# SIAMITE® glass-ceramic – the breakthrough gemstone reflection material

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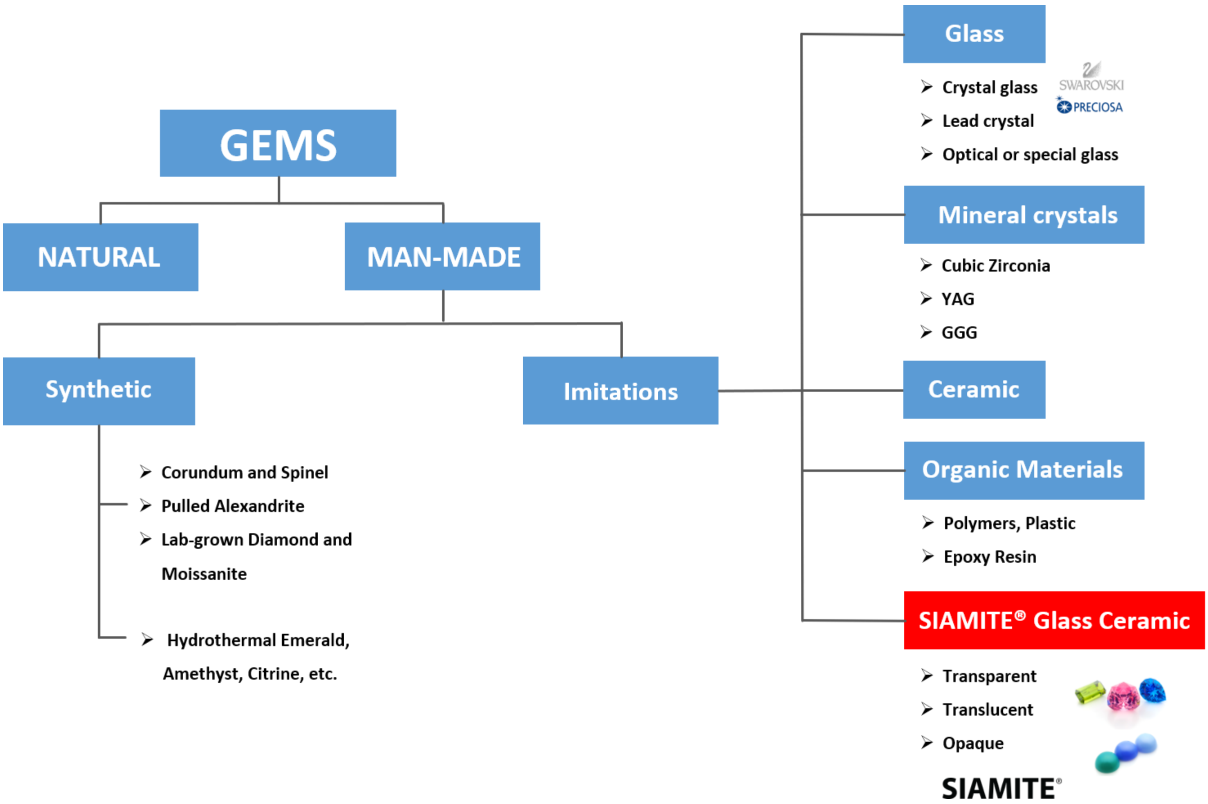
**Gems** are an essential component of jewelry. Along with natural ones, man-made stones are also widely used. **Man-made artificial stones** are traditionally divided into **Synthetic Crystals** (with the same chemical and physical properties as natural gems) and **Imitations** (that do not exist in nature) (Table 1).

**Table 1. Jewelry stones classification.**




**Synthetic crystals** include lab-grown diamonds and moissanite, hydrothermal emerald, alexandrite, quartz, sapphire, ruby, and others. Until recently, **Imitations** were represented by two main types of materials: glass or crystal-glass (Swarovski, Preciosa, Asfour...) and crystal-mineral (Cubic Zirconia, YAG, GGG). However, recently, imitations such as ceramics (polycrystalline material), polymers (Kyocera opal), epoxy resins, and other organic materials have become widely used.

**SIAMITE®** gemstone reflections debuted in the market of imitation-colored gemstones just over 20 years ago. **It was Formica that first developed the technology and began producing a completely new material for the jewelry industry - glass ceramics** (patented in the USA and 25 other countries). Its early trade names were **nanocrystal** and **nanogem**; later in 2018, we officially registered the trademark **SIAMITE®**.

During this time, it has become highly sought after by many jewelry manufacturers and is widely used by world-famous brands. However, many gemologists and jewelry specialists still do not have an accurate idea of the nature of this material and often wonder "how does it differ from glass, cubic zirconia, corundum, and other traditional materials and why is it better than them?".

**Minerals or mineral crystals** (natural gemstones, synthetic and imitations) have a fixed proper chemical composition and a crystalline grid. The main problem inherent in all minerals is color variation. This is because the composition of the melt or solution at the end of crystallization process is different from the initial one. **Glass or crystal glass** (Swarovski, Preciosa, Murano, ...) does not contain a crystalline structure and can be defined as an amorphous solid or completely frozen liquid. Colored glass is very homogeneous in color, but inferior to minerals in hardness, brittleness, luster, and refractive index. **Glass-ceramic** is a hybrid composite material that contains both a crystalline phase and an amorphous glass at the same time.

So, **SIAMITE® glass-ceramic,** created by Formica, is an entirely new type of gemstone imitation that did not exist before. Consequently, many people have question: **what is the glass-ceramic?**

**Glass-ceramics are ceramic materials formed through the controlled crystallization of glass.** Production takes place in two stages: in the first stage, a special high-temperature glass is produced using almost standard glass making technology, and in the second stage, this glass undergoes special heat treatment, during which nuclei and then crystals of minerals emerge. It is important to emphasize that crystallization occurs in the solid state (without melting), and the composition, size, and quantity of crystals depend on the initial glass composition, the temperature, and the duration of the heat treatment. This controlled crystallization allows the production of transparent (crystal size less than 10 nm), translucent (10–20 nm), and opaque (more than 20 nm) glass ceramics.

Clearly, the physical properties of glass-crystalline material significantly differ from those of the original glass. This breakthrough hybrid material combines valuable properties inherent in both crystals and glass, which cannot be found in glass or crystals alone.

Glass-ceramics are developed and implemented in various fields of science and technology. They are used for **cookware, electric stove tops, telescope mirrors, and missile randoms** (**Fig.1**).


**Figure 1.** (a) NOXTON glass-ceramic cooktop (www.amazon.com) (b) PYROCERAM glass-ceramic missile radomes (www.corning.com)

Their composition is highly variable depending on the application and the required properties. Many applications of glass-ceramics are based on their superior resistance to failure due to thermal shock. This particular property became the main reason prompting the author to extensively investigate existing types of glass-ceramics and choose the most suitable system for imitating color gemstones.

So, the criteria for selection were **resistance to thermal shocks** at the melting temperatures of silver, gold, bronze, and other jewelry alloys (960-1200°C), relatively **high hardness, density, and refractive index** values, as close as possible to similar parameters in the most sought-after natural gemstones.

Having thoroughly studied the properties of a large number of glass-ceramic materials, we settled on the so-called cordierite system **$SiO_2$-$Al_2O_3$-MgO** (**Fig.2**). The trademark **SIAMITE®** was chosen based on two considerations: 1) the chemical formulas of the three main components start with **Si**, **A**, and **M** (SiAM); 2) Formica established the production of its material in Thailand, historically known as **SIAM**. The ending "**ite**" is commonly used in mineralogy and petrography for many minerals and rocks.

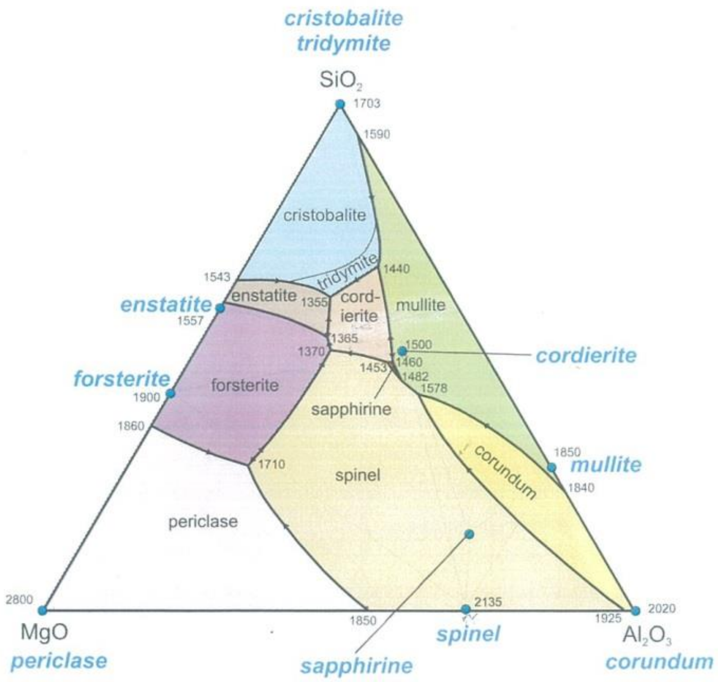



**Figure 2.** $SiO_2$-$Al_2O_3$-MgO phase diagram (Levin et al. 1964)

In addition to the three main components mentioned above, the material contains $TiO_2$, $ZrO_2$, ZnO, $Li_2O$ as well as some nucleating, fining, and coloring agents. This composition allows obtaining, in the first stage, a homogeneous and color-consistent high-temperature glass, and then crystallizing **nanosized** (one nanometer is one-billionth of a meter) crystals of **zinc spinel** – **gahnite** within it. Alongside spinel, nanocrystals of rutile, zirconium titanate, and others also form. Their presence is determined through **X-ray diffraction analysis** (**Fig.10**).

Thus, **SIAMITE® is a nanocrystalline glass-ceramic material, comprising nanosized crystals of spinel and other minerals (depending on color), uniformly distributed in the amorphous high-temperature aluminosilicate glass matrix.** The size and concentration of nanocrystals affect the degree of transparency of the material and its color. As they increase, the transparent material becomes first, translucent, and then opaque.

The physical properties of **SIAMITE®** gemstone reflections (**hardness 7.5-8, density 2.9-3.3 g/cm$^3$, RI** = **1.60-1.63**) are optimally close to such natural gemstones as **tourmaline, topaz, and emerald** (see the attached Table 2). The quartz group (amethyst, citrine, smoky quartz, etc.) lags behind Siamite® in all three indicators, while corundum, spinel, and garnet have higher densities and refractive indices. Corundum surpasses Siamite® and all other gemstones in hardness.

**Table 2. Physical properties of SIAMITE® and natural gemstones.**

| | Mohs Hardness Scale | Density g/cm$^3$ | Refractive Index |
|---|---|---|---|
| **Siamite®** | **7.5-8** | **2.9-3.3** | **1.60-1.63** |
| Tourmaline | 7.0-7.5 | 2.82-3.22 | 1.61-1.67 |
| Topaz | 8 | 3.5 | 1.61-1.64 |
| Emerald (Beryl) | 7.5-8 | 2.67-2.78 | 1.56-1.6 |
| Quartz | 7 | 2.65 | 1.54-1.55 |
| Spinel | 7.5-8 | 3.61 | 1.719 |
| Garnet | 6.5-7.5 | 3.56-3.73 | 1.71-1.74 |
| Corundum | 9 | 4 | 1.76-1.78 |

It is known that many natural and synthetic crystals and glasses cannot be used for the "Setting Stones in Wax" method because they crack or change color under the influence of a high temperature melt of gold, silver, bronze, or brass. Therefore, one of the most important advantages of SIAMITE® over other synthetic stones and imitations is its **resistance to thermal shocks** (Fig.3). This is primarily determined by the low thermal expansion coefficient both in the crystalline phase and in the residual glass. In other words, during heating or cooling, the dimensions of the stones hardly change, and therefore, they do not crack or break.

**Figure 3.** Silver jewelry tree and pendants with SIAMITE® stones made by the lost wax casting process.

The second very important advantage of glass-ceramics is the **uniformity and homogeneity of color**. This is due to the nature of this material, its composition, and structure. In this sense, all types of glass-ceramics are similar to the original glasses because they are also uniform in color despite the complexity of their compositions. The subsequent crystallization of glasses and their transformation into glass ceramics does not disrupt the uniformity of color due to the even distribution of nanocrystals throughout the material volume.

The complete catalog of **transparent SIAMITE®** gemstone reflections include about **780** different colors and shades (**Fig. 4,5,6,7**), along with more than **200** translucent and opaque varieties (**Fig.8**). They are part of **104** transparent color groups (groups of emeralds, blue topazes, sapphires, rubies, tourmalines...) and approximately 50 translucent and opaque groups (groups of turquoise, moonstones, lapis lazuli, jadeites...).


**Figure 4.** SIAMITE® Samples Catalog and small size cut stones package and color range.

**Figure 5.** SIAMITE® reflections of the most common natural gemstones.

The ability to produce many colors, shades, and saturations is another unique feature of SIAMITE®. This allows for the creation of a wide range of imitations of natural gems from different deposits: emeralds ranging from yellowish-green to bluish-green (Zambian, Brazilian, Colombian, and other types); sapphires from gray-blue to violet-blue (Australian, Ceylon, ...); amethysts from violet to purple-blue and purple (Brazilian, Uruguayan, ...); topaz (London Blue, Swiss, Sky Blue), and so on (**Fig. 6**).


**Figure 6.** SIAMITE® Topaz reflections - Greenish Blue, Swiss Blue, Sky Blue and London Blue color.

And the abundance of choices in saturation enables the production of cut stones in any shape with consistent color, ranging from 0.8 mm to at least 20 mm (**Fig. 7**).

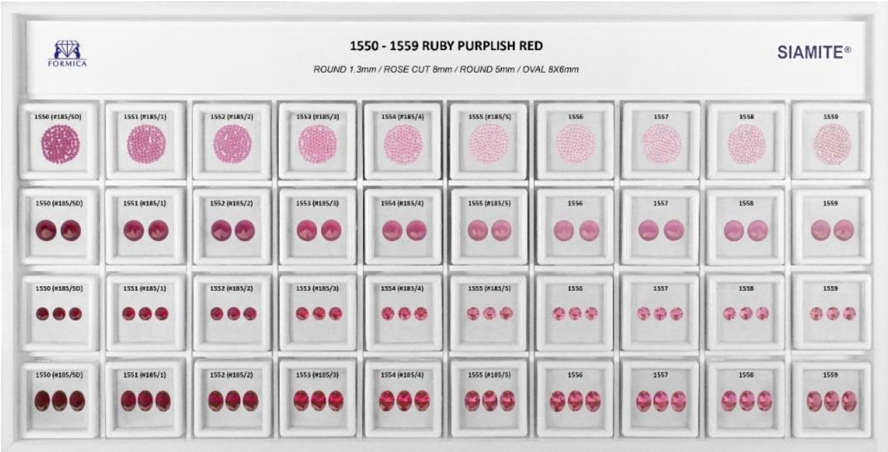



**Figure 7**. SIAMITE® Ruby reflections of different saturation - color group 1550-1559. Sizes of cut stones: round 1.3 and 5 mm, rose cut 8 mm, oval 8x6 mm.

The uniqueness of the properties of glass-ceramics allows for an unlimited range of varieties not only in color but also in transparency. This is achieved by controlling changes in the concentration and particle size of nanocrystals. The **translucent and opaque SIAMITE®** imitate decorative gemstones such as **moonstone, cacholong, chrysoprase, jade, lapis lazuli, turquoise, black spinel, and others** (**Fig. 8**). The hardness, density and resistance to thermal shock are approximately the same as those of transparent SIAMITE®.

**Figure 8**. Translucent and Opaque SIAMITE®: Moonstone, Cacholong, Chrysoprase, Jade, Lapis Lazuli, Turquoise reflection. Cabochon size 12 mm.

It is important to consider that the degree of transparency is determined not only by the size and concentration of nanocrystals of spinel and other minerals but also by the thickness of the cabochon or cut stone. In other words, a stone that appears translucent, for example, at 3 mm will become almost opaque at 8-10 mm. Consequently, as the transparency of the stone decreases, its color gradually changes (**Fig. 9**).

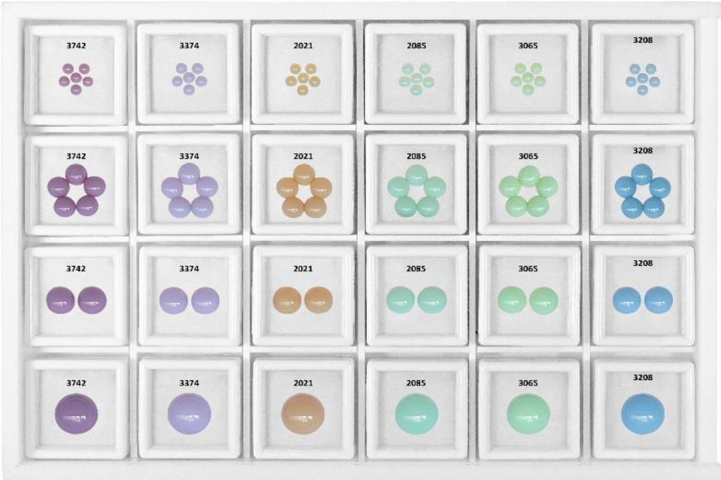



**Figure 9**. Translucent and Opaque SIAMITE®. The transparency of cabochons in a row: 3-6-8-12 mm is gradually reduced.

Thus, the **SIAMITE® completely replicate the brightness, color, and density of the most widely used gemstones**. In connection with this, a common question arises – how to distinguish faceted SIAMITE® stones from natural gemstones? This question is quite relevant, as many buyers of our stones have already turned to gemological laboratories in many countries worldwide and received incorrect conclusions – "glass", "special glass", "natural tourmaline", "topaz" ...

Gemologists worldwide have a standard set of criteria for identifying gemstones: **color, refractive index, density, magnification, absorption spectrum, fluorescence**. However, the nature of SIAMITE® glass-ceramic makes classic gemological techniques less valuable or even useless. How to diagnose that SIAMITE® is a glass-ceramic material, not glass or a natural stone? This can be definitively done only through **X-Ray diffraction analysis** (XRD) (**Fig.10**).

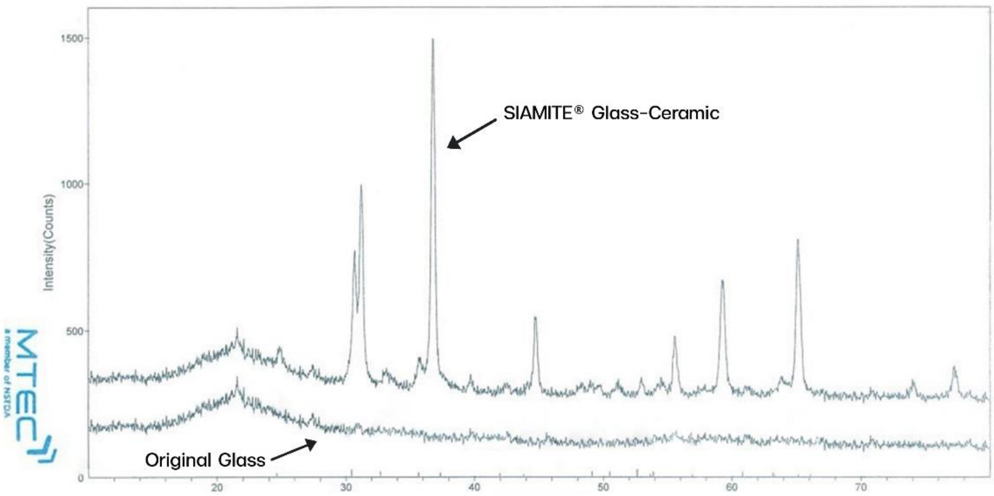



**Figure 10.** X-ray diffraction pattern of Emerald Green SIAMITE® glass-ceramic, confirming the presence of nanocrystals of spinel, rutile, and zirconium titanate. An X-ray diffraction pattern of the original glass is also shown for comparison. (analyzed in MTEC, Thailand)

XRD is the only laboratory technique that non-destructively and accurately obtains information, such as phase composition, crystal structure, and crystallite size of powder, solid, and liquid samples. In an X-ray diffractometer, different crystal phases yield distinct diffraction patterns. Phase identification can be performed by comparing patterns obtained from unknown samples to those in reference databases (ICDD - International Center of Diffraction Data). This process is akin to matching fingerprints in a crime investigation.

Glass – by definition, cannot contain any crystalline phases, even if it is "special," optical, or from prestigious brands. The distinction between SIAMITE® and glass is well illustrated in the attached **Figure 10** – the X-ray diffraction pattern of glass forms a smooth line, while in the emerald-like SIAMITE®, peaks of zinc spinel (gahnite), zirconium titanite, and others are clearly visible.

Naturally, this analysis reveals that SIAMITE® is not the natural mineral it imitates. **X-ray phase analysis is the most accurate and reliable tool for diagnosing any crystalline phase, from nano-sized to large crystals.** In our opinion, it should be included in the existing set of gemological methods for diagnosing gemstones and materials.

## SIAMITE® is a green technology gemstone.

SIAMITE® is **lead-free** and compliant with the strictest regulatory industry norms and laws regarding the restriction or prohibition of certain substances. The production process is virtually waste-free and environmentally friendly - akin to glass production, **all low-quality or defective products are recycled** as additives to the production charge. Energy for production comes solely from electricity, resulting in **no carbon dioxide emissions into the atmosphere.**

As reserves of natural gems dwindle and their value increases, mining them causes irreparable damage to nature. Consumers are increasingly aware of this and are prioritizing environmentally friendly products. A notable jewelry brand recently switched from natural diamonds to lab-grown ones. While colorless SIAMITE® cannot compete with lab-grown diamonds, moissanite, or even cubic zirconia due to its relatively low refractive index, **colored SIAMITE® excels at imitating most colored gemstones, allowing us to preserve nature and avoid disfiguring it with quarries, trenches, and mines.**

Lab-grown SIAMITE® glass-ceramic offers unique combinations of properties, including an extremely low thermal expansion coefficient, optical transparency or translucency, high hardness, fracture strength, toughness, and chemical durability. **Available in a wide range of colors, shapes, and sizes, and affordable to the masses,** SIAMITE® offers numerous creative design possibilities through various application techniques, making it ideal for the jewelry and accessories industries. This breakthrough gem reflection material undoubtedly has a promising and bright future!

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