conventional materials. Materials processing begins with mixing water, ethyl alcohol, a catalyst, and tetraethylorthosilicate. Subsequent steps depend on what type of composite is to be prepared, but they all take place at much lower temperature than the usual glass- or ceramic-forming processes, potentially a considerable economic advantage.

Attempts to improve ceramics are still dominated by traditional "heat and beat" methods.

To make lightweight, transparent polymer-oxide composites with controllable indices of refraction, for example, the solution is cast in a mold and allowed to gel, which produces a transparent silica gel comprising a network of particles about 5 nanometers in diameter and pores between the particles about twice this size. After drying and heat-treatment steps, the porous gel is impregnated with monomers, which subsequently polymerize at room temperature in pores of the gel. The porosity can be controlled by the catalyst and by the temperature and time of the heat treatment. Polymers including polymethyl methacrylate and silicone and copolymers (polymer alloys) involving these and other polymers have been incorporated in this way. The polymer species and concentration determine the index of refraction.

One problem with ceramics made by the sol-gel process is that they are highly susceptible to cracking because of the large shrinkage (up to 85% in experiments at UCLA) that occurs during the drying and heat-treatment stages. However, it is possible to make large, crack-free solids by adding a particulate second phase to the initial solution. It turns out that the second phase reduces the shrinkage. After the usual mixing, casting, gelation, drying, and heat-treatment steps, one obtains a porous ceramic composite. Pope mentioned several second phases that had been successfully incorporated into silica gels by this means, including silicon carbide whiskers, alumina, and silicon nitride. A silica–silicon carbide composite exhibited a maximum shrinkage of 30% for heat-treatment temperatures up to 800°C, while others did less well.

Finally, Pope discussed the fabrication of so-called triphasic composites by the impregnation of liquid monomers into porous composites followed by room-temperature polymerization. One remarkable lightweight silica–silicon carbide–polymethyl methacrylate triphasic exhibited a metal-like maximum deformation (strain) of 13.5% before fracturing under compressive stress, had a resistance to abrasion almost as good as that of commercial silica glass, and had a maximum processing temperature of 60°C. Pope attributed the large deformation to the possible retardation of crack growth by the silicon carbide.

Eventually, researchers would like to control structure at the molecular level. At Illinois, Klemperer, Vera Mainz, and D. M. Millar are trying what they call the molecular building block approach to the synthesis of ceramic materials. The idea is to start with a molecule with a controllable composition and structure that is to be the colloid particle in the sol. Subsequent hydrolysis and condensation reactions leading to the gel are, it is hoped, gentle processes that do not disrupt the basic structure of the building block but only remove the unwanted organic groups and water molecules. The particular molecules being investigated are polysilicic acid ester monomers, such as $[Si_3O_2](OCH_3)_8$ and $[Si_8O_{12}](OCH_3)_8$. At the moment, the Illinois chemists have demonstrated the utility of nuclear magnetic resonance techniques to study the progress of the reactions but have yet to find the reaction conditions that will allow them to produce silica glass by the sol-gel route with these monomers.

All in all, these two examples give hardly more than a flavor of current activity. The MRS symposium alone had 117 oral and poster papers, up from about 50 at the previous "Better Ceramics Through Chemistry" session 2 years ago. Moreover, sol-gel processing is far from the whole story. Researchers are keenly interested in adapting other concepts from organic synthesis and polymer chemistry to the fabrication of inorganic ceramics, as well. Nonetheless, while the large number of American industrial participants (no papers were given by Japanese authors) suggests that companies are interested in the new ideas, most of the reports dealt with processing stages that occur well before the fabrication of a densified ceramic product, indicating a promising but as yet unproven contribution for chemistry in making better ceramics. ■

ARTHUR L. ROBINSON

ADDITIONAL READING

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Briefing:

Planetary Rings May Not Be Forever

The more closely planetary scientists look at the rings circling the outer planets, the harder it is for them to imagine that the rings they see today are the same ones they would have seen 100 million years ago or will see even a few decades hence. The forces eroding the rings seem to be working too fast on some of them for such stasis. Rather than dating from the formation of the solar system 4.5 billion years ago, some rings may be young, formed by the violent destruction of a moon or the breakup of an earlier ring.

The latest indication of the possible mutability of planetary rings is reported in this issue of *Science* (p. 74) by Lyle Broadfoot of the University of Arizona and his colleagues on the ultraviolet spectrometer team of the Voyager 2 spacecraft. Their instrument focused on the uppermost reaches of the detectable Uranian atmosphere, including its emission of the mysterious electroglow that in pre-Voyager observations masqueraded as auroral emissions. The electroglow's source of energy is unknown, but in the course of driving the electroglow it also breaks down hydrogen molecules into hydrogen atoms that have enough energy to escape the atmosphere in large numbers. This atomic hydrogen boiling away from the planet joins an exceptionally dense extended hydrogen atmosphere bound to the planet that has a density of 100 to 1000 atoms per cubic centimeter at the distance of the Uranian ring system.

Particles orbiting through this extended atmosphere would not feel much of a breeze by terrestrial standards, but the resulting drag could pull any particles except large boulders into a slow spiral ending within a few billion years in incineration in the lower atmosphere, according to calculations by the ultraviolet spectrometer team. A 1-micrometer ring particle unconstrained by any other forces would survive just 100 to 1000 years. The plethora of dust rings and bands discovered in Voyager images suggests that gas is indeed dragging such particles across the system from the rings, where particle collisions presumably create them.

Larger particles, from centimeter- to meter-sized, would last 100,000 to a billion years, still far short of the age of the solar system. An unconstrained ring having particles all the same size and a mass as large as that of the epsilon ring, the most massive of the Uranian system, would last only 600 million years. In fact, the epsilon ring and probably the other nine narrow Uranian rings are constrained. Small moons orbiting to either side hold a ring together by gravitationally herding errant particles back into the ring, hence the name "shepherds."

Scott Tremaine of the University of Toronto, a co-originator of the shepherding theory, believes that the massive epsilon ring probably survived since the origin of the solar system, but less massive rings such as alpha and beta might have had serious problems resisting that long, he says. Perhaps they formed more recently. At a minimum, the lesser rings could look much different now than they did a while ago. Gas drag might also have played a role in removing smaller, less resistive ring particles, Tremaine notes. That selective removal could explain the dearth of ring particles smaller than 10 centimeters, a discovery of Voyager's radio science team.

Gas drag at Uranus is only the most recent problem complicating the stabilization of rings against the forces of dispersion and disruption. At Saturn, the A ring is the main problem. At least five small moons scurry around the edge of the A ring and interact with it gravitationally. That interaction should have driven the moonlets outward, doubling their distance from the ring, and driven the ring inward over as little as 10 million years. Anchoring each moonlet to large outer satellites through gravitational interactions and supplying momentum to the ring might hold the system together for 4.5 billion years, but no one has found a way of doing either.

The behavior of two of the A ring moons, Janus and Epimetheus, also suggests that much has changed there of late. Jack Lissauer of the University of California at Santa Barbara, Peter Goldreich of the California Institute of Technology, and Tremaine recently pointed out that the special relationship of Janus and Epimetheus, in which they have nearly the same orbit and periodically exchange orbits, could not have existed for more than about 20 million years. During that time, the moons' gravitational effort of shepherding the outer edge of the A ring has closed the gap between their shared orbits to 50 kilometers. Before 20 million years ago, their orbits would have been too far apart to maintain the present relationship.

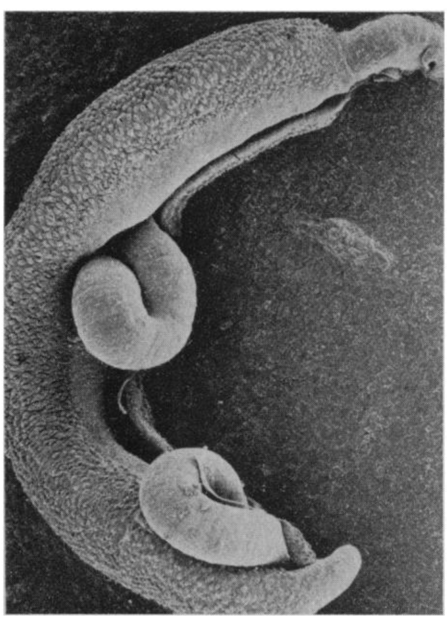
Larry Esposito of the University of Colorado has a solution for the A ring problem. "Sometime in the past 10 or 100 million years, one of those ring moons suffered a collision, which blew it to smithereens. The pieces that were left over are now rapidly evolving, spreading, and pushing away other ring moons, creating the situation that we see right now." In the future, as soon as a few decades, the arrangement of moons would be slightly though measurably different. There is little evidence that whole ring systems have been created in recent times through collisions of moons with asteroids or comets, but Esposito suggests that it may be more practicable and philosophically more attractive to create the A ring and perhaps rings elsewhere that way. ■

RICHARD A. KERR

Progress Toward a Schistosomiasis Vaccine

After years of wondering whether a schistosomiasis vaccine is even possible, researchers now, "are incredibly optimistic," says Alan Sher of the National Institute of Allergy and Infectious Diseases. "There have been very rapid developments. The state of the technology is very advanced."

Sher made his remarks upon returning from a World Health Organization meeting, Prospects for Immune Intervention in Human Schistosomiasis, which was held in Geneva on 26 to 28 May. There schistosomiasis researchers reported their most recent evidence that vaccines are feasible.



Miles Pharmaceuticals

Schistosome parasite

Schistosomiasis, an ancient disease that afflicts 200 million to 300 million people—1 in 20 of the world's population—is caused by a worm that can live as long as 20 years in its human hosts. It is a disease of poverty, of a lack of sanitary facilities. Thus the problems with eradicating schistosomiasis are economic and political as well as medical. And the researchers' enthusiasm for vaccine development is tempered by their realization that the disease would disappear if living conditions in Africa, the Middle East, Central and South America, China, the Philippines, and Malaysia were improved. The situation is further complicated by the fact that there is a drug, praziquantel, that is highly effective against the disease. But the drug is expensive for developing countries. So the disease continues.

The eggs of the schistosomiasis worms are excreted in the feces of infected persons. If the feces get into fresh water, tiny embryos emerge from the eggs. These embryos are taken up by snails, where they multiply. Within a month or two, the snails start releasing thousands or even tens of thousands of larvae a day. The larvae home in on people who are in the water and infect them. The schistosomiasis cycle continues.

Before even considering a vaccine against schistosomiasis, investigators had to convince themselves that immunity to the disease is possible. The schistosomiasis worm, once established in veins feeding the upper or lower intestine or the bladder, depending on the worm species, is essentially untouched by the immune system. The question, then, was, Does a previous schistosomiasis infection protect people against subsequent infections, even though the immune system cannot get at established worms? The answer, as Anthony Butterworth of the University of Cambridge reported at the meeting, is, clearly, yes.

Another requirement for a vaccine is to use nonliving material to produce immunity in experimental animals. Six different groups report that they have accomplished this goal. Moreover, three groups, including those headed by Sher, by Andre and Monique Capron of the Institut Pasteur, and by Ronald Smithers of the National Institute for Medical Research in Mill Hill, England, have cloned immunizing antigens.

Although some observers feel a vaccine is not necessary because praziquantel can cure the disease, the vaccine proponents point out that a vaccine need only be given once. Although a previous infection provides some immunity to reinfection, the immunity is far from complete. All too often, people who are cured of schistosomiasis after taking praziquantel show up the next year with a new infection. Yet this still leaves the difficult issue of what company would develop and test a schistosomiasis vaccine, Sher points out.

But the research results are encouraging. "The point is, we feel these developments now put us at the front of immunological parasitology work," says Sher. "Progress has been enormous in the past year or two and the group's combined feeling is that we can someday immunize in man." ■

GINA KOLATA