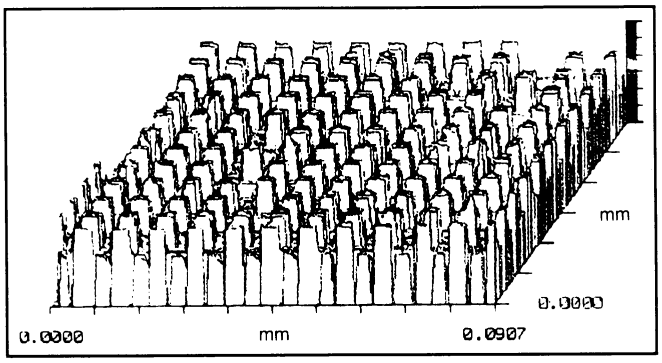
Microscopic pillars test catalytic theories



Zuburtikudis & Saltsburg/SCIENCE

Micrograph of multilayered catalytic pillars.

By adapting a technique commonly used in microelectronics, chemical engineers have devised a new way to make metal catalysts in very small sizes.

This new architecture – which consists of millions of layered, microscopic pillars crowded onto a silicon wafer – casts a shadow on current thinking about how tiny catalysts work, says Howard Saltsburg of the University of Rochester in New York. He and Ioannis Zuburtikudis, now with Eastman Kodak Research Labs in Rochester, N.Y., describe this structure and its effects on catalytic activity in the Nov. 20 SCIENCE.

To make their pillars, Zuburtikudis and Saltsburg first used a process called physical vapor deposition to lay down 100 alternating layers of nickel – the catalyst – and silicon oxide on a 3-inch silicon wafer, topping them off with silicon oxide. With microlithography and etching, they then sliced the layers into pillars, each measuring about 1 micron square. In this way, they exposed the catalyst as parallel, horizontal stripes on the faces of the pillars. Vapor deposition enabled them to control precisely the thickness of these stripes, which they made 2 to 10 nanometers thick, says Saltsburg.

They could then examine a phenomenon called "size effect," seen in the irregular, nanometer-scale particles used in commercial catalytic processes. In larger particles, the rate of a chemical reaction increases in proportion to an increase in surface area. In these very small particles, however, this relationship does not hold. This inconsistency is the size effect, says Saltsburg.

Based on the average diameter of these irregular particles, some theoreticians have calculated the total number of atoms in a particle and correlated that with the particle's catalytic behavior and the size effect. Some attribute this inconsistency to a loss of metallic properties in particles with very few atoms; others say the number of atoms affects the structure of the particle, explains Richard Masel, a chemical engineer at the University of Illinois at Urbana-Champaign.

Until now, no one has been able to resolve the question, in part because of the difficulties involved in making and observing uniform particles. But with their pillars, "you can address the problem in a very concrete and experimental way," says Zuburtikudis.

"It's a way to arrive at things that scientists might not be able to arrive at in other ways," comments Masel.

Zuburtikudis and Saltsburg tested how fast samples with different-width stripes caused hydrogen to break apart ethane and propane. They observed a size effect that correlated with the height of each stripe the same way it correlates with a typical particle's diameter.

"Even if there's only one dimension in the nanoscale, it's enough for the size effect to be observed," says Zuburtikudis.

"It means that the number of atoms is not an appropriate measure of what is going on," says Saltsburg. "The number of atoms is not a good metaphor for structure." They next plan to make pillars out of different catalysts and to characterize the pillar structure in an effort to further narrow down the possible causes of the size effect.

A car's catalytic converter depends on microscopic metal particles to break down pollutants such as nitrous oxides. The petroleum industry harnesses these catalysts to convert crude oil into gasoline. While the multilayered pillars cost too much to make and to use in these applications, studies using the pillars should help engineers understand how they can improve the efficiency of these catalytic materials, says Saltsburg.

– E. Pennisi

NSF: A mouse that roars science policy?

With only 3 percent of total federal research and development (R&D) dollars at its disposal, the National Science Foundation ranks as a minor player, financially, in the national R&D picture. But last week, an independent commission urged the National Science Board, which oversees NSF, to take the lead in promoting the development of a national science and technology policy. For years, federal officials have debated the need for a national technology policy but have not yet formulated one.

"We're calling for a stronger and more coherent policy, in which science and technology can contribute more strongly," says Robert W. Galvin, cochair of the commission and an executive at Motorola, Inc., in Schaumburg, Ill. "The National Science Board should be facilitators of the dialogue to accomplish this goal."

Convened in August by the science board, the Special Commission on the Future of NSF also clarified NSF's role in promoting industrial competitiveness. "Technology is inescapably influenced by science, but technology is not what the National Science Foundation does," says Galvin. "I do not see NSF trying to cure industry's problems." The report, "A Foundation for the 21st Century," blamed poor management practices by companies, not slow technology transfer, for the decline in U.S. competitiveness. It also noted that as defense industries become more consumer-oriented, they will rely even more on scientific advances.

For NSF to make the best of this transition, the commission suggests, it should involve more industry scientists on its advisory committees and staff, and it should seek more input from society in general when determining national research needs, allocating resources to research programs, and evaluating those programs. "There really is an emerging spirit of collaboration, and this collaborative spirit will draw us closer together," Galvin told the science board when he introduced the report last week in Washington, D.C.

Also, just as many companies now depend on more specific measurements to assess productivity, NSF should rely more on rigorous, data-intensive analyses of its activities, says the report.

The group praised the agency for its key role in promoting science in the United States and attributed NSF's success to its broad scientific mandate, its support of peer-reviewed, individual grants and of science and math education, and its ability to link engineers, scientists, and academic institutions. However, it also called on NSF to pay more attention to "strategic" research goals and to become more effective in stimulating interdisciplinary research.

"The report confirms my original view that the environment for science and engineering is changing in many ways," says Walter E. Massey, director of NSF. The National Science Board will now consider this report – as well as ideas in 800 letters from scientists, professional organizations, and universities – to develop long-range plans for the agency, he adds. *– E. Pennisi*