alchemy of color

enlightening nanoworlds

Jean-Marc Chomaz & Olga Flór – March 23, 2023

• *nanoscience* • *nanoparticles* • *lithography* • *sculpture* • *color* • *alchemy* • *light* • *fluids* • *landscape* • *oscillation* • *behavioral matter*

Alchemy of Color: Enlightening Nanoworlds is a research/creation project designed to challenge the certitudes of our perception, by presenting gold and silver objects *sculpted* at a nanoscale, invisible to all optical processes. The result is two complementary installations: *A Thousand Shades of Green, an Attempt – nanolithographies*, a nanoengraving on a glass disk, and *Alchimie de la lumière – nanosculptures*.

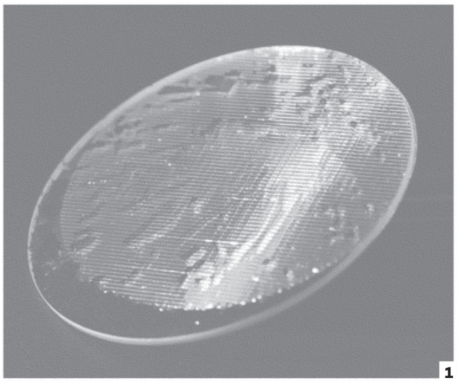
Coloring is an artistic gesture, a sensitive use of light associated with human visual perception. But coloring is also a physicochemical process associated with the interaction between photons and the molecular matter of pigments and inks. The colors of nanoparticles are a consequence of another light and matter interaction. Smaller than the photons that strike them, the metal nanosculptures are electrified and deflect the rainbow's path. Here, color is no longer a molecular property of light absorption by pigments or dyes but a resonance that makes form tangible. This photonic resonance of light with nanoscale textures belongs to the family of structural coloration. It differs from the latter through interferences that occurs when the object is larger, a fraction of a micron in size, about half the photon's wavelength. Classical pigments absorb light, as do plants: they appear green since the chlorophyl absorbs the blue and the red of the visible spectrum.

One of alchemy's ancient goals was to transmute matter, lead into gold, copper into silver. In the present project, the nanoscale sculptures that interfere with light are made of gold and silver and the alchemy refers here to the transmutation of the photons into plasmon. In an inversion of roles, invisible gold and silver objects are performing, in front of the spectator, the alchemical transformation of light, producing new colors, as if light and colors were matter.

A Thousand Shades of Green, an Attempt, is a nano engraving test using electronic lithography employing millions of gold cylinders, whose diameters increase from 50 to 100 nanometers, on a 2-square-centimeter glass disk. During the process, some parts of the metal layer deposited through the lithographic mask—too large for current technologies (limited to 1 square millimeter)—are torn away when the mask is peeled off. The damaged areas then reveal a world of iridescence, in green, orange, and blue.

The two installations, *Alchimie de la lumière – nanosculptures*, resemble cabinets of curiosity cabinet; they were created for the exhibition *OU\/ERT* in Bourges (2019) and Bourges contemporain in 2021. The glass forms, isolated or creating a landscape, change color according to the transformations of the light scene. The blown forms contain metallic nanoparticles, produced by chemical assembly, which emit a thousand new shades of green, depending on the angle that we look at it from. The aqueous nanoparticle solution thus appears green when seen in direct light and orange or blue in transparency.

Thus, the two installations constitute a modern form of vanities. In classical painting, earthly goods, money, scientific instruments, or symbols of knowledge were represented scattered or broken on the ground, alluding to their all being in vain with respect to a higher, inaccessible reality, a transcendence. Here, the nano engraving on the disk is broken and the perfect silver and gold nano spheres are invisible and only reveal their presence in the transformation of light into the multiple shades produced, the sensible dimension taking over the sensitive control.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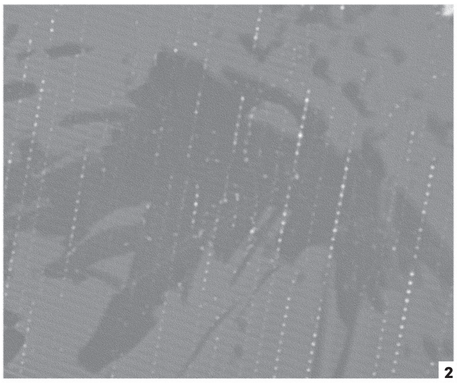
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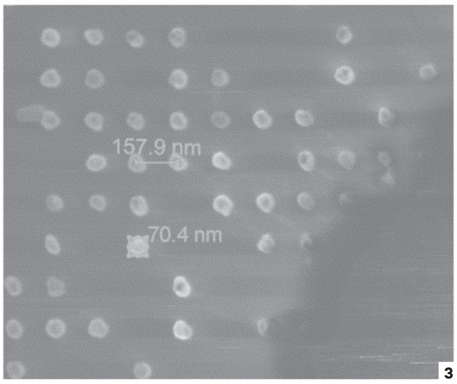

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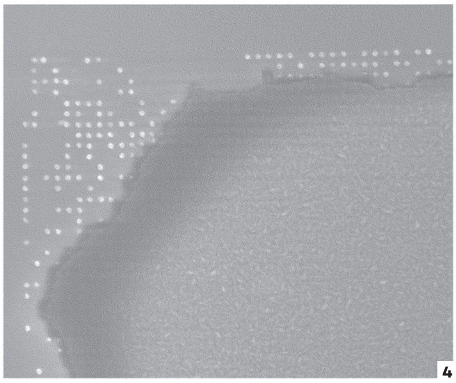
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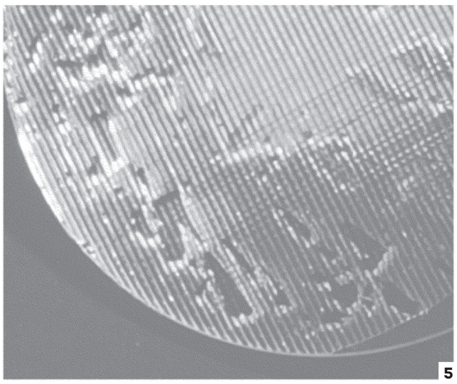
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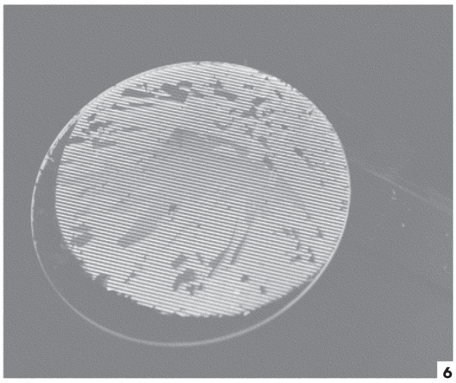
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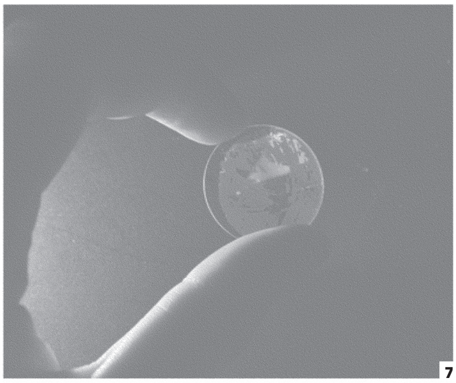
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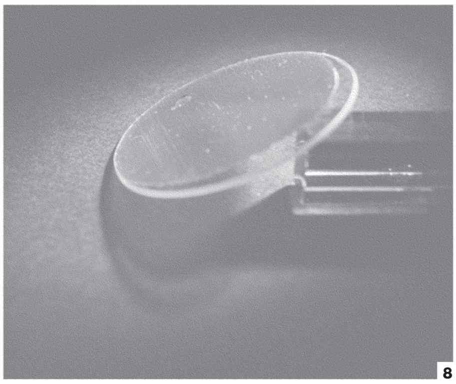
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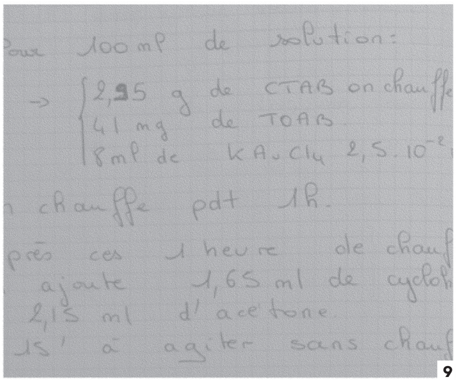

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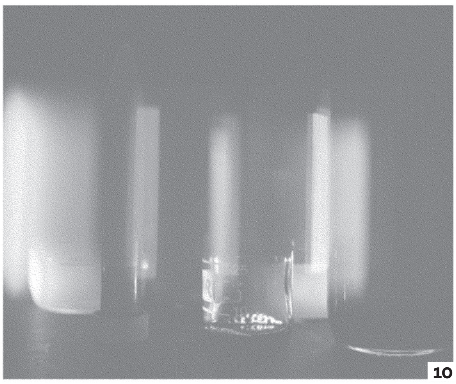
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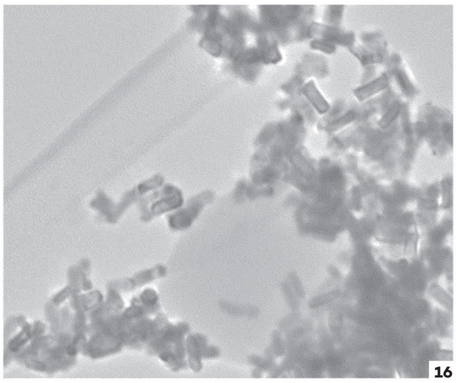

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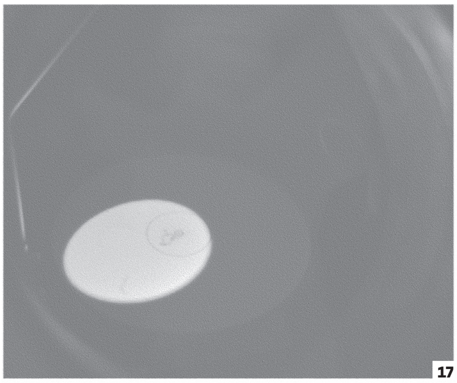

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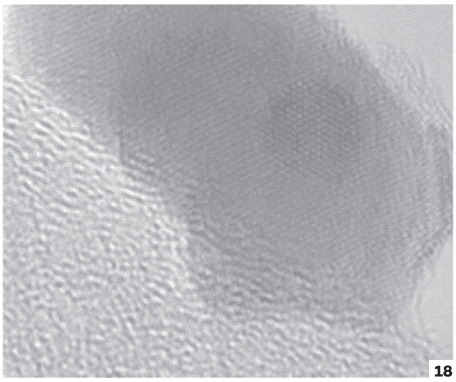

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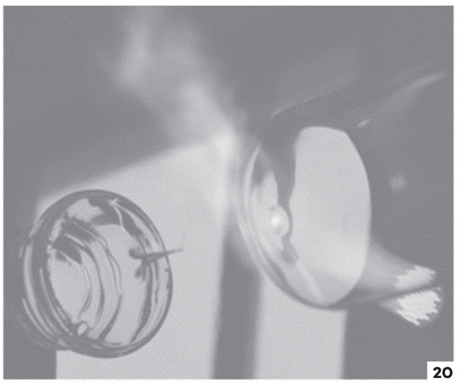

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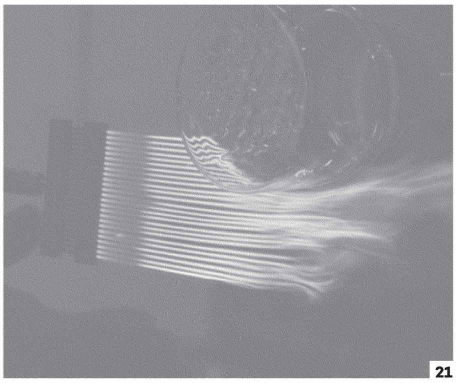

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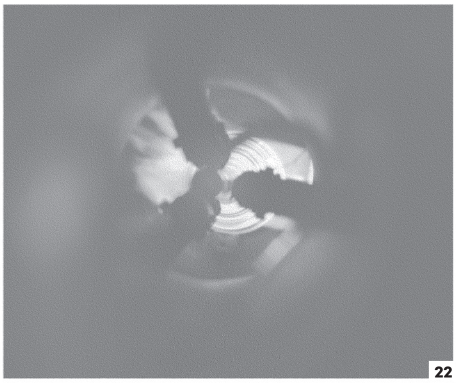

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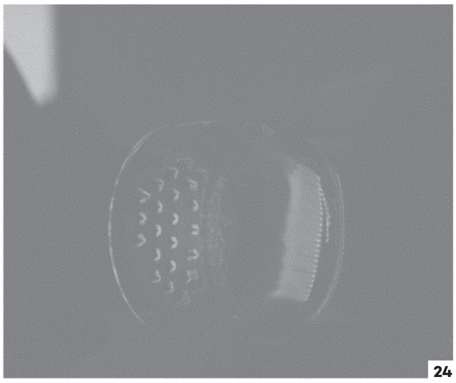

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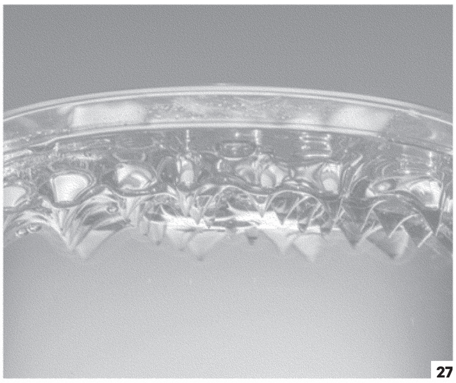

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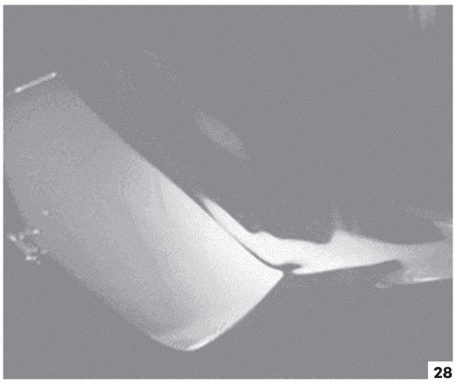

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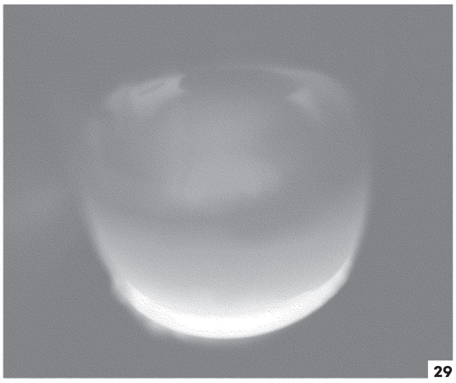

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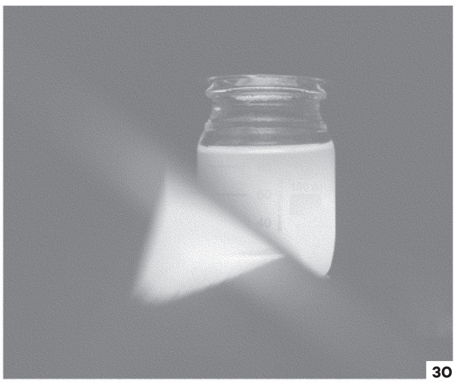

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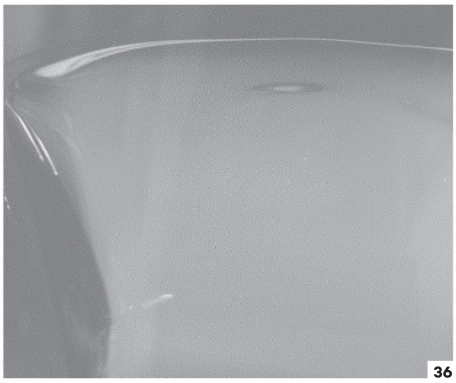
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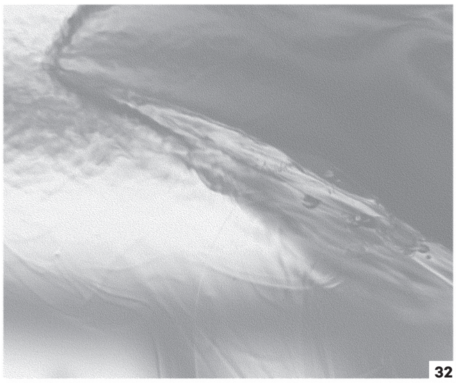
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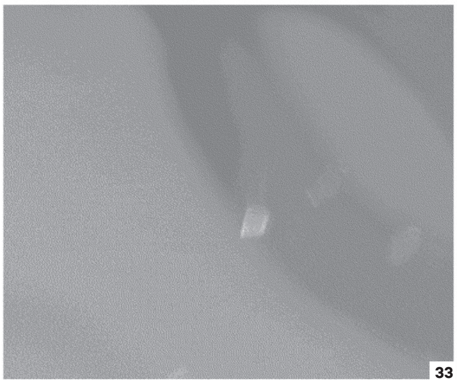
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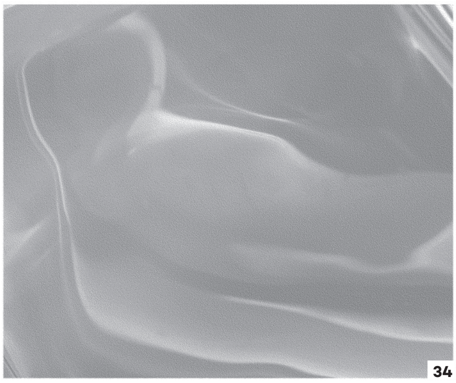
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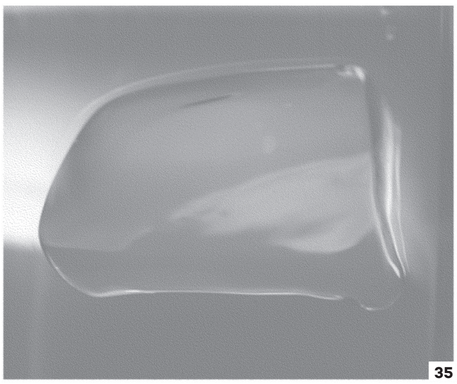
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image captions

1. Reproducing all the shades of green in a peacock feather. English scientist Robert Hooke, who in 1665 was astonished that the wet feathers turn gray, qualified the colors as “fanstastical.”

2. “In the center, a glossy black heart shape is surrounded by a changing green color that from certain aspects appears to be a beautiful purple or a bright blue.” Translated from the entry for “Peacock,” Daubenton, Venel, and Jaucourt, in *L’Encyclopédie*, 1765.

3. These iridescent colors arise from the dispersion of light through the texture of a feather on a scale of 1:10 of micron (100 nanometers). We tried to recreate the pattern by engraving a layer of gold on a glass coin.

4. The project is seemingly unfeasible: the world’s leading machine is able to engrave 100 million gold nanocylinders on a surface of 1 mm^2; we would like 2-cm^2 . Despite this, a laboratory in Turin took up the challenge, making two attempts at engraving with an electron beam.

5. A thin pellicle of silicone is deposited on the glass and then engraved by the electron beam; the vaporized gold is nested in the engraving. By removing the pellicle, which must be done by hand, a part of the etching is removed.

6. Asking for the impossible has forced technology to give up, causing iridescent color tears to appear.

7. Until now, the largest nanolithographs measured one millimeter at most. Through its failure, the attempt to rupture the separation of scales by engraving a macroscopic object has managed to produce an iridescent nanoworld that, via our fingers, interacts with light.

8. But birds do not engrave the nanotextures of their feathers, the patient process of evolution has taught them to let chemical kinetics happen, and thus the resulting instabilities that dynamically create these nanoforms.

9. Chemical and physical systems out of equilibrium generate an infinity of complex shapes, galaxies, landscapes, DNA, etc. In order to recreate these in a laboratory, alchemical recipes need to be invented.

10. Researchers in the physical chemistry laboratory write their alchemical recipes in a notebook, in order to create nanosculptures from gold. According to their shape, a red, blue, or green plasma submerges their surface once illuminated.

11. The mixing and reduction of gold salts and chemical reagent allows the chemical kinetics to create different shapes.

12. A transmutation is provoked by radiolysis, an exposure to intense ionizing gamma radiation from the laboratory’s source, which is protected in a bunker under meters of soil and concrete, on which a luxuriant nature grows.

13. Access to the bunker is restricted to authorized personnel wearing a dosimeter to monitor their radiation levels. As recorded in the notebook, the vial that contains the gold salts is placed at a precise distance from the source to receive the radiation.

14. The radiation slowly reduces the salts and pure gold condenses into nanosticks whose size increases along with exposure time and determines the color. For the green, the duration of the irradiation is eight hours.

15. These nanosculptures are smaller than visible light (wavelength of 0.4 to 0.7 micron); their shape can only be revealed by an electron microscope. A small bead of the nanoparticle solution is dropped on a tiny grid, then introduced into the unit.

16. The first image made by the researchers of the CEMES in Toulouse shows the nano-artwork, a tangle of identical gold rods, all 50 nanometers long.

17. The electron beam is absorbed by the nanoparticles. The shadow projected is distorted due to the intense electromagnetic fields (like in old cathode-ray tube TVs) and appears on the operator’s screen.

18. By focusing the image, even the shadows of the atomic structure are perceptible: grains of 0.1 nm in gold rods of 50 nanometers.

19. How can we showcase sculptures that are smaller than the size of the light? These gold nano-objects only reveal their shape through the color changes that fascinated Hooke.

20. Bird feathers and butterfly wings are the natural repositories for those nanotextures, which give them their particular color and iridescence.

21. The emphasis in these alchemical nanosculptures made by the researchers for this project, is the color and its flow. The container must be visually dematerialized, letting only the color show.

22. Instead of stabilizing and integrating nanoparticles in a glass composition—as the Roman craftsmen did in creating the Lycurgus Cup, a technique that has been lost—here the transparency of glass is used to observe a constant fusion with light.

23. A first prototype is made by Jean-Michel Wierniezky, glassblower at the École Polytechnique, deforming a carbon plate bristling with 35 steel spikes with a disk of molten glass.

24. An array of 35 2-centimeter-deep cavities are thus created, each of which are able to receive a different nanosculpture solution.

25. This disc will be placed on a large glass cylinder created specifically for this installation.

26. The cylinder is filled with glycerol, which has the same optical index as glass. The interfaces of the cavities are thus rendered invisible, meaning only the light combining with the nanoparticles in the solution are perceptible.

27. We chose nanosculptures that mainly refract green. The color changes according to the size of the cavity and the light: from yellow to blue, red to purple. Surprisingly, these tints also evolve over time, as if these nano objects were alive.

28. A second more voluminous prototype was made to experiment and showcase the slow evolution of the nanoparticle solutions.

29. Within the perspective of creating a mobile, multiple glass forms are made and filled with solutions containing different stacks of gold and silver nanotriangles, producing dichroic tints of green and orange.

30. The gold-silver nanoparticles are created in a physical chemistry laboratory by a fast, surprisingly oscillating, reduction reaction. The color of these solutions depends on the size of the stack of triangles it contains—for green nanosculptures they measure 50 nanometers.

31. The sedimentation of the nanoparticles occurs when the liquid is at rest. The structure that forms reflects the balance between gravity and Brownian motion. Variations of this concentration result in a flurry of vibrant color schemes.

32. When the nanoparticles homogeneously spread, the dominating color is orange.

33. The glass object containing the nanoparticles behaves like a crystal. The plasmons scatter according to the angle of light, which results in a change of color; the coherent plasmas formed by light are on the surface of the nanosculptures.

34. The slightest disruption of the object's quiet state breaks the delicate balance.

35. Sedimentation of the color after two weeks' immobility.

36. The gold-silver triangle nano-sticks in motion are like a mineral universe in the making. Their "fantastical" interaction with light performs the alchemy of color.

This contribution was published on www.able-journal.org in a story.able format:

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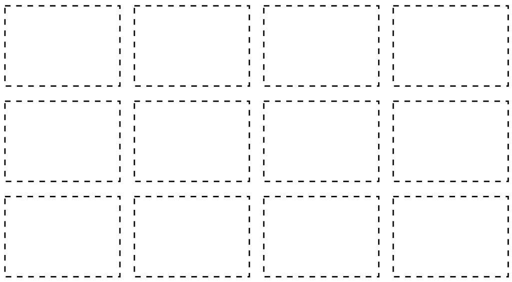

credits

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Olga Flór is an artist-designer who lives and works in Eindhoven. A graduate of the Design Academy Eindhoven in 2020, she is interested in the close relationship that people have with things, space, and time. She composes and builds with color, light, and sound, as well as various materials expressing her singular perception of elements at different scales.

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