Crystallizing Desirable Properties

The discoveries of science have often given technologists the means of manipulating nature effectively and making the most efficient uses of natural processes in designing the artifacts of modern life. It is a case of art imitating life selectively and judiciously. Now we have a case of life imitating art. A group of physicists at Bell Telephone Laboratories in Murray Hill, N.J., Raymond Dingle, Arthur C. Gossard, Pierre M. Petroff, Albert Savage and William Wiegmann, report that they have produced a crystal nature never made. Their paper is in the Sept. 15 APPLIED PHYSICS LETTERS.

Artificially built up by a process called molecular beam epitaxy, the material is called a monolayer crystal, one in which the composition of each layer of atoms is individually controlled. According to a Bell Labs announcement, it is the first synthetic monolayer crystal produced. Success in this procedure opens the possibility of making various kinds of crystals with desirable optical or electronic properties tailored in. Such artifacts could prove better for technological applications than Mother Nature's offerings.

These synthetic monolayer crystals have two basic advantages, Gossard told SCIENCE NEWS: They are highly ordered, lacking the dislocations and impurities common in natural substances. This opens the possibility of building in any electrical or optical property for which order might be an advantage. The layering makes the crystal's structure highly anisotropic, and anisotropy also gives interesting optical properties. One of the capabilities of the specific crystal concerned in this announcement, basically made of gallium and arsenic, is polarization of light.

Molecular beam epitaxy is a technique by which crystals can be grown in a very controlled way to provide desired composition and dimensions, especially extremely flat, smooth surfaces. In an ultrahigh vacuum, beams of molecules or atoms of the substances out of which the crystal is to be made are directed against a selected substrate on which the crystal is built. The beams are controlled by shutters that start and stop them according to the composition of the desired crystal.

In the present case, the physicists started with a base of gallium arsenide. On this they laid down a layer of gallium atoms, then layers of arsenic, aluminum, arsenic and again gallium. Repeating the sequence hundreds of times produced a crystal resembling a highly polished mirror.

Molecular beam epitaxy has been used for years to grow high-quality semiconductor crystals. (In 1968 John R. Arthur of Bell Labs showed that was possible, and later Alfred Y. Cho, also of Bell Labs, developed the technique for fabricating microwave devices and semiconductor lasers.) But the method had never before been used to fabricate a crystal layer by layer. Therefore, even though the crystal's light-polarizing quality was presumptive evidence of its monolayer character, tests with a transmission electron microscope were run for confirmation. The short wavelength (0.02 angstroms) of the electron microscope and its high magnification allowed detailed study of the layer-by-layer construction of the crystal and verified its monolayer character. The background of the illustration is an electron microscope image of such an ultrathin layered structure.


Bell Telephone Laboratories

World's first synthetic monolayer crystal.

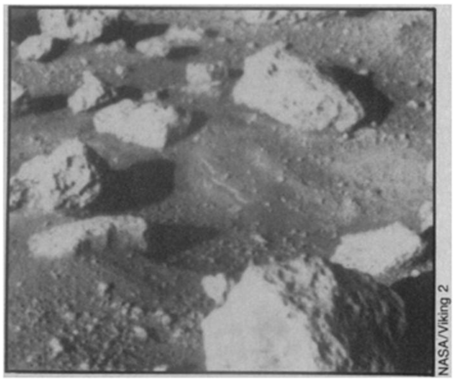
Gossard declines to speculate on specific applications for monolayer crystals: "We're engaged in basic research," he says of himself and his colleagues. However, the new crystal has the same average composition as the crystals used in fabricating the light-emitting diodes that promise to be more and more used as the communications industry begins to employ light beams in optical fibers for signal transmission, so it is perhaps not an egregious misdirection to suspect possible applications there, especially for a polarizing crystal. Gossard also confirms that the group is working on production of other kinds of monolayer crystals. But he declined to name them because patent clearance for the new operations has not yet come, and the company naturally wishes to protect procedures that it has developed at its own expense until they are safely under patent protection. □

Viking: The quest for organic molecules

"It was supposed to get easier with the landers down," says Viking Project Manager James Martin, "but it doesn't seem to be happening." The four-spacecraft Mars mission, in fact, is proving so complicated and providing so much data that, combined with the pressure to get everything done before solar conjunction cuts off communications in November, the pressure on the 800-member flight team is just about as great as it was months ago when the first U.S. landing on another planet was the primary goal. Last week, when the first data came in from the biology instruments aboard Viking lander 2 in the Martian northlands, the exciting results just intensified the pressure.

The labeled-release experiment (LR), which monitors the rate at which radioactive carbon dioxide gas is given off from soil exposed to a nutrient containing carbon 14, showed an early release rate about 30 percent higher than that of the two active experiment cycles run by lander 1. At the same time, however, the gas-exchange experiment (GEx), looking for changes in the atmosphere surrounding a moistened soil sample, yielded an initial oxygen peak only about one-fifth the size of that from the first lander. One interpretation of the positive LR and GEx results from lander 1 was the presence of a strong oxidizing agent such as a peroxide, superoxide or ozonide. Indeed, the smaller initial oxygen peak in the lander 2 GEx data was consistent with such an agent, reduced somewhat in potential by the greater amounts of water expected at the lander 2 site from measurements of atmospheric water vapor overhead. "On the basis of those two thoughts," says LR team leader Gilbert V. Levin of Biospherics, Inc., "we might have expected to have seen less of a positive response in the LR experiment." Instead, it was even greater, suggesting the possibility that a more complex chemistry—or biochemistry—is at work, with two or more different oxidants involved.

Whatever the nature of the oxidants, their presence at both landing sites posed a separate problem in the possibly vital matter of detecting organic molecules in the soil, which would make some of Viking's biologists feel considerably easier about accepting living microorganisms as the explanation for their results. Originally, the second lander's organic chemistry instrument, a gas chromatograph/mass spectrometer (GCMS), was to have been given a soil sample from right next to the site of the biology sample. But



Organic sample site: Crusty evaporites?

when the craft's soil-sampling arm stuck last week, a problem since resolved, the delay amid the press of time gave rise to second thoughts. A special chemistry working group headed by GCMS team leader Klaus Biemann of the Massachusetts Institute of Technology concluded that the similar biology-instrument data from the two sites probably promised a similar lack of organics if the GCMS soil samples were taken from virtually the same places. It would mean a lot of extra work to change the mission's tightly interdependent programming so that the GCMS could get its samples from other types of terrain. But the group argued persuasively that the labor was worth it.

The first alternate site was a spot that appeared in the lander's photos to be topped with a crusty layer, possibly representing evaporite deposits formed by water migrating upward through water-soluble salts. The chance of more water, the salts and the hope that the crust might offer protection from the sun's ultraviolet radiation all contributed to the choice. The sampling operation, delayed from Sept. 13, was set for Sept. 25.

The second possibility, if all goes well with the first, is to use the sampling arm's scoop-head to push a rock out of the way and dig in the uncovered spot, in hopes that the rock would have provided long enough protection from UV to have given organics a chance to form and survive. The Martian rocks are an unknown quantity, however, and fear of damaging the lander's only arm has led to more meetings and yet another working group, dubbed "The Rolling Stones." Viking officials have even ordered some custom-made Mars-rock replicas to be made, using photographs and stereo contour diagrams for guidance, to use in practice rock-rollings. This week's plan called for moving the real rock on Oct. 8, with the dig to follow four days later; the four days' UV exposure, says Biemann, is unlikely to destroy all detectable organics, if they are there at all.

The changes involved in doing all this site-switching and rock-rolling are affecting Viking's other scientific teams as well. The rock-rolling dig, especially, could restrict lander 2's photographic plans and even the relatively nondemanding collection of weather data, since it may require most of the earth-to-Mars "instruction period" for three days running. In addition, the computers at Jet Propulsion Laboratory are so busy with data from the four craft that the photos being taken by the orbiters as they walk around the planet are hardly getting a glance when they come in. In fact, says one Viking engineer, just out of a rock-rolling meeting, if anything else delays the start of the roll-and-dig operation, "we may just leave the whole thing until after conjunction." □

Superheavies: Neutron star origin?

Now that there is experimental evidence for the existence of superheavy elements with atomic numbers 126, 116 and 124 in nature, nuclear theorists and astrophysicists must figure out some way nature could have made them. Two communications in the Sept. 9 NATURE, one by George L. Murphy of the University of Western Australia and one by J. E. Pringle, D. S. P. Dearborn and A. C. Fabian of Cambridge University's Institute of Astronomy, present similar answers. Both blame neutron stars and black holes. (There are more things in heaven and earth, Horatio, that are being blamed on neutron stars and black holes nowadays.)

The question of elemental origins is not so simple as it might at first seem. Cosmologists tend to agree that the lightest elements, the isotopes of hydrogen, helium and lithium, could have been made before the galaxies formed in the big-bang process that began the universe. Elements of middleweight range, up to about nitrogen and oxygen, are made by nuclear fusion processes in stars. The elements in about the heaviest half of the periodic table, the long-known terrestrially present ones, that is, still present something of a mystery, although theory says they can be made in supernova explosions.

To make the ultraheavies, an environment loaded with neutrons is necessary, and that leads Pringle and company and Murphy to the outer regions of a neutron star as their birthplace. One way of scattering the superheavy elements from the neutron-star surface into the universe at large that both parties suggest is tidal disruption by an encounter between the neutron star and a black hole. Additionally, Pringle and collaborators suggest that a neutron star that has accreted too much matter from a possible binary companion may collapse into a black hole, throwing off some of its surface on the way. Another suggestion by Murphy is that during the supernova explosion that makes the neutron star, the neutron star's surface produces superheavies as quickly as it forms, and droplets of such matter evaporate into space virtually simultaneously with the supernova explosion. □

The sex life of flowering plants

Flowering plants usually propagate by fertilizing themselves with their own pollen or by exchanging pollen with a member of their own species. Once an acceptable pollen grain (comparable to an animal sperm) reaches a flower's receptive female stigma, the grain hydrates (takes up water from the stigma), swells and produces a short pollen tube that penetrates the flower's papilla cuticle. The tube then grows down into the ovary of the flower, fertilizes an egg, and the resulting embryo (seed) is capable of becoming a new plant.

How a flowering plant recognizes its own pollen or that of its own species, and not that of another, has now been determined by R. Bruce Knox, a botanist at the University of Melbourne and his co-workers. It is through special cell membrane receptors for the pollen. These results also shed light on a largely neglected field—how plants recognize their own kind.

Knox and his co-workers studied pollen recognition in the flowering plant species *Gladiolus gandavensis*. (The *Gladiolus* genus consists of plants with sword-shaped leaves and spikes of brilliantly colored irregular flowers.) *G. gandavensis*, they found, accepts either its own pollen or that of other plants in its own species. Within 20 minutes of landing on a receptive stigma, the *G. gandavensis* pollen hydrates, swells and produces a short pollen tube that penetrates the papilla cuticle after an hour or so. Pollens from other genera in the same family, Iridaceae, can also land on the *G. gandavensis* stigma, hydrate, swell and make a pollen tube. But their tubes are not able to penetrate *G. gandavensis's* papilla cuticle. Pollens from other families do not even get to first base with the stigma of *G. gandavensis*—they don't even hydrate.

Scanning electron micrographs of Gladiolus gandavensis stigma after pollination with compatible pollen (top) and after being exposed to totally incompatible pollen.