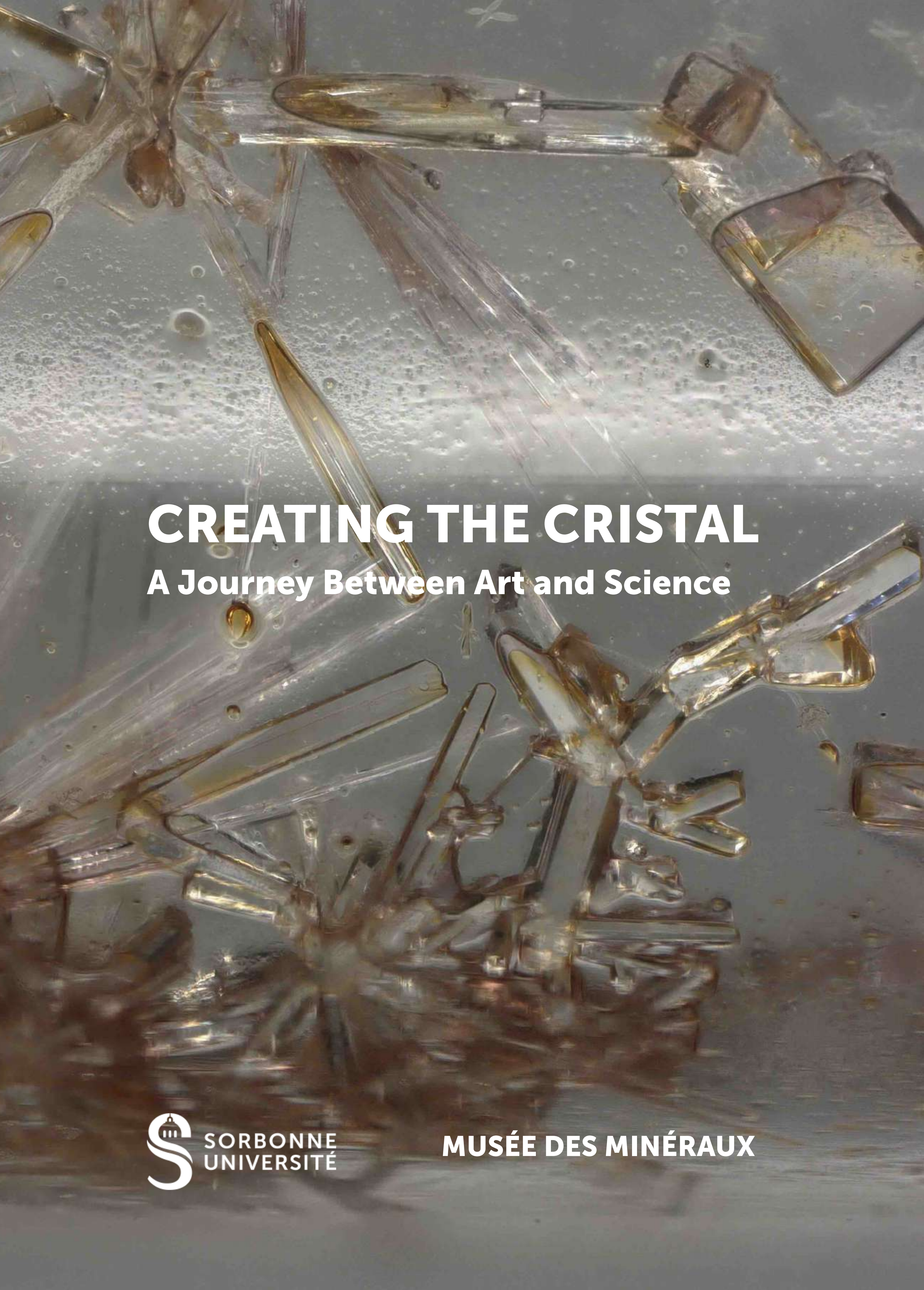

CREATING THE CRISTAL

A Journey Between Art and Science

SORBONNE UNIVERSITÉ

MUSÉE DES MINÉRAUX

Creating Crystal, a Journey Between Art and Science

This exhibition results from an inventory work on the crystal synthesis from the mineral collection of Sorbonne University. This work had highlighted the specific richness of this collection, beside its patrimonial interest.

The purpose of the exhibition is to:
Define crystallogenesis ; Present some of mastered manufacturing methods ; Give some examples of actual application of crystal synthesis from organic and inorganic origin.

Then the exhibition take a more aesthetical way thanks to the work of four plasticians.

SHOWCASE 1

Crystal and crystallogenesys

Crystals need matter, favorable conditions, and time to form. A crystal is composed of chemical elements that are arranged in an orderly and periodic manner. Its chemical composition and crystalline structure are what define a crystal.

It was only in the 18th and 19th centuries that rapid advances were made in crystallography :
Jean-Baptiste Romé de l'Isle was the first to use the concepts of “primitive form” and ‘truncation’ and introduced the “law of constancy of angles between planes”.

René-Just Hauy, regarded as the father of modern crystallography, suggested that crystals result from the aggregation of small identical geometric solids: “integral molecules”.

Torbern Bergman discovered the relationship between the geometry of the main minerals and the nature of their substance.

Gabriel Delafosse demonstrated the relationship between the symmetry of the crystal, the lattice, and the "physical molecule." He introduced the concept of the "unit cell."

The mineralogical approach was then quickly complemented by Johann F. C. Hessel (1796-1872) and Auguste Bravais (1811-1863) with their work on the concepts of symmetry.

Chance and necessity

The necessity for the creator of synthetic crystals is to find the best conditions to obtain the desired crystal. The conditions of synthesis, the nature of the reagents, the temperature, the pressure, and the solvent are all parameters that can lead to success or failure. It is through controlling these parameters and learning from chance that high-quality crystals, reliable processes, and reproducible results are achieved.
The main methods used are slow cooling of a molten compound, growth from a oversaturated solution, and vapor phase deposition.

In 1877, Edmond Fremy, professor at the École Polytechnique and the MNHN, obtained centimeter-sized ruby crystals, marking the advent of industrial synthesis (No. 1).

Around 1888, Paul-Gabriel Hautefeuille (1836-1902) developed an anhydrous or molten flux process. (No. 2).

At the beginning of the 20th century, Auguste Verneuil revolutionized gemstone synthesis by using an oxyhydrogen torch (oxygen and hydrogen). This process enabled the industrial production of high-quality synthetic rubies and sapphires, which were marketed from 1904 onwards (No. 3).

The growth of zirconia (No. 5) in a self-crucible requires a temperature of around 2750°C. No material can withstand this temperature except zirconium oxide itself.

The Czochralski method, used in the manufacturing of yttrium aluminum garnet (YAG) and ruby, allows obtaining samples in pulling up crystals from a molten bath. (No. 7 and No. 10)

High Pressure High Temperature (HPHT) process (No. 9 - Diamonds)

Method developed in 1953 by the Swedish electricity company ASEA, then in 1954 by the American Trecy Hall.

SHOWCASE 2

Crystals exist in various forms: from large single crystals to microcrystalline powders, and from thin films to nanoscale particles. Their atomic structure is periodic and perfectly organized, governed by strict symmetry rules of types 2, 3, 4, or 6. However, crystals can exist in multiple forms (phases).

Quasicrystals were discovered by Dan Shechtman (1941–) and his colleagues in 1982 (by cooling an aluminum-manganese alloy extremely rapidly). Diffraction patterns show the presence of peaks arranged in a pentagonal geometry, that is, with 5-fold symmetry. These are solids whose structure is ordered but not periodic. This structure, which was considered impossible at the time, was drawn by mathematician Roger Penrose (1931-) and is reproduced here by artist Lea Barbazages during her residency at Paris-Saclay University (in collaboration with Denis Gratias (IRCP), a leading expert on quasicrystals.

The other section of the window features several works by visual artist Ada YU (artist name ADA), who uses potassium alum-saturated baths to grow crystals on objects and architectural elements destined for the trash (minimum duration: 2 to 3 weeks). She typically works in abandoned buildings, those undergoing renovation, or those slated for demolition, transforming these neglected spaces into objects of interest. Thus, a simple tile or brick is adorned with sparkling crystals, like diamonds.

SHOWCASE 3

Perfect and Imperfect

The perfect crystal is sought after for its purity, brilliance, homogeneity, and physicochemical properties. However, the perfect crystal does not exist.
Synthesis makes it possible to limit imperfections or at least control them. This is due to the fact that many applications require the presence of defects within the crystal, in the form of dopants. These dopants can occupy only a few well-defined sites and enable the material to acquire a specific property.

Ruby (chromium-doped corundum, Cr^{3+}), for example, enabled Theodore Maiman (1927–2007) to discover the laser (1960).

A laser (light amplification by stimulated emission of radiation) is a device that produces a beam of coherent light, in which all photons have the same wavelength and travel in phase in the same direction.

Other crystals quickly replaced the ruby laser and more efficient dopants, particularly yttrium aluminum garnet (YAG), doped with lanthanides (rare earth elements) such as neodymium (Nd-YAG), ytterbium, or erbium.

Certain matrices such as KDP, KTP, and LBO even allow for the modulation of the radiation frequency and the development of high-energy lasers. Some of these highly durable lasers were carried on the Curiosity (2012) and Perseverance (2021) space missions.

While properties related to chemical composition are sought after for lasers, what matters in batteries is the crystalline structure. It is this structure that enables energy storage.

SHOWCASE 4

To crystallize life

In organic chemistry, the study of crystals has revealed structural phenomena such as chirality. We can thank Louis Pasteur for this fundamental discovery, which would influence the history of mineral chemistry and our understanding of the living world.

Louis Pasteur wonder why the tartrate rotates the polarized light to the right contrary to the paratartrate, which is inactive. Both of them are from organic origin (wine).

Pasteur synthesized the two compounds in crystalline form, examined the paratartrate crystals under a microscope, and observed symmetry anomalies (hemihedries). He separated the crystals by hand, dissolved them, and demonstrated that the resulting solutions caused polarized light to deviate to the right in one case and to the left in the other. He was thus the first to establish the connection between the hemihedry of the crystals, their optical properties (right/left), and their chemical composition.

Two works by Vincent Gontier explore this phenomenon here. The artist sculpts newspaper as precise material data, drawn from a specific event, time period, or selected information. He layers them one on top of another, then presses them between two metal anvils to give them the desired shape. This process evokes the crystallization of a natural or synthetic mineral. Here, he gives a nod to the principle of chirality in living organisms and DNA.

Located in the cell nucleus, deoxyribonucleic acid (DNA) is a biological macromolecule that contains all the genetic information essential for the functioning and reproduction of living organisms.
It results from the assembly of a large number of chiral base units, called nucleotides. The DNA molecule consists of two complementary strands of nucleotides. Only one of the two strands is copied into a sequence of nucleotides (this copy is RNA), which leaves the nucleus and enters the cell's cytoplasm, where it is translated into amino acids.

To understand the functioning or the dysfunctioning of these proteins, as well as their structure, the researcher crystallized them. John Bernal and Dorothy Crowfoot Hodkin observe in 1934 that the crystals of proteins (pepsin) creates patterns by X-ray diffraction. Thus, they understand positioning of the atoms and the structure of the protein.

When the first protein structures were determined, models were built by hand using steel rods or electrical wires. It is the case of the uteroglobine, a protein which the structure was resolved at the " laboratoire de Minéralogie et de Cristallographie de Paris" in 1977.

SHOWCASE 5

Art and synthesis

We conclude this exhibition by delving once more into the worlds of two artists.

Ada Yu grows her potassium alum crystals by immersing architectural elements of mineral or organic origin in a heated, supersaturated bath. The piece featuring sodalite is a previously unseen work created on a facing stone from the museum’s entrance prior to its relocation in 2014. Her work engages in a dialogue with the newspaper sculptures by Vincent Gontier, who is also inspired by a certain form of architecture.