A NEW TYPE OF SYNTHETIC FIRE OPAL: MEXIFIRE

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Synthetic opals have been produced and used in jewelry for more than three decades, and various imitation opals have been introduced in the trade. This article describes a new type of synthetic fire opal marketed as "Mexifire." Some of the gemological properties of this synthetic are similar to those of natural fire opal. However, a low SG value (<1.77) offers strong evidence of synthetic origin, and further indications are provided by a relatively low RI value (<1.40) and the presence of scattered pinpoints when examined with magnification.

Natural fire opal is known mainly from Mexico (see, e.g., Spencer et al., 1992). Other locations include Kazakhstan, Turkey (O'Donoghue, 2006), Ethiopia (Johnson et al., 1996), Oregon (Laurs and Quinn, 2003), and Java (Sujatmiko et al., 2005). The high value and commercial interest in fire opal from various locations has stimulated the production of synthetic counterparts.

Natural opal is hydrated silica, amorphous to microcrystalline, with the chemical formula $SiO_2 \cdot nH_2O$ (Webster, 2002). Soon after the structure of opal was determined, in 1964, the first attempt at manufacturing synthetic opal was reported; it was introduced commercially in 1975 (see, e.g., Smallwood, 2003).

Synthetic opal is produced by a number of sources, including Gilson, Kyocera/Inamori, and some Russian manufacturers (e.g., Quinn, 2003; Smallwood, 2003). Several varieties are available, with or without play-of-color, ranging from white and black to pink, orange, or brown. This article describes the properties of a new type of synthetic fire opal (figure 1) developed by one of the authors (RB) and manufactured by Rhea Industries, which is marketed as "Mexifire."

Most of the synthetic opal produced in the past showed distinct play-of-color, which was caused by a three-dimensional array of uniformly sized particles (Nassau, 1980; Schmetzer, 1984; Smallwood, 2003). These synthetic play-of-color opals can be achieved by: (1) producing suitably uniformly sized silica spheres; (2) settling these spheres into a close-packed structure; and then (3) solidifying, aggregating, dehydrating, and compacting the array into a stable product. The Mexifire synthetic opals do not exhibit play-of-color and are made using a different process (modified sol gel). Under specific conditions, silica precursors (tetraethyl orthosilicate [TEOS] in this case) are used to produce a matrix of silica, which is similar to the structure of natural fire opal. As in natural fire opal (Fritsch et al., 1999, 2006), the orange color is caused by traces of iron. Unlike natural opal, these synthetic opals do not craze (see below).

MATERIALS AND METHODS

We examined 38 faceted fire opals: 26 synthetic (0.23–3.50 ct; again, see figure 1) and 12 natural that were said to be from Mexico (0.30–4.00 ct; e.g., figure 2). Only a limited range of sizes for synthetic samples is reported here, but larger pieces may become available in the future.

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GEMS & GEMOLOGY, Vol. 44, No. 3, pp. 228–233.

Figure 1. These samples (0.23–3.50 ct) of synthetic fire opal, marketed as "Mexifire," were studied for this report. Photo by G. Choudhary.

Standard gemological tests were performed on all samples. Refractive index was measured using a GemLED refractometer. Hydrostatic specific gravity was determined using a Mettler Toledo CB 1503 electronic balance. A polariscope was used to check for strain patterns. Fluorescence was checked with exposure to long-wave (365 nm) and short-wave (254 nm) UV radiation. Absorption spectra were observed with a desk-model GIA Prism 1000 spectroscope. We examined the internal features of the samples using both a binocular gemological microscope (with fiber-optic and other forms of lighting, including darkfield and brightfield) and a horizontal microscope with the samples immersed in water.

Energy-dispersive X-ray fluorescence (EDXRF) qualitative chemical analyses of all 38 samples were performed using a PANalytical Minipal 2 instrument under two different conditions: Elements with low atomic number (e.g., Si) were measured at 4 kV tube voltage and 0.850 mA tube current; transition and heavier elements were measured at 15 kV and 0.016 mA.

Infrared spectra of all 38 samples were recorded in the 6000–400 cm^{-1} range at a standard resolution of 4 cm^{-1} and 50 scans per sample using a Nicolet Avatar 360 Fourier-transform infrared (FTIR) spectrometer at room temperature with a transmission accessory. Multiple IR spectra were collected to find the orientation of best transmission, which was greatly affected by the cut of the samples.

Several tests for possible crazing were conducted over a period of one year. A total of 20 additional

Figure 2. Among the natural fire opals studied for a comparison to the Mexifire synthetics are these brownish orange (left, 0.30–0.86 ct) and orangy yellow samples (right, 0.67–0.81 ct), all of which are reportedly from Mexico. Photos by G. Choudhary.

Mexifire synthetic opals and 10 additional natural fire opals were placed under a 100 watt lamp for 240 hours. The samples were observed at regular intervals for signs of crazing.

RESULTS AND DISCUSSION

Visual Characteristics. The 26 Mexifire synthetic opals ranged from medium-to-dark brownish orange to orangy yellow (again, see figure 1). The 12 natural fire opals tested for comparison fell into two color groups: One was a brownish orange similar to the Mexifire product (again, see figure 2, left), while the other was a brighter orangy yellow (figure 2, right). All the synthetics were evenly colored when viewed from the table. When viewed from the side, one of them was darker in the girdle area than in the pavilion (figure 3). This color variation also has been seen in natural fire opal (see Gübelin and Koivula, 2005, p. 498). All the samples appeared transparent under normal viewing conditions, but they displayed a slight haziness when observed with a fiber-optic light. In addition, all the synthetic samples took a good-quality polish, but a few of the natural samples appeared to have a duller luster as a result of their regular use in research and educational activities in the laboratory (which caused some abrasions and scratches).

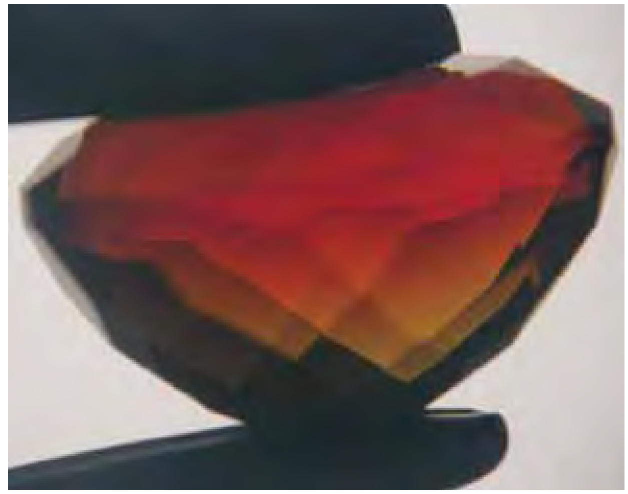

Figure 3. One of the synthetic fire opals displayed variations in bodycolor when viewed from the side. The girdle area appears darker than the pavilion. Photomicrograph by G. Choudhary, brightfield illumination; magnified 15×.

Gemological Properties. The gemological properties of the 38 synthetic and natural fire opal samples are described below and summarized in table 1.

TABLE 1. Properties of Mexifire synthetic opal and natural fire opal.

Property	Mexifire synthetic fire opal	Natural fire opal
Color	Brownish orange to orangy yellow	Brownish orange to orangy yellow
Color distribution	Typically even	Often color zoned; flow-like or wavy pattern
Diaphaneity	Transparent under normal viewing conditions; translucent/turbid with fiber-optic light	Transparent to translucent
Quality of polish	Good	Dull to good
Refractive index	1.380–1.405	1.400–1.435 (this study) 1.420–1.430 (O'Donoghue, 1988)
Specific gravity	1.63–1.77	1.92–2.06 (this study) 2.00 (Webster, 2002)
Polariscope reaction	Strong strain pattern with snake-like bands	Weak strain pattern; no snake-like bands seen
Long- and short-wave UV fluorescence	Inert	Inert
Desk-model spectroscope	No features	No features
Internal features	1. Turbidity following zones (with fiber-optic light) 2. Scattered pinpoints 3. Whisker-like inclusion (in one sample)	1. Turbidity following zones (in one sample) 2. Scattered inclusions of pyrite or some flake-like inclusions 3. Dendritic inclusions common 4. Flow patterns, cloudy zones, fluid inclusions, and a feather-like feature; whisker-like inclusion (in one sample)
EDXRF analysis	Presence of Si, Fe, and Ca	Presence of Si, Fe, and Ca
FTIR spectroscopy	Absorption band in the 5350–5000 cm^{-1} region; hump ranging from 4600 to 4300 cm^{-1}; detector saturated at wavenumbers below 4000 cm^{-1}	Absorption band in the 5350–5000 cm^{-1} region ; hump ranging from 4600 to 4300 cm^{-1} (absent from some natural stones); detector saturated at wavenumbers below 4000 cm^{-1}
Stability to crazing	No crazing seen in 20 samples	Three of the 10 samples crazed within a week to a month

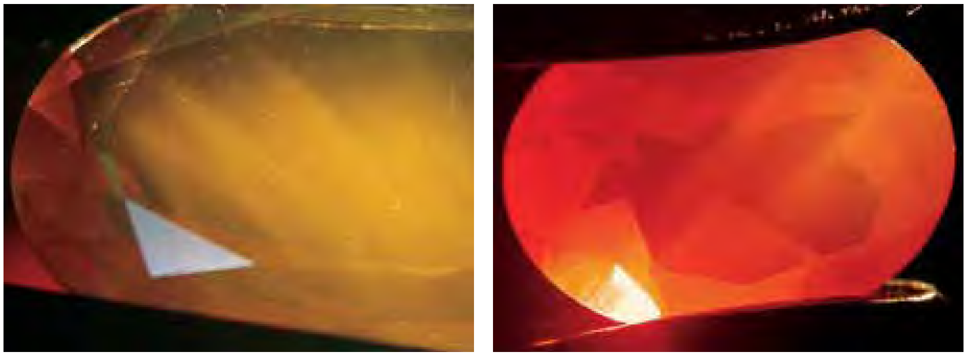

Figure 4. Turbid zones were observed in almost all the synthetic samples (left; magnified 20×) and in one of the natural opals (right, magnified 15×). Also note the scattered pinpoints throughout the sample on the left. Photomicrographs by G. Choudhary, fiber-optic illumination.

Refractive Index. All the synthetic fire opals gave RI readings in the range of 1.380–1.405 (four at 1.380, one at 1.382, one at 1.385, and 11 at 1.390, while four displayed a shadow edge at 1.395, three at 1.400, and two at 1.405). All the natural fire opals tested for comparison displayed RIs of 1.400–1.435. O'Donoghue (1988) stated that the typical refractive index value of Mexican opal falls in the range of 1.420–1.430, but on rare occasions it may go as low as 1.37. Expanding the range of color to include "smoky" opal with play-of-color, however, O'Donoghue (2006) gave a different value of 1.4625 for Mexican opal, and a range of 1.44–1.46 for opal in general. Measuring a refractive index below 1.400 in a material that looks like fire opal should create suspicion.

Specific Gravity. The Mexifire samples had SG values in the range of 1.63–1.77. These values are low for synthetic opal. Although Smallwood (2003) reported SGs down to 1.74 for a Russian product, and Gunawardene and Mertens (1984) measured an SG of 1.91 for Gilson polymer "Mexican fire opal," some synthetic opals have shown SG values up to 2.27 (e.g., Kyocera: Quinn, 2003). The SGs for the tested natural opals varied from 1.92 to 2.06. Therefore, specific gravity values that are significantly below this range provide an excellent indication that an opal is synthetic. During the SG measurements, the synthetic specimens did not show any signs of porosity; this also was reflected in the quality of polish they displayed.

Polariscope Reaction. All the synthetic samples gave a strong strain pattern with snake-like bands. By contrast, the strain pattern in the natural opals was much weaker and did not exhibit snake-like bands.

Fluorescence. All samples, natural and synthetic, were inert to long- and short-wave UV radiation.

Spectroscope Spectrum. In both the synthetic and natural samples, no absorption features were seen with the desk-model spectroscope.

Internal Features. Examination of the Mexifire samples with the gemological and horizontal microscopes revealed the following features:

1. *Turbidity:* Most exhibited moderate-to-strong turbidity when illuminated with a fiber-optic light. In darkfield illumination, however, they appeared transparent. The turbidity was somewhat zonal (figure 4, left), as seen in one of the natural samples examined for this study (figure 4, right) and in some other natural fire opals (Choudhary and Khan, 2007).
2. *Pinpoints:* All synthetic samples exhibited scattered pinpoints throughout the stones (again, see figure 4, left). These pinpoints were best seen when the samples were illuminated with fiber-optic light; only a weak effect was visible in darkfield. Even at higher magnification, the exact nature of these pinpoints could not be resolved. Although similarly scattered flake-like inclusions have been seen previously in natural opals, and Gübelin and Koivula (2005) mentioned tiny grains of pyrite scattered throughout a stone, we did not find any reports of such "pinpoint" inclusions in a natural opal.
3. *Whisker-like Inclusion:* One of the synthetic fire opals displayed a whisker-like inclusion (figure 5, left) that broke the surface. Its exact nature could not be determined, but it looked like a hollow tube filled with an epigenetic material. One of the natural opals displayed a similar inclusion (figure 5, right). Johnson et al. (1996) reported similar-shaped inclusions in fire opal from Ethiopia.

Over the years, synthetic and imitation opals have been differentiated from natural material by the

Figure 5. One of the synthetic samples contained the whisker-like inclusion on the left (magnified 75×), which appears to be a hollow tube filled with an epigenetic material. A similar feature was seen in one of the natural fire opals (right, magnified 80×). Photomicrographs by G. Choudhary, fiber-optic illumination.

presence of a "lizard skin" or "chicken wire" effect and/or a columnar growth pattern (see, e.g., Gübelin and Koivula, 1986, 2005; O'Donoghue, 2006, 2007). Detailed examination of the inclusions and growth patterns in the Mexifire samples was conducted using various types of illumination and techniques, but no lizard skin or chicken-wire effect was observed. This effect is visible only in synthetic opals made of uniformly sized silica spheres with a close-packed structure, which serves as further evidence that the structure of these new synthetic opals is different from that of most synthetic or imitation opals described previously. One exception involves some Russian synthetic opals that also do not show a lizard skin effect (Smallwood, 2003).

Some additional internal features seen in the natural opals that were studied for comparison are shown in figure 6. See Gübelin and Koivula (2005) for detailed illustrations of inclusions in natural opals.

EDXRF Analysis. Qualitative EDXRF spectroscopy of all the samples, synthetic as well as natural, revealed the presence of Si as the major element, which is expected for opal. In addition, the samples in both groups contained traces of Fe and Ca. We did not detect any Zr, which has been used for impregnating and stabilizing opal (Webster, 2002; Smallwood, 2003).

FTIR Analysis. The infrared spectra recorded for the synthetic and natural samples displayed similar features in the range 6000–400 cm^{-1} (e.g., figure 7; also compare to Johnson et al., 1995). Slight differences in the intensity and appearance of the absorption pattern were caused by variations in the amount of transmission; better transmission revealed sharper absorption features. All samples had an absorption band in the region of 5350–5000 cm^{-1}; this feature also consisted of sharp peaks, depending on the transmission. A hump was observed in the 4600–4300 cm^{-1} range, often with small peaks, in all of the synthetic samples and in seven of the 12 natural opals in this study. The absence of the absorption feature at 4600–4300 cm^{-1} may provide a useful identification criterion for determining natural origin. The detector was saturated by strong absorption at wavenumbers below approximately 4000 cm^{-1}.

Some Inamori/Kyocera products are regarded as imitations rather than synthetics because they use polymers as binding agents. Although the low SG values of the Mexifire products are consistent with the presence of polymers, this could not be confirmed with IR spectroscopy due to complete absorption in that region of

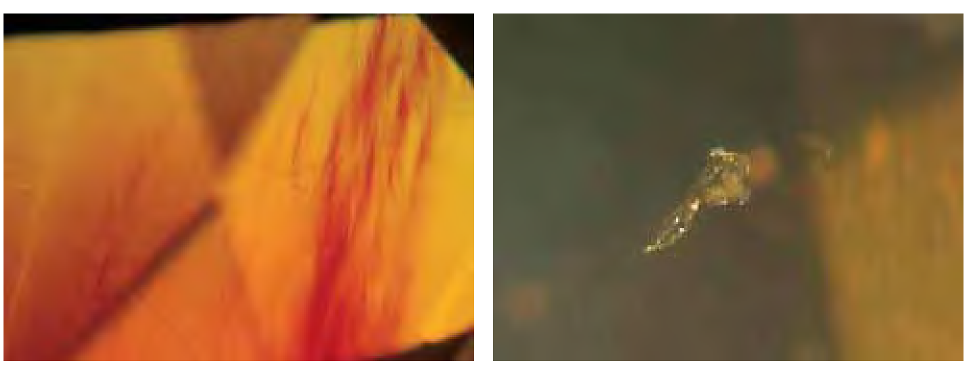

Figure 6. Some of the natural fire opals studied for comparison displayed internal features such as wavy flow patterns with color concentrations (left, magnified 45×) and a feather-like inclusion (right, fiber-optic illumination, magnified 80×) that were not seen in their Mexifire synthetic counterparts. Photomicrographs by G. Choudhary.

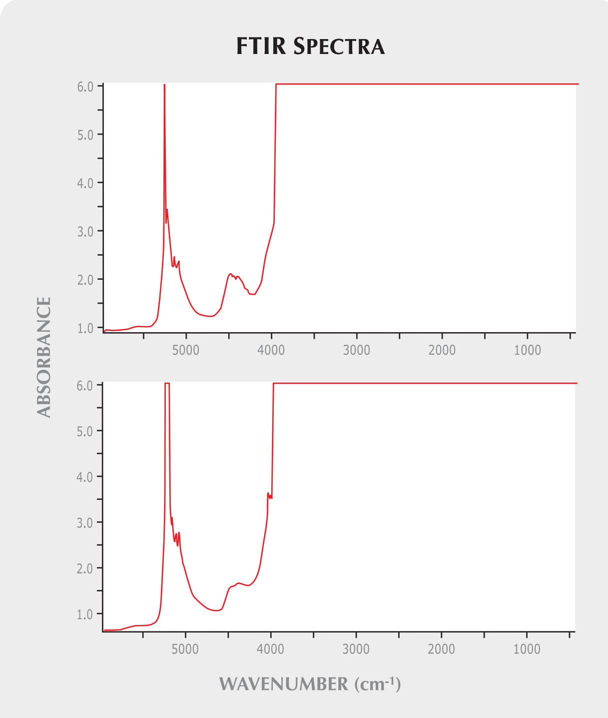

Figure 7. These representative IR spectra of Mexifire synthetic opal (top) and natural fire opal (bottom) exhibited similar features: an absorption band in the 5350–5000 cm^{-1} region, a hump in the 4600–4300 cm^{-1} range (which was absent from the spectra of some of the natural samples), and total absorption below approximately 4000 cm^{-1}.

the spectrum. Nevertheless, the manufacturer claims that no polymer is present in these Mexifire opals.

Stability to Crazing. None of the 20 Mexifire pieces exhibited any signs of crazing during these experiments, but three of the natural fire opals crazed within a week to a month. The seven other natural samples did not exhibit any signs of crazing.

CONCLUSION

Similarities in some of the gemological properties, as well as in the chemical composition and IR spectral features, were noted between Mexifire synthetic opals and their natural fire opal counterparts. However, a low SG value (<1.77) is an excellent indication that a fire opal is not natural, and additional evidence is provided by a relatively low RI value (<1.40) and internal features such as scattered pinpoints. In addition, the absence of a hump at 4600–4300 cm^{-1} in the IR spectrum suggests that the sample is natural.

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