Science & Technology

Space and the revolution in materials-processing

by Marsha Freeman

In 1977, when the first Space Shuttle had not yet come off the production line, the McDonnell-Douglas Astronautics Company began designing an apparatus to separate biological materials in the microgravity of space which could revolutionize the medical treatment of chronic diseases.

Now, eight years later, the company's Continuous Flow Electrophoresis (CFES) experiment has flown several times in Shuttle orbiters, demonstrating a 716-fold increase in flow production rate, and a 4-fold to 5-fold improvement in purity over use of the same technology on Earth. McDonnell Douglas and Johnson & Johnson have indicated that the materials could potentially cure, not just treat, diseases such as diabetes, hemophilia, and dwarfism.

Over the next decade, other industrial concerns and universities will be designing and testing materials-processing technologies in space, taking advantage of the near-zero gravity and the near-perfect vacuum. In the Space Shuttle, experiments can be run for up to 10 days. As the space station comes into operational use in the early 1990s, longer-duration testing will become possible.

With a permanent manned space station, free-flying space-materials-processing factories can be launched. They will be man-tended for delivery of raw materials to be processed and recovery of the finished product. They can be repaired or technologically renovated from the space station, when improvements become available.

On the heels of the dramatic success of the McDonnell-Douglas/Johnson & Johnson CFES program, in which animal and then human testing of the new pharmaceuticals could begin later this year, a number of other agreements have been signed with the National Aeronautics and Space Administration to fly materials-processing experiments on the Space Shuttle.

NASA offers a program, called a Joint Endeavor Agreement, in which companies can get a free ride on the Shuttle if they are testing a new technique. When the technology is proven effective, the factories will be launched on a pay-as-you-go basis, like any other commercial payload.

If Shuttle prices are not increased—which would prematurely kill industrial investment in space processing—new and improved materials will emerge in the biological sphere, and in metal alloys, crystals, glass, and other areas.

Growing crystals in space

The 3M Company, Minnesota Mining and Manufacturing, has planned a series of 72 experiments to be flown in the Space Shuttle over the next decade, to investigate the growth of crystals in space.

Their first experiment, which flew last November, was designed to grow organic crystals in microgravity. The Diffusive Mixing of Organic Solutions (DMOS) equipment used consists of six chemical reactor units, each with individual heaters, thermocouples, and electrical motors which control each experiment.

Unlike similar experiments performed on Earth, when the crystals are formed out of solution, they do not fall to the bottom of the chamber or touch the walls. They remain suspended in the liquid under ideal conditions, allowing them to grow in size with exceptional purity.

The Shuttle experiment mixed urea dissolved in a methanol solvent, with toluene to form urea crystals. Salts and other undisclosed, proprietary materials were also mixed in crystal-growth experiments.

3M is interested in studying the photo-optical, magnetic and other properties of the crystals, to see how they might be used in advanced-generation products in electronics, videotapes, and computers. The company's second Shuttle experiment, scheduled for this spring, will also involve the growth of organic crystals, but will attempt to arrange them in a thin film over a substrate material.

A third experiment, this summer, will test the effects of microgravity and the space vacuum on the directional growth of microcrystals in thin organic films. It will be the first in the series of experiments in which the material is carried outside the orbiter in the payload bay, allowing the experiment to be exposed directly to the space environment.

Reporting on the results from the first Shuttle experiment, 3M's Vice-President of Research and Development Dr. Lester C. Krogh said that the experiment was "99% perfect, an unqualified success."

He reported that there were hundreds of crystals obtained from the experiments, and that 3M scientists would be conducting x-ray, laser, and other tests of the crystals' photo-optical properties. Twenty-four scientists and specialists have worked on the project.

3M's materials-processing in space program has already changed the way the company does research on Earth. For the space experiment, 3M scientists designed six football-sized stainless-steel chemical reactors in which to grow the crystals. When the laboratory apparatus was tested on Earth, these reactors already produced larger and more perfect crystals than were obtainable with their previous technology.

3M has announced the formation of a new Space Research and Applications Laboratory, with a research staff of 15 scientists. The company will also be assisting NASA in developing a chemistry laboratory for the space station.

Protein crystals for medical research

In February, a number of large universities and drug companies signed agreements with NASA to fly hundreds of experiments that will grow protein crystals in space, to provide biology researchers with crystals that are large enough to be used to study the multi-dimensional atomic structure of protein molecules.

During the Spacelab flight in November 1983, West German scientist Walter Littke grew one type of protein crystal that was 1,000 times larger than the control crystal on the ground, and 30 times larger than his ground crystal grown using the space-designed process.

Using x-ray crystallography, pharmaceutical companies will be able to determine the precise geometric structure of the large space-grown proteins. With that knowledge, they can genetically engineer, for example, proteins with the same structure but a different chemical composition, to block disease-causing agents.

They could also use genetic engineering to produce a gene to duplicate the fine structure of a needed protein, which could be used to supplement the natural production of the protein in someone who has a specific deficiency.

Research in this protein crystal growth area is so promising that the experimental program will begin on the next Space Shuttle mission. The next flight will include the first 36 crystal-growth experiments, which will be supervised by Charles Walker of McDonnell Douglas, who will be making his second trip into space with the electrophoresis equipment.

In August, a Space Shuttle mission will carry 100-200 additional protein-crystal experiments into space. The three-year agreement signed in February will be broadened to include more experiments and institutions.

Also in February, the Grumman Corporation of New York signed a memorandum of understanding with NASA for a research program in space-materials-processing. Grumman will focus on the production of gallium arsenide and other semiconductor crystals, and various metal alloys for magnets and electrical motors.

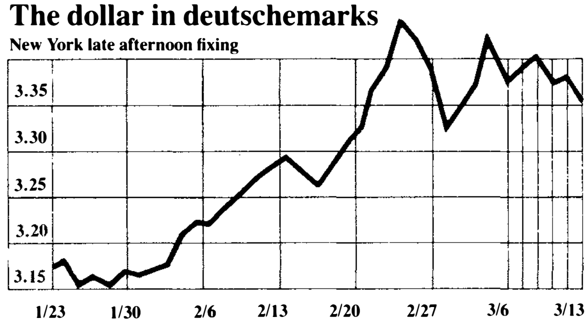
The process will involve directional solidification, using precisely controlled temperatures to melt and then solidify a material. During the process, the material's crystalline structure or molecular geometry is aligned so as to virtually eliminate any imperfections in the compound. This could lead to higher-speed electronic devices that consume less power, and are even more miniaturized than today's microcircuit chips.

Materials processing is the area of private industry investment in space which promises to yield the greatest returns over the next two decades, because it will produce new materials which can cure disease and will create new industries on Earth.

Currency Rates

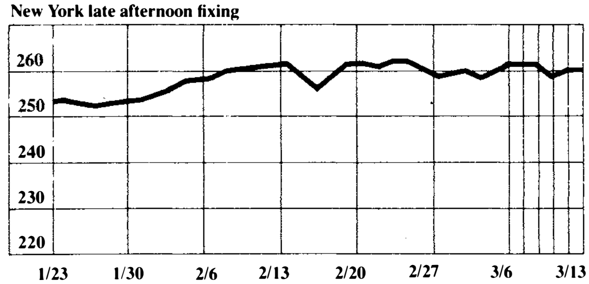
The dollar in deutschemarks

New York late afternoon fixing



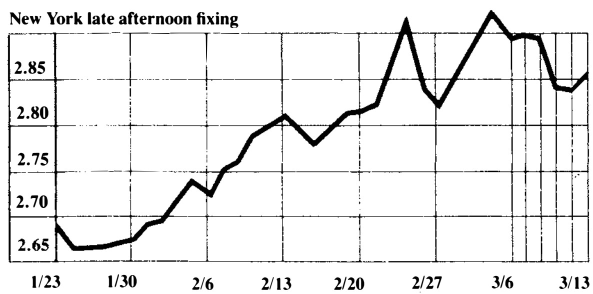
The dollar in yen

New York late afternoon fixing



The dollar in Swiss francs

New York late afternoon fixing



The British pound in dollars

New York late afternoon fixing