35 YEARS ON
A NEW LOOK AT SYNTHETIC OPAL

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ABSTRACT

The 1964 discovery of the structure of precious opal led to a rush among scientists to replicate the material in the laboratory. The CSIRO in Australia was at the forefront of these experiments. About the same time technology for the process associated with the original patent was being investigated in France and the Pierre Gilson Laboratories produced the first truly 'synthetic' opal. This paper reviews the history of those early days of synthetic opal manufacture, as well as examining the more recent production of synthetic and imitation opals from Japan, Russia, and China. Tables of gemmological constants are provided for comparison with those of natural opal.

INTRODUCTION

The first attempt at manufacturing synthetic opal was made soon after the determination of the structure of opal in 1964 Sanders[1]. Details of the procedure used to first synthesise opal are preserved in the original patent documents registered by the CSIRO in Australia, Great Britain and the USA during 1964[2,3,4]. The original patents for the synthesis procedure were finally accepted some seven years later, on October 11th 1971.

During this time Pierre Gilson Laboratories were also involved in research into the synthesis of opal, and Gilson's first opal was manufactured in the late 1960's; but this man-made opal was of very poor quality. The first commercial production of 'synthetic' opal was not manufactured until 1975, with the introduction of the Gilson™ created gemstones. 'Synthetic' opal was a reality and it began to appear in items of jewellery with its properties and features being reported in gemmological literature[5,6].

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Hearsay suggests that all of the earliest attempts at manufacturing synthetic opal were dogged by instability of the final product that resulted in the opaline material cracking and crazing.

Today, the accepted procedure for manufacturing both synthetic and imitation silica based opals is essentially the same as those recorded in the original CSIRO patents. Essentially, this consists of:

1. A method of producing suitably sized spheres of silica.
2. A method of settling and separating randomly sized spheres into uniform sizes, and depositing or precipitating these into an ordered array.
3. A method of solidifying, aggregating, dehydrating and compacting the array into a stable product.

TYPES OF MAN-MADE OPAL

Man-made simulants of gemstones may be separated into two groups: synthetic gemstones that are an exact chemical equivalent of the natural material; and imitations that are simply look-alikes and otherwise chemically distinct from natural opal. Imitations can be further subdivided into those imitations that have a very similar chemical composition to the natural material, and those that have an entirely different chemical composition but have a similar appearance to the material they are meant to imitate.

In reality, all of the so-called 'synthetic' opals are, in fact, imitation opals—for by strict gemmological definition their chemical compositions differ (to variable extents) from those of natural opals. Natural opal is hydrated silica that has the chemical formulae of $SiO_2.nH_2O$. The early synthesis of opal attempted to produce synthetic opal to this chemical composition, however it is likely that at some stage during the refinement of the manufacturing process that two modifications were made. First, some of the water was removed from the synthesised opal. The second was the introduction of a suitable 'stabilizing' chemical that was designed to preserve the solidity of the end product.

As a group of non-natural types of opal, these man-made opals can be subdivided into three groups:

- Mostly silica containing so-called 'synthetic' opal.

- A 'polymer' impregnated silica containing imitation opal.
- A category of imitation opals that have been made entirely of polymers or glass.

As this classification is the one that is used commonly in the gemmological literature, for consistency, these terms will be used in the subsequent discussion.

Early (Historical) Synthetic Opal

Soon after the ordered, sphere-based structure of opal was revealed by CSIRO scientists, innovative potential synthesisers of this material started to postulate the various methods by which synthetic opals could be manufactured. All that was needed were suitably sized spherical particles of a suitable transparent medium. In fact, any transparent material capable of being flocculated and deposited into a three-dimensional ordered spherical array would be suitable for producing imitation opal; provided the spheres produced were of suitable size and optical transparency, and that they were arrayed in the appropriate Bragg relationship.

Two types of imitation opal were originally produced: a plastic variety with "latex" (actually polystyrene) spheres, and a silica based variety. The method of production of the silica spheres is noted in the CSIRO Patent Specification[2] as:

"Particles of the size required for producing diffracting arrays according to the invention by heating a pure silica sol, prepared by de-ionizing a sodium silicate solution with ion-exchange resins suitable for the removal of both cations and anions, for periods of many hours, 30 to 300 for example, at 100°C............"

The methods of further processing these spheres was then discussed in following pages that detailed the aggregation of these spheres into a suitable size and their subsequent sedimentation and compaction.

An examination of the earliest manufactured synthetic opal reveals a white material that shows almost no *play-of-colour*. This opal was too soft and porous to take a polish. Additionally when immersed in water the porosity was such that a substantial amount of water was absorbed by the material. The result of this synthesis (Fig. 1) was a white or light opal that displayed some very small patches of *play-of-colour* that were subdued, usually of a single colour and quite random in distribution. A SEM (Scanning Electron Micrograph) image of this opal reveals a substantial degree of porosity in this material, and that the actual stacking of the spheres is not very tight, that is close packed (see figure 2). In addition, the particles of silica forming this synthetic opal are not really spherical when compared with the SEMs of either natural opal or other more modern synthetic opals.

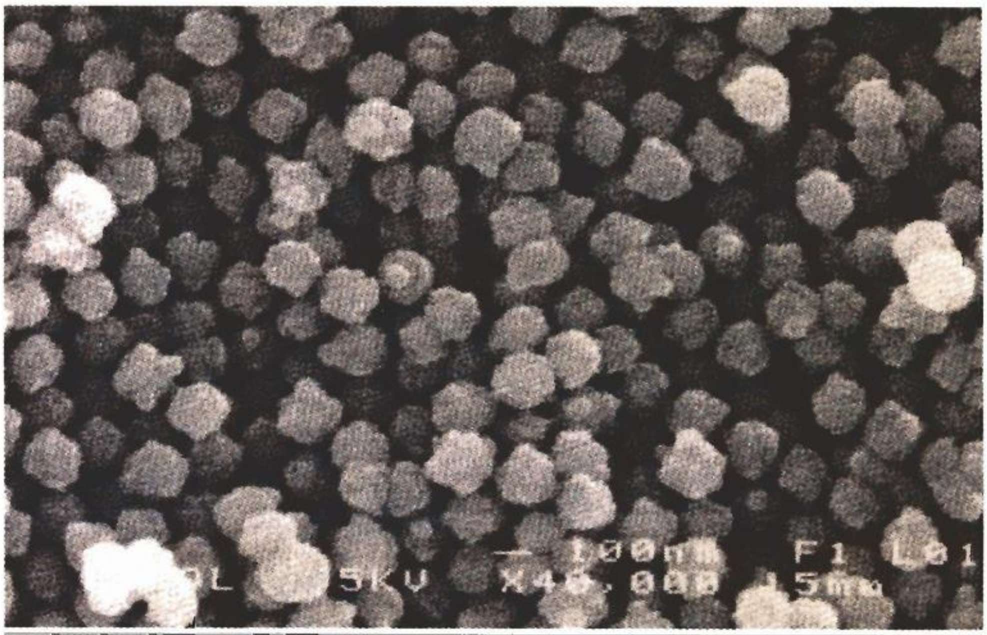

Fig. 2. SEM photomicrograph illustrating the structure of the synthetic opal illustrated in figure 1.

Gilson Synthetic Opal

Early production of synthetic opal from the Gilson Laboratories from the 1970's was a material that had a distinct pinkish background to its *play-of-colour* (Fig. 3). However, this manufacturer soon refined his process so that he was able to produce both black, and white 'synthetic' opal (see figure 4). Specific details of the Gilson manufacturing process for opal have never been revealed. However, some specific detail about this material is available in literature.

According to Darragh & Perdrix[7], the arrival of Gilson 'synthetic' opal in the marketplace was announced in 1972 by a New York jeweller who stated this opal would be available for sale in early 1973. Early descriptions of this new 'synthetic' opal and its properties were provided to delegates to the 25th International Gemmological Conference that was held in Sydney in 1976[8]. Subsequent papers by Ball[9] and later by Darragh *et al.*[10] and Jobbins *et al.*[11] gave the first descriptions of how this opal could be identified by visual characteristics that included:

- a structure that consisted of columns usually perpendicular to the base of the cabochon; and,
- the observed presence of the so-called 'lizard skin' or 'chicken wire' pattern on the surface of

the opal that was formed from sub-grains within colour grains or colour patches that had typically crenulated outlines.

Electron microscopy also revealed some differences in the internal structure of the spheres that formed this opal. Examination of SEM images of natural and 'synthetic' opals reveals that natural opal (Fig. 5) is formed from spheres that show a series of concentric rings due to the circumferential aggregation of smaller 'protospheres', while these 'protospheres' are not present in the 'synthetic' opal (Fig. 6).

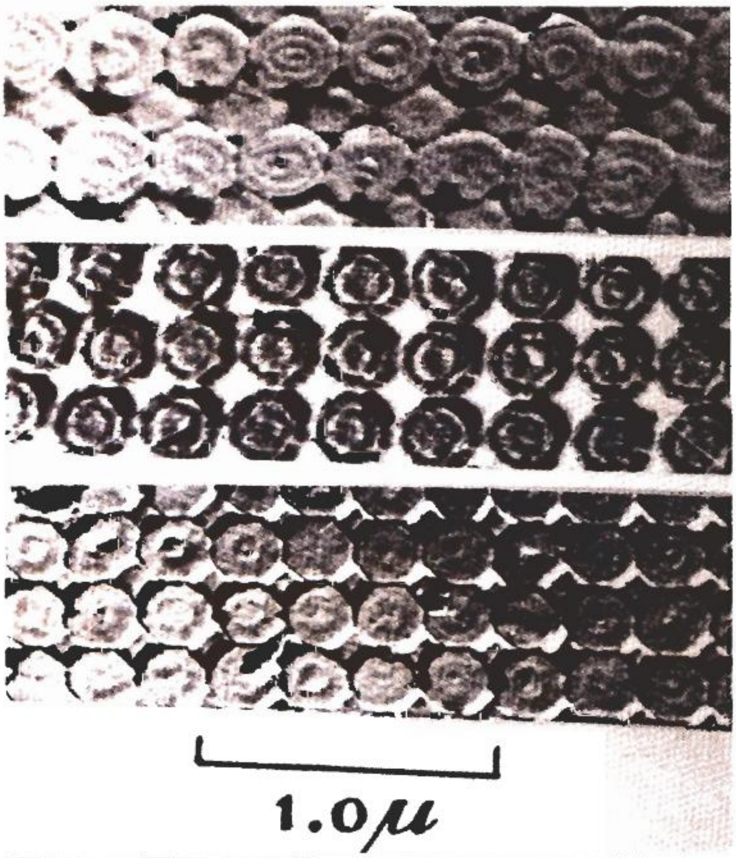

Fig. 5. Electron micrograph of natural precious opal spheres showing concentric growth of the spherical particles from smaller 'proto' spheres. A copy of an early CSIRO photomicrograph.

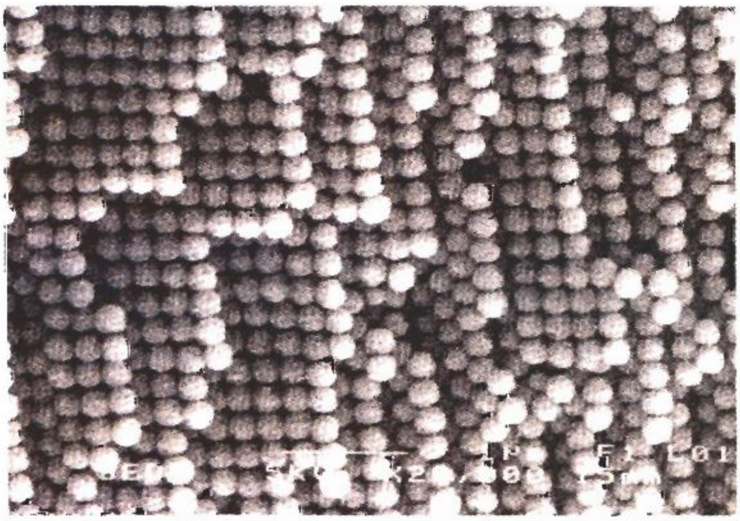

Fig. 6. Electron micrograph of spheres in 'synthetic' opal showing no concentric growth of spheres.

Later production runs of Gilson white, crystal and black 'synthetic' opals gradually improved the visual appearance of these opals to such an extent that while the distinctive 'lizard skin' appearance of this synthetic opal has never been removed, it is often cunningly disguised by cutting cabochons at an angle to their basic columnar structures. However, close observation always reveals the presence of these tell-tale structures in Gilson 'synthetic' opals.

In 1980 the Gilson patents and processes were sold through Dr Nakazumi to a Japanese company, Earth Chemicals. It is a fact that while the original Gilson 'synthetic' opal disappeared from the marketplace, it has more recently been replaced by a Japanese product based on the Gilson process of manufacture. The trend that followed has seen the appearance of man-made opal with large sized colour grains (colour patches) within the pattern of the opal, and with the availability of distinctly more presentable blue-green coloured 'synthetic' opal as well as the more usual red predominant variety. In both instances, while the identifying 'lizard skin' pattern and the columns can be observed in these opals, they are becoming distinctly more difficult to find.

In time details of a slightly different chemical nature of newer Gilson 'synthetic' opal were revealed in the literature. Schmetzer[12] and Simonton *et al.*[13] revealed the addition of small spheres of zirconium oxide (ZrO_2) to the mix of silica spheres on which this product was based; the deliberate depletion of water from these man-made opals; and the presence of some organic material in Gilson black 'synthetic' opal.

This additional information provided grounds for some very interesting speculation and perhaps also offered further aids for identification to the gemmologist. For many years, there has been much discussion concerning the cause of the black colour in the natural opals from Lightning Ridge. Until recently, it was doubted if sufficient organic material could be found in black potch opal to provide it with its black colour. However, with their hypothesis that microbial action could be an etiological agent in opal formation, a new theory for opal formation proposed by Behr and Watkins[14] suggests that the presence of organic material, as a possible cause for the black colour of opal, remains a possibility. However, Simonton *et al.*[13] suggested in his analysis of black Gilson 'synthetic' opal that the amount of 'carbon' they detected was not sufficient to cause the black body colour of that opal.

Simonton *et al.*[13] refer to the Gilson 'synthetic' opal as 'Gilsonite', and also reveal a structure for this 'synthetic' opal that consists of small crystalline spheres of zirconium oxide (zirconia) that are present in the interstices between the close packed array of silica spheres. One can only speculate that the zirconia is used either to further promote the 'diffraction grating effect' by a change in refractive index, or to add to the stability of the silica sphere structure.

Fig. 1. Photograph of a water-filled phial of opal that was manufactured in Melbourne by the CSIRO patented process, and the dried sample of this opal that was used for testing. Specimen courtesy of T. Roper, Tasmania.

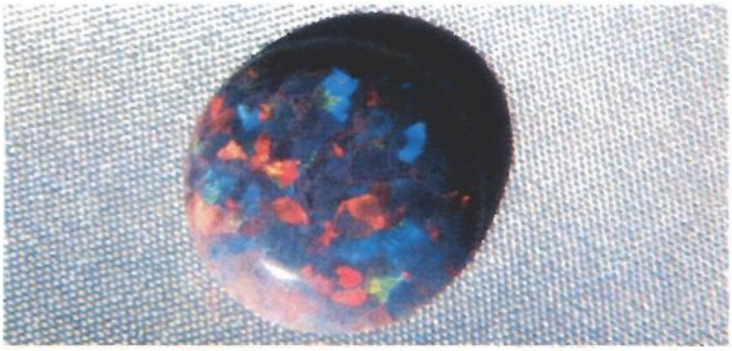

Fig. 3. Photograph of the original Gilson™ 'synthetic' opal. An oval cabochon measuring approximately 13 x 12 x 4mm, 3.21cts.

Fig. 4. Photograph showing three oval cabochon stones of the more modern Gilson™ 'synthetic' opals.

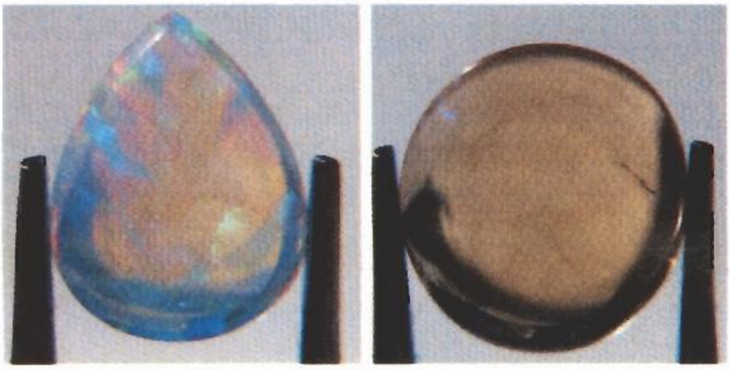

Fig. 7. Photograph in transmitted light showing a comparison of a natural light opal oval cabochon and a pear shaped 'synthetic' opal cabochon, note the yellowish colour of the natural opal when compared to the pinkish colour of the 'synthetic' opal.

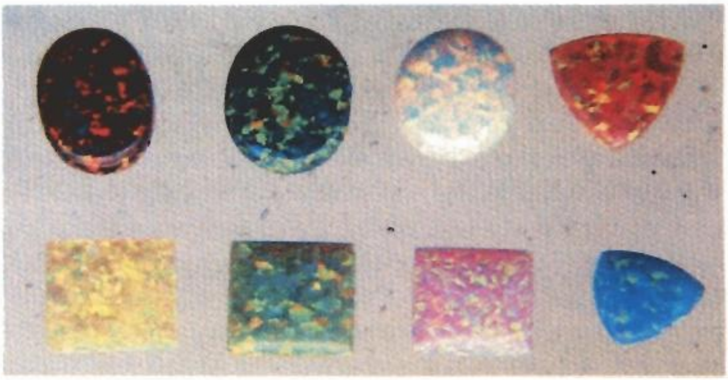

Fig. 8. Photograph showing 'colours' of Kyocera/Inamori 'polymer' imitation opal.

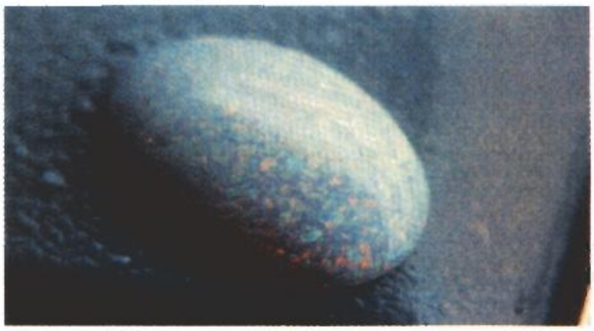

Fig. 11. Photograph in oblique lighting showing the 'transparent' or grey looking colour grains in a Russian synthetic light opal cabochon 'Type 4'.

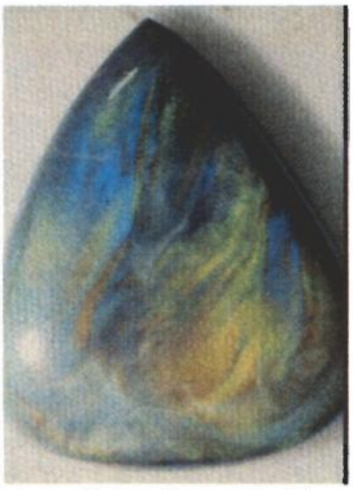

Fig. 12. Photograph of a pear shaped cabochon cut dark Russian synthetic opal showing a wavy, fibrous, paintbrush pattern of very small colour grains.

Fig. 13. Photograph of part of a strand of free form shaped Russian 'synthetic' opal beads Specimens courtesy of Manfred Zsykora.

It is interesting for the gemmologist to note that when 'crystal' opal varieties of these all-silica 'synthetic' opals are viewed in transmitted light, they show (Fig. 7 – LHS) a slightly pinkish body colour. In contrast, all the natural varieties of these types of opal show a distinctly yellowish body colour (Fig. 7 – RHS). This difference may also be caused by included zirconia or polymer in the man-made opals, whereas according to McOrist and Smallwood[15] the slightly yellowish body colour in natural opals may be due to inclusion of other trace elements of which iron and aluminium are a possibility as they are often present in these opals.

Inamori and Kyocera synthetic and imitation opal

The introduction of the Kyocera synthetic and imitation opal products has stimulated less interest in gemmological literature. Schmetzer & Henn[16] reported on this product and discussed and illustrated that these man-made opals displayed similar characteristics, compositions and structure as the Gilson 'synthetic'. US Patent documents[17], registered by the Kyocera Corporation (Inamori), describe the process of manufacturing of synthetic opals in some detail. This patent includes details of how zirconia is included into the sphere structure of man-made opal. This patent also lists the purpose of this deliberate inclusion as giving the material a "markedly improved weather-ability, heat resistance and chemical resistance".

The patent describes the manufacturing process as:

- A step of producing a structure composed of regularly three dimensionally arranged amorphous silica spheres. For example, agitating a pure silica sol, obtained from an aqueous solution of sodium silicate by ion exchange treatment, under heat over several weeks and separating the resulting precipitate of silica spheres by centrifugal separation; or alternatively, by hydrolysing an emulsion of tetra ethyl silicate at a controlled rate. The mixture of amorphous silica spheres and water is left to stand gently for several weeks to several months to subject it to spontaneous sedimentation. The resulting jelly-like precipitate is spontaneously dried and then calcined to a temperature of 700 to 900 °C to form the three dimensionally arranged structure.
- A step whereby a zirconia alkoxide, in the form of a solution, is impregnated into the three-dimensional silica sphere structure. The suitable concentration of the zirconium alkoxide, in the solution, may differ depending upon the pore (void) content of the structure. The impregnated solution is contacted with water to precipitate the zirconium alkoxide in the form of an oxide or hydroxide within the pores of the structure.
- A step whereby the resulting structure in which the zirconium compound is precipitated in the pores is then ?calcined to obtain a final product. Calcination may suitably be carried out at a temperature of 1,000 to 1,300 °C for a period of 20 – 36 hours.

It is interesting to note that the Kyocera patent describes a slightly differing form of the zirconia in the manufacturing process, as the zirconia is 'precipitated' into the voids between the silica spheres by chemical processes; whereas Simonton *et al*'s paper suggests the deliberate inclusion of zirconia 'spheres'.

As these processes all seem to be occurring about the same time, it becomes difficult to determine which manufacturer is responsible for which material; and one has to wonder as to the competition that may have been playing a part in the production of these synthetic and imitation materials.

These patent documents also reveal the reason for changing the composition of previous attempts at 'synthetic' opal production, from production processes using plastics or polymers. It was noted that these 'polymer' imitations degrade over time with the polymer component "turning yellowish" with age.

At about this time, another form of imitation opal had started to appear. This material was a combination of silica and a polymer mixture, a polymer-impregnated silica imitation opal. This imitation opal appears to be first discussed in literature in 1984 by Gunawardene & Mertens[18] and Schmetzer[19]. The first indications were from one sample labelled as a 'Mexican synthetic opal' by Gilson. This material had a "yellowish brown body colour". This imitation opal was tested by thermogravimetric analysis (TGA), and shown to have a composition of approximately 16% of some organic compound.

More recent marketing of Kyocera and Inamori 'imitation' opals reveal its availability in many, often quite artificial, body colours. Figure 8 reveals that these body colours are due to the appropriately pigmented polymer components of these imitation opals.

In a recent analysis by the author, using a similar TGA method one specimen of polymer-impregnated man-made opal (See the orange specimen in figure 8), a specimen of this polymer imitation opal was heated in air from room temperature to 800 °C The results indicated that only a small amount (3.495%) weight loss, possibly representing the loss of water to 236 °C. From that point to approximately 400 °C a 16.73% a weight loss occurred that was attributable to the polymer content of this 'opal'. A residual 1.378% weight loss occurred to ~450 °C, leaving a residue of 78.32% silica. These results are similar to those discussed in the above references.

Scanning Electron Micrography (Fig. 9) suggests some separation of the two materials into separate phases, with closer examination of the sphere structure suggesting that the usually seen stacked sphere structure is present but has some degree of 'coating' over the surface of the spheres in the 'polymer rich' areas (Fig 10).

Fig. 9. Electron micrograph showing the phase separation of 'polymer' darker areas and 'silica' lighter areas of an Kyocera/Inamori 'polymer' imitation opal at 186x.

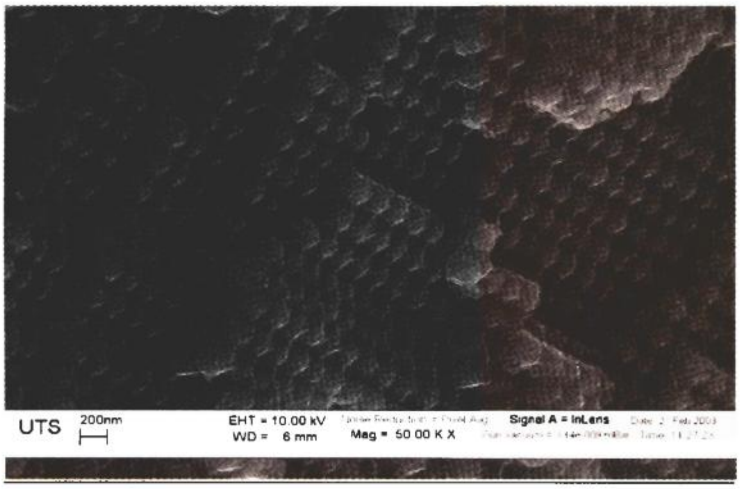

Fig. 10. Electron micrograph showing polymer 'washing' over and between the silica sphere structure in an Kyocera/Inamori 'polymer' imitation opal.

Russian synthetic opal

It is unknown when investigations into the manufacturing of synthetic opals commenced in Russia, and it was not until quite recently that some information about these all-silica opals was published in literature by Filin *et al.*[20] and Milisenda[21]. Details of how the Russian all-silica opals are manufactured are provided in the paper by Filin *et al.*

There appear to be a number of attributes common to all of the early products of Russian origin, these include:

1. All the early specimens of synthetic opal, whether of light or dark body colour, had a high degree of porosity. The latest modern production of light synthetic opal is less porous.
2. The colour patches (grains) are all very small, almost of pinpoint sizes, and less than 1 mm in overall dimensions. Often this opal displays more of a 'sheen' type of effect rather than a true *play-of-colour*.
3. These synthetic opals have lacked the normally seen 'lizard skin' patterns, and while some show a columnar structure it is often very indistinct.
4. Most samples have a subdued and consistent type of colour, with their play-of- colour being predominantly all greenish or all reddish without much change in *play-of-colour* as a consequence the movement of the stone.
5. The colour patches also tend to be more 'dramatic' in their colour change, moving or blinking from 'green' to 'red' all at the same time, whereas in natural opal there is often a more smooth gradation and randomness through the spectral colours.
6. In the more modern light opal production, often 'dark spots' or colourless grains can be seen next to 'bright' colour grains, and neighbours can look more 'transparent', hence the pattern of small colour grains can show a distinct directionality effect (see figure 11).
7. Many of the darker varieties show a distinctly brownish body colour, and have a type of 'paint brush', or swirl type pattern (see figure 12).
8. Due to the porosity it is difficult to obtain good polish on the surface of finished opals and so the lustre is not as bright being more resinous.

One strand of dark beads, that has been examined, contains beads with some layers of synthetic 'potch' type opal that are quite unusual when compared with other synthetic and imitation opals. These characteristics are illustrated in figures 13 and 14. Scanning Electron Micrographs (Figs 15 & 16) also reveal the degree of porosity present in these opals.

It would seem there have been several producers of synthetic and imitation opal from Russia. Henn *et al.*[22] reported on a then new Russian 'synthetic' opal production in 1994, as well as new Chinese imitation opal. Their paper, in German with an English abstract, gave details of these man-made opals complete with electron micrographs of the structure of these opals. Testing indicates that the Chinese material is a polymer type imitation opal with similar characteristics to the Japanese Inamori imitation opal discussed above. However the electron micrographs of the Chinese material show a distinct difference in the sphere structure as illustrated in Figure 17 by permission of the authors.

Gemmological properties of synthetic and imitation opals

Gemmological properties

The refractive index and specific gravity of various synthetic and imitation opals are listed in table 1. For

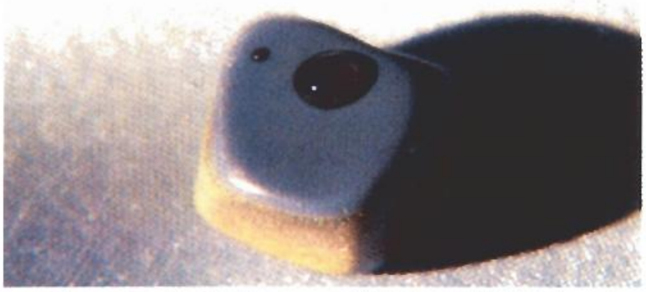

Fig. 14. Photograph of a single Russian 'silica' 'synthetic' opal bead showing the absorption of a drop of water, the nature of the grey 'potch' surface, and indistinct columnar nature of the colour 'grains' or patches. Specimen courtesy of Manfred Zsykora.

Fig. 18. Diagram of the 'lizard skin' effect seen in 'synthetic' and 'imitation' opals.

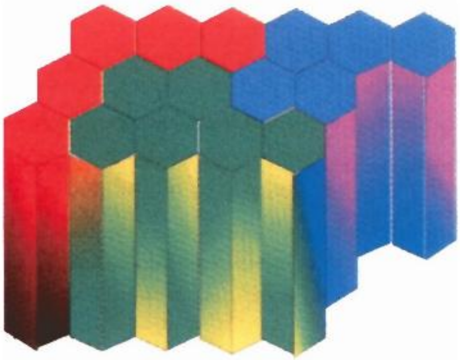

Fig. 19. Diagram showing the relationship between the 'lizard skin' or 'chicken wire' effect seen in 'synthetic' and imitation opals and the relationship of this pattern with the columnar structure.

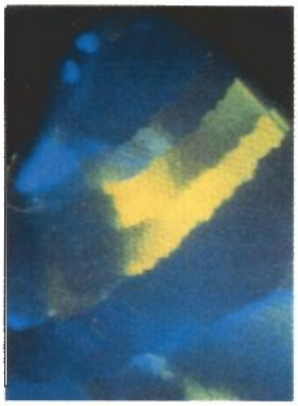

Fig. 20. Photograph of a triangular cabochon specimen of natural Lightning Ridge dark opal showing a 'pseudo lizard skin' pattern. Notice the slightly more subdued pattern, lack of columnar structure and natural potch on one end.

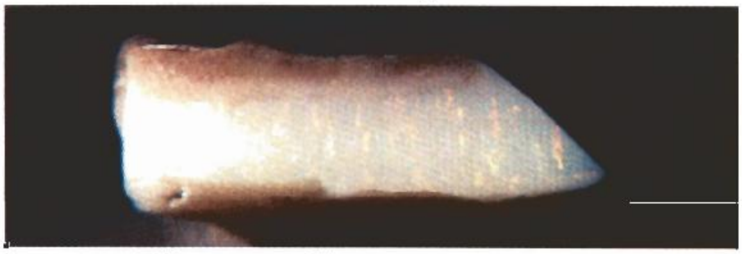

Fig. 21. Photograph of a specimen of natural light/white opal from Coober Pedy showing a 'pseudo columnar' structure.

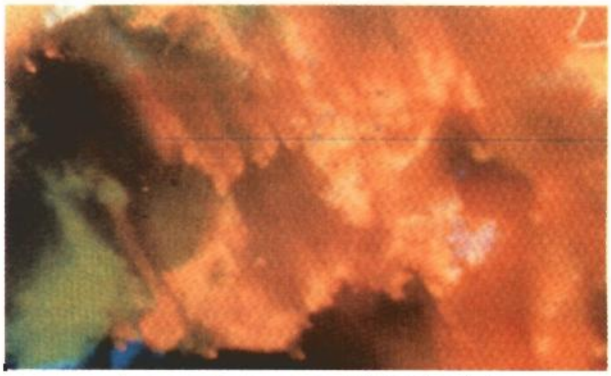

Fig. 22. Characteristic 'dangling stalactitic' colour distribution in a Gilson manufactured fire opal (imitation). Oblique lighting. 40x, Reproduced (with permission) from figure 8 of Gundawardene, M. & Mertens, R. (1984) Gilson created fire opal imitation with play of colours. Journal of Gemmology. 19(1), 43-53.

comparative purposes, the gemmological properties for a range of natural opals are listed in table 2.

Due to the porosity of Russian-manufactured opals, some difficulty may arise when one attempts to determine both their specific gravity and refractive index. The hydrostatic method of specific gravity determination is not useful, as the porosity of the materials allows the absorption of the water into the opaline structure. Also the porosity provides a difficulty in obtaining an accurate refractive index, as the material readily absorbs refractive index contact fluids—often leaving a brown stain on the "white' or light body coloured specimens. Careful use of these methods should still, however, realise reasonable results as listed in the tables.

Photoluminescence

Most gemmological literature describes photoluminescence as an important aspect of the identification of opal. Particular emphasis is placed on the length of time of the phosphorescence for opals under long wave ultraviolet (LWUV) light stimulation. Early descriptions of the identification of 'synthetic opal' suggest that this phosphorescence is of 'short'

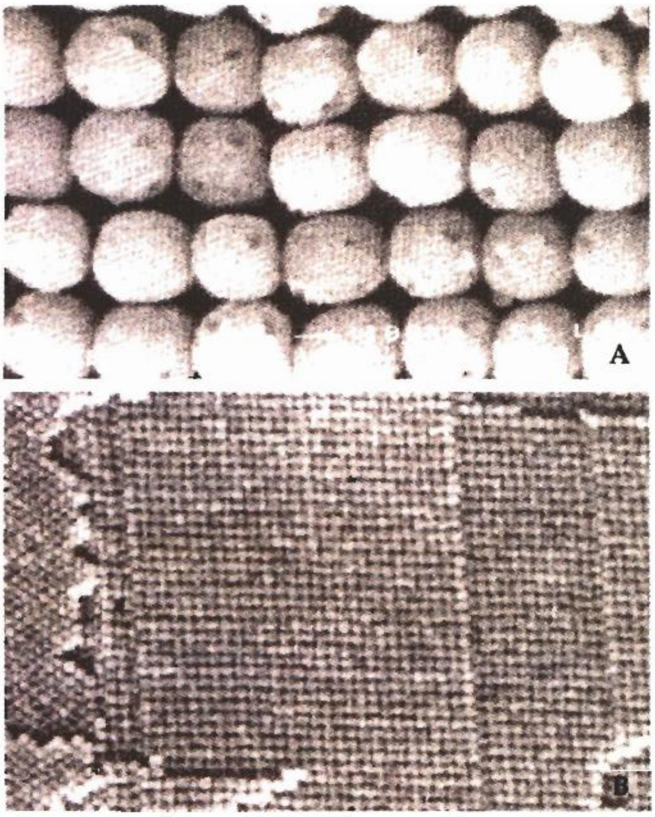

Fig. 15. Electron micrographs of a sample of one Russian grey body coloured porous silica 'synthetic' opal beads in figure 12. 80,000x

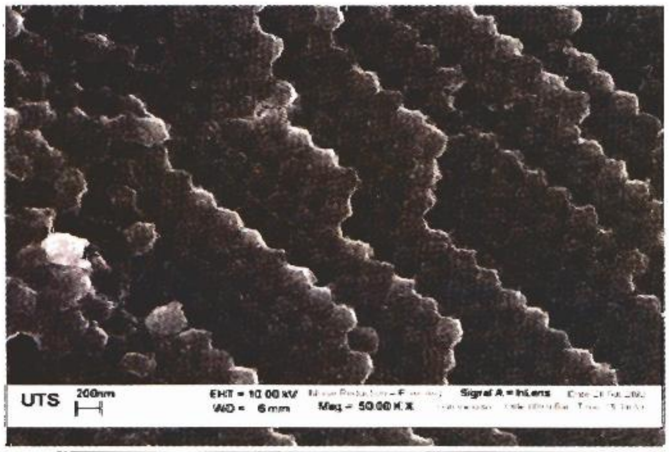

Fig. 16. Electron micrograph of Russian brown body colour porous silica 'synthetic' opal.

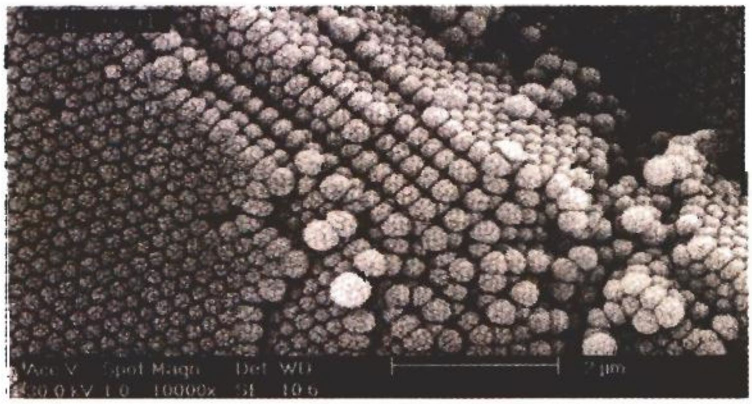

Fig. 17. Electron micrograph of 'Chinese' 'polymer' imitation opal. Note the composite nature of the silica spheres. Reproduced (with permission) from figure3 of Henn, U., Ackermann, L.& Schoder, K. (1995) Synthetic opals from China and Russia. Z. Dt. Gemmol. Ges. 44(1), 9-15.

duration (1-2 seconds), in comparison to natural Australian light opals that display 'long' phosphorescence of 8-10 seconds duration. In this author's experience, all of the latest production of synthetic and imitation opals (of white, black and transparent variety) display no fluorescence or phosphorescence to LWUV. However, some of the polymer-coloured imitation opals give differing fluorescence responses, depending on the nature of the colouring pigment used in the polymer.

This aspect of luminescence is likely explained by the lack of water in the synthetic opal structure, and the type of water in the synthetic opal structure when this is compared with that of natural opal[23]. This is especially true, as all methods of manufacture involve some degree of "drying and stabilising by a heating process". This heating then makes these materials more similar in luminescence to the so-called 'volcanic' type natural opals, however the inclusion of zirconia in these products is also reflected by an increase in the constants of Specific Gravity (SG) and Refractive Index (RI), see table 1.

Visual or microscope observations

In order to identify synthetic opal and modern silica-based opal imitations, there still remains a need for the modern gemmologist to be familiar with observation of the characteristic 'lizard skin' pattern and 'columnar structures' that characterise most man-made opals—even though the new Russian synthetic opals do not show these effects. These features are illustrated in figures 18 & 19. However, both a 'psuedo columnar structure' and a 'psuedo lizard skin' pattern can be observed in some natural precious opal as illustrated in figures 20 & 21. Fortunately, close examination of other characteristics that include the nature and type of potch inclusions, (or ironstone in boulder opal) in combination with other methods of gemmological testing, will always provide complete and positive discrimination between natural opal and synthetic and imitation opal.

Separation of natural and synthetic opals

While in routine gemmological testing there is never one specific test for identifying the origin of an opal (natural, synthetic or imitation), in the experience of the author the following suggestions may assist the modern gemmologist discriminate these materials. Whilst not all are strictly scientifically or gemmologically correct testing procedures.

1. All Australian white or light opal can be separated from its synthetic and imitation counterparts by photoluminescence or UV examination. Simply put, natural opal will phosphoresce, while and the synthetic opals will not.
2. The observation of a 'lizard skin' pattern combined with colour rising in columns, and no ultraviolet photoluminescence, will confirm the presence of a

TYPE OF IMITATION OPAL	REFRACTIVE INDEX	SPECIFIC GRAVITY (DENSITY)
Silica 'synthetic' opals		
Original Gilson (pinkish) silica 'synthetic' opal	1.490 – 1.498*	1.82 – 1.93
Gilson Black silica 'synthetic' opal	1.466 – 1.467	2.24 – 2.27
Gilson Light silica 'synthetic' opal	1.466 – 1.470	2.22 – 2.23
Kyocera/Inamori Light silica 'synthetic' opal	1.461 – 1.463	2.20 – 2.24
Kyocera/Inamori Black silica 'synthetic' opal	1.462 – 1.464	2.20 – 2.24
Russian silica 'synthetic' opal (Henn[13]).	1.440 – 1.450	1.74 – 1.86
Russian all silica grey beads (Fig 11)	1.468 – 1.483*	1.77 – 1.82*
Russian silica 'synthetic' brown body colour	1.450	1.83 – 1.84*
Russian silica 'synthetic' opal Type 3 (Milisenda[20])	1.400 spot	1.95
Russian silica 'synthetic' opal Type 4 (Milisenda[20])	1.400 spot	2.05
Silica and Polymer imitation opals		
Gilson polymer 'Mexican fire opal' (Gunawardena[18])	1.41	1.91
Kyocera/ Inamori coloured 'polymer' imitation opal	1.459 – 1.470	1.83 – 1.90
Mexican Fire opal 'polymer' imitation opal (spot reading)	1.450 – 1.466	1.89 – 1.90
Chinese "polymer" imitation opal (Henn[13]).	1.450 – 1.468	1.80 – 1.90
Russian polymer imitation opal (M.Z.)	1.440 – 1.455	1.86
Other imitation opals		
Glass imitation opal (Slocum Stone)	1.480 – 1.485	2.46 – 2.51
Chinese all polymer (plastic) imitation opal	1.535	1.17
All polymer (plastic) imitation opal	1.495 – 1.500	1.16 – 1.17
Kyocera polymer imitation opal chips in "resin"	1.47 spot	1.52 – 1.56

* porosity may effect the reading of constants by normal gemmological methods.

Table 1. Comparative properties of 'synthetic' and 'imitation' opals from various manufacturers.

TYPE OF NATURAL OPAL	REFRACTIVE INDEX	SPECIFIC GRAVITY
Australian Varieties		
Lightning Ridge black	1.440 – 1.453	2.09 – 2.13
Lightning Ridge potch	1.450 – 1.457	2.09 – 2.10
White Cliffs light	1.450 – 1.460	2.08 – 2.10
Coober Pedy light	1.442 – 1.455	2.05 – 2.11
Andamooka Light opal	1.440 – 1.460	2.11 – 2.13
Mintabie opal	1.450 – 1.456	2.11 – 2.13
Lambina	1.445 – 1.458	2.12 – 2.13
Boulder opal	1.457 – 1.458	2.11 – 2.13*
Treated Andamooka matrix	1.420 – 1.430 spot	2.11 – 2.12
Tintenbar	1.422 – 1.440	1.98 – 2.02
Overseas Varieties		
Slovakian	1.439 – 1.442	2.09 – 2.11
Virgin Valley (USA)	1.360 – 1.445	1.90 – 2.00
Mexican Fire	1.438 – 1.444	1.99 – 2.02
Indonesian	1.440 – 1.458	1.98 – 2.12
Brazilian	1.465 – 1.472	1.97 – 2.00
Ethiopian	1.439 – 1.438	1.98 – 2.03
Peru	1.425 – 1.450	2.05 – 2.09
Cat's-eye (various)	1.420 – 1.450	1.94 – 2.11

* Two samples only separated from the ironstone back

Table 2. Comparative properties of natural opals from various localities around the world.

synthetic opal.

3. Observation of a pinkish body hue, in transmitted light, with no ultraviolet photoluminescence, will confirm observation of a synthetic crystal opal.
4. Closer observation of synthetic crystal and black opals, especially those cut obliquely to the column axis will often show a subdued columnar effect so called 'dangling' or 'stalactitic' or colour grains.[18] (see figure 22). These 'columns often point to where the lizard skin effect can best be seen with correct orientation.
5. Porosity indications, a drop of water on the surface will often be easily absorbed by the surface and may be an indication of synthetic opal in dark varieties. Some gem merchants are known to test this by placing the stone on the tongue.
6. Lightweight heft in the hand, and a plastic 'feel' between the fingers can also be an indication of plastic or 'polymer' type imitations. Hot point testing will confirm the presence of either but care must be taken as this is a destructive test. Most natural opals do not like the application of heat in this procedure, and it may cause the stone to crack and craze.
7. Crystal 'synthetic' opal varieties will be separated from the 'Australian' type crystal opals by photoluminescence and the presence of 'hanging stalactites' of colour in the 'synthetic' opal. Volcanic 'type' transparent opals will be separated by their constants of RI and SG, with those of the natural varieties being substantially lower.

Addendum – A technological application for synthetic opal

It would appear that synthetic gemstone production and treatment are always associated at some time with an industrial process. Synthetic opal is no different, and recently there has been much interest shown in refining the production of same sized silica spheres for industrial purposes. Many papers are appearing in literature regarding such materials as photonic crystals, or inverse opals[24,25]. These papers discuss methods of producing an ordered array of same sized silica particles (spheres), and then coating these spheres with other compounds such as carbon and gold. The silica of the spheres is then etched out of the structure, leaving a series of ordered 'shells' of the carbon for use in so called 'photonic' devices that 'trap' certain wavelengths of light, very much analogous to the structures normally used in semi-conductor technology that trap electrons and 'holes' in electronic devices.

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