



Form from Fire

Self-propagating heat waves can engender new and improved materials, but only recently have researchers found ways to monitor these ultraquick chemical reactions

by Arvind Varma

Think of a burning trail of gunpowder. The fire races along its length, leaving nothing behind except loose ash and gases. Now imagine igniting the end of a different trail of powder. This time the bright, glowing wave of heat that surges through the mixture leaves a solidified mass in its wake. This seemingly paradoxical effect—that burning need not always use up materials or break them down—is entirely real and is the essence of one of the most promising innovations in materials science: combustion synthesis.

Scientists have known about combustion synthesis for three decades, and they have learned to create more than 500 compounds, many of which have proved to be invaluable as ball bearings, nuclear safety shields, abrasives, high-temperature superconductors and other technologically advanced items [see box on page 61]. But despite this long history, trial and error has been the primary means of invention. For example, a researcher might eventually realize that starting with finer powders can make the synthesized material stronger, but he or she could only guess at the reasons why. As a result, the applications of combustion synthesis have remained highly specialized. Only recently have engineers begun to understand how a heat wave actually propagates through the original mixture, leaving the desired material in its wake. Knowing precisely what happens between starting components and final product is the best way for researchers to refine techniques of combustion synthesis for widespread use.

Since prehistoric times human beings have been burning

things for advantageous ends. About 13,000 years ago people discovered that baking a piece of malleable clay transformed it into hard ceramic. Modern technologists have learned how to fire special clay powders in a furnace to produce ceramic shields that are strong and heat-resistant enough to protect spacecraft. In both cases, the process applies external heat to break the chemical bonds of the original material and to rearrange them into a new structure.

When scientists observed in the late 19th century that shuffling chemical bonds can release significant heat energy, they began to wonder whether it might be possible to use this energy directly to synthesize useful materials. In 1972 scientists in the former Soviet Union discovered how to harness enough of this energy to drive a synthesis reaction without continuing to heat the mixture. Thus, combustion synthesis not only makes a new solid from disparate starting components, it also self-propagates—once heat is applied to start the reaction, it runs on its own. And all it takes to ignite a combustion-synthesis reaction is a brief heat pulse from sources such as a tungsten coil or a laser beam, which use significantly less energy than do industrial furnaces, the most common method for creating advanced materials.

Saving energy is just one of many advantages that combustion synthesis holds over conventional techniques of materials production. The energy-consuming nature and size of furnaces limit the volume of material that can be converted. Combustion synthesis can yield objects of virtually any size,

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