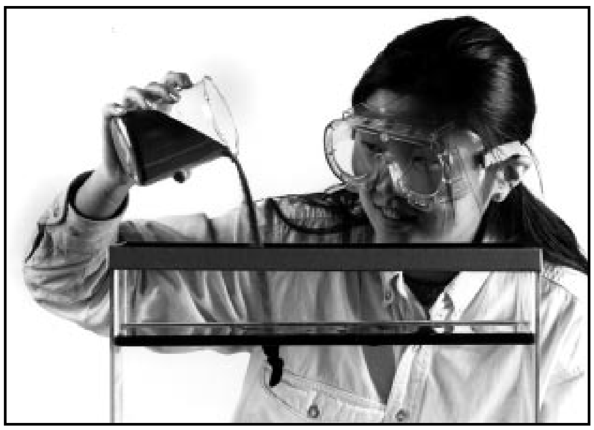
Magic Sand

by David P. Robson

When little kids play at the beach, they learn how to build model ponds, canals, and sand castles. They also learn about the properties of water and sand: Water "wets" sand and flows freely between the grains. Sand is denser than water, and sinks. If a lot of water is mixed with sand, it acts more like a fluid than a solid: The wet mixture slides, slumps, and resists the kids' attempts to construct a perfect sand castle. The moat, built to protect the sand castle, eventually causes it to collapse when wet sand flows from the castle's foundation. But there is another type of sand, called *magic sand*, that doesn't behave this way.

Years ago, magic sand was sold as a toy. The instructions suggested putting water in a large glass bowl and sprinkling in a small amount of magic sand. Instead of sinking, like beach sand, the magic sand would float! By sprinkling more and more onto the sand raft, it could be made to plunge to the bottom. If you were to hold beach sand in one hand and magic sand in the other and lower both hands into the water, the beach sand would clearly show individual grains. The magic sand, however, would appear to be surrounded by a silvery layer looking like plastic film. When you lifted your hands out of the water, the beach sand would be wet, with its grains clumping together. The grains of magic sand would not be clumped together—in fact, they would be perfectly dry! This is because the magic sand was surrounded by a large air bubble; the silvery layer was the curved surface of the bubble. What is magic sand and why does it act so strangely?



PHOTOS: AARON LEVIN

This experiment begins with a layer of motor oil floating on water (top photo). When Magic Sand is added (bottom photo), it sinks and carries a glob of oil with it to the bottom.

Inside sand

Beach sand is mostly mineral quartz broken into tiny pieces. Its chemical name is silica and the grains consist of silicon and oxygen, covalently bonded in a three-dimensional network of billions of atoms. The interior of the particle contains twice as many oxygen atoms as silicon atoms, and can be represented by the formula SiO_2. However, the surface of the particle contains oxygen atoms that are covalently bonded to hydrogen atoms (see Figure 1). These are *polar* covalent bonds, like the O–H bonds in water molecules. This means that both the surface of the sand and the water molecules have positive and negative electrical charges and, consequently, water is attracted to the sand. Water "wets" sand (that is, a drop of water will spread out on a sand grain instead of gathering into a bead.) In the jargon of chemistry, the sand grains are hydrophilic—water loving.

Where's the magic?

Magic sand is beach sand coated with minute particles of chemically treated silica. Researchers at the Cabot Corporation perfected a process for exposing glass, silica, and other materials to vapors of a silicon compound called trimethylchlorosilane, $(CH_3)_3SiCl$. As shown in Figure 2, these molecules attach to the microspheres and give it a new surface of nonpolar covalent bonds. These bonds do not attract water and thus make the particles hydrophobic—water hating.

When a few grains of magic sand are sprinkled on water, the polar water molecules attract other polar water molecules so strongly that

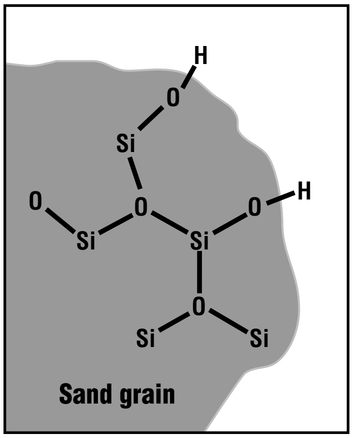


Figure 1: Most sand is impure silica, which has a network of oxygen and silicon atoms. At the surface, the oxygen forms polar covalent bonds with hydrogen atoms. These O–H groups carry partial electrical charges that attract similar partial charges in water molecules. The attraction of opposite charges makes water adhere to each grain of sand.

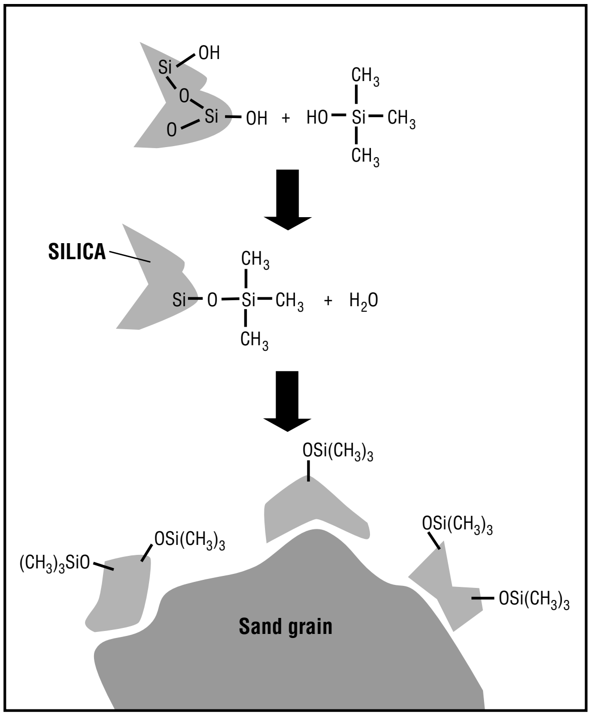


Figure 2: Magic sand consists of ordinary sand grains coated with tiny particles of pure silica which have received a special chemical treatment. When the particles are exposed to trimethylhydroxysilane, a reaction takes place between two –OH groups. This results in the formation of water, and the bonding of the silane compound to the silica particles. Following this treatment, the exterior of the particle contains $-CH_3$ groups that are soluble in oil but are insoluble in water.

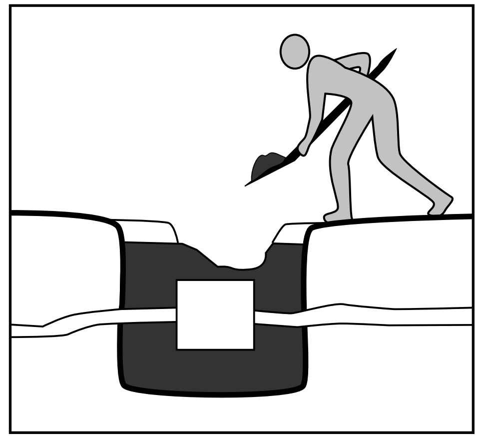


Figure 3: Digging through frozen Arctic soil normally requires hours of work with power tools. To speed underground repairs, utility companies can cover electrical junction boxes with magic sand and cap the sand with just a few inches of soil. Rainwater flows around, not through, the magic sand (color) and, when the soil freezes solid, the magic sand remains dry and loose. It is easy to break through the frozen cap, then shovel away the loose magic sand.

they prevent the grains of magic sand from breaking through the surface until the layer of sand becomes rather thick. When the magic sand finally sinks, the same surface tension effect also keeps it dry. The air between the grains cannot be forced out because the water molecules will not flow between the hydrophobic grains. However, oil will readily flow between the grains, and magic sand can absorb a surprising quantity of oil.

Magic at work

When the Cabot Corporation originally developed magic sand, workers expected it might be useful for cleansing water of oily contamination. It was also suggested that magic sand might be useful for trapping petroleum spilled from oil tankers in coastal waters. When sprinkled on floating petroleum, magic sand would mix with the oily material, add weight, and make it sink. This would prevent the petroleum from contaminating marshes and beaches and, theoretically, permit the petroleum to be later dredged from the bottom.

If you have ever raised potted plants, you know how difficult it is to water them correctly. If you under-water the plants, they wilt; over-water, and the roots rot. The problem is that the roots of most plants need to be exposed to both water and air. If you give the plant too much water, you will displace the vital air. When magic sand is added to potting soil, the hydrophobic grains permit air to flow between them, but not water, and thus maintain open air channels to the surface.

Magic sand has also been tested by utility companies in the Arctic. The utilities prefer to bury electric and telephone wires to protect them from the harsh weather but, if a wire or junction box needs repair during the winter, it is nearly impossible to dig up the deeply frozen earth. If the junction box is covered with magic sand, however, it can be serviced easily because the magic sand remains dry and loose year round (see Figure 3).

The future of magic sand is in your hands

The applications described above have all been tested successfully but, for a variety of reasons, are not being used today. The manufacturer of magic sand, the Clifford W. Estes Company, is searching for new uses. Can you think of a new application for magic sand? If so, try some simple experiments to test your idea, then enter the *Chem Matters* magic sand contest.

REFERENCES

Vitz, E. "Magic Sand: Modeling the Hydrophobic Effect and Reversed-Phase Liquid Chromatography," Tested Demonstrations, *Journal of Chemical Education* 1990, *67*(6), 512.

Hoffman, A. B. *Journal of Chemical Education* 1982, *59*, 155.