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Silicon-based chemicals from sand

UNIVERSITY OF MICHIGAN

Discovery by U-M materials scientist likely to exert major impact on dozens of industries

ANN ARBOR---Building on his own past research, Richard Laine, University of Michigan professor and materials scientist, has discovered an inexpensive and relatively non-toxic method for producing a variety of silicon-based chemicals from sand or rice hull ash and antifreeze [J. American Chemical Society, 122, 10063-72 (2000)]. Once implemented, the new technology will enable manufacturers to create silicon-based compounds without expensive, high-temperature processing and toxic by-products. Silica-based compounds are currently used in hundreds of products ranging from ceramics, glass, rubber, and building materials to electronic and telecommunications devices, personal care products, and pharmaceuticals.

In his original experiments, which were initiated at the University of Washington and funded by the Air Force Office of Scientific Research, the Office of Naval Research and the Federal Aviation Administration, Laine and several students used beach sand, ethylene glycol (antifreeze) and a caustic to produce silicon-based chemicals that included transparent conducting polymers, flame-resistant polymers, liquid crystalline polymers, and silicate glasses. Laine's latest studies were prompted by work done by Dr. Cecil Frye of Dow Corning Company in the early '70s. Based on Frye's findings, Laine saw the potential for making his process "greener" by reducing the amount of caustic and, perhaps even more important, creating a catalytic reaction.

Laine's research group correctly theorized that this new catalytic approach would open up the process dramatically, making it possible to use almost any source of silica and thus produce a wider range of compounds. One of those sources was rice hull ash, created as a byproduct in the routine burning of thousands of tons of brown rice hulls daily. Laine's work has shown that this waste product, when combined with simple chemicals such as those that can be recovered from used antifreeze, is capable of yielding numerous novel and common silicon-containing chemicals, polymers, plastics, and even very pure silica which can be employed, among other things, as a filler for polymers, in paper making and the production of optical glass. Several of the compounds produced with this newly developed process are very similar to those found to offer pharmacological activity such as wound healing and hair growth.

Most of today's polymers and plastics are made from petroleum-derived chemicals rather than silicon. This despite the fact that petroleum comprises less than 1 percent of the earth's natural resources while silicon-containing materials account for some 25 percent of the minerals on the planet. The reason for this disparity has to do with manufacturing processes. Current technology for producing silicon-based materials uses a very old metallurgical process that requires heating minerals like quartz sand (silica, SiO_2) in a furnace at extremely high temperatures, then using an electric current and a carbon compound to remove the oxygen and create an impure silicon metal. Surprisingly, the process of producing silicon-containing chemicals often involves returning the silicon metal to something approximating its original chemical state. Studies at Dow-Corning suggest that fully 70 percent of the energy consumed in producing these silicon-based chemicals, including silicone rubbers, is lost as gases during the process.

Commenting on his research, Laine notes: "You can imagine how surprised we were to discover that we could take the primary ingredient in antifreeze, add a little caustic to dissolve silicon and produce a wide variety of silicon-containing compounds that are now being manufactured by a costly, high-temperature process."

In comparing traditional manufacturing methods with his new process, Laine explains, "We have discovered an extremely low-cost route to silicon-containing chemicals and polymers, with very few of the environmental hazards that are extant in current processes." The wider implications of the research are significant. "There are many large-scale processes we can improve upon," Laine says. "Rather than relying on expensive high-temperature processing that generates byproducts such as hydrochloric acid, we're looking at a relatively eco-friendly process---one that uses rice hull ash, low-toxicity antifreeze and trace amounts of caustic chemicals to produce a high-quality silica and silicon-containing chemicals, polymers and plastics that can be used in a multitude of products."

Laine and several partners have formed a company called Tal Materials (talmaterials.com), with the goal of beginning large-scale production of commercially viable silica-based materials. The group is currently seeking investors. In the meantime, Laine, who is a professor and research scientist in the College of Engineering, is conducting follow-up studies working closely with collaborators at the U-M as well as in Japan and France.

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