a demand for these synthetics at the price that would have to be charged that prevents their becoming trade items.

The appearance of synthetic cubic zirconia as a diamond imitation is so close to the "real thing" to anyone other than an expert that a better imitation is unlikely. It would hardly pay to perform the extended development work required to bring a new product to the market and obtain at best a marginal improvement, especially given the low cost of CZ rough.

The last two decades have been a trying time for gemologists, filled with problems brought on by new and improved synthetics, as well as by new treatment technologies. I believe that the period ahead may be less hectic, enabling gemologists to catch up with the flood of recent changes and develop new tests to ease the problems of identification.

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