From Atoms to Autos

Researchers in laboratories across America are playing God to create a host of new materials virtually from scratch. These substances have astonishing properties with a wide range of potential uses in industrial and household products. Some finished products already exploit the remarkable qualities of aerogels, superplastic steel, ceramic metals and other Space Age materials. But what's happening in the labs today is raising troubling questions about design's role in the development of tomorrow's products. Can industrial designers keep up with the rapid changes in the materials field? And why aren't they pioneering more applications for these exotic substances?

By John Sedgewick

Extraordinarily advanced new materials are now emerging from the nation's labratories, constructed in some cases atom by atom with powerful new tools like scanning tunneling microscopes and enhanced computer modeling. The results would make Dr. Frankenstein proud: "aerogels" that, although solid, are so light they have been dubbed "frozen smoke" and have tremendous insulating properties besides; "superplastic" steel that is as moldable as plastic and considerably more durable than conventional steel; ceramic metals, or "cermets," that are lighter than aluminum but nearly as tough as diamonds; "piezo-electric" materials that bend when given an electric charge and give an electric charge when bent, thereby imbuing an object with a crude intelligence; and mammoth liquid crystal displays that can whiten an entire wall of glass at the flip of a switch.

The potential of new materials

It is not hard to imagine the products such materials might generate. The aerogels could free refrigerators of ozone-depleting chlorofluorocarbons, and make them lightweight and, possibly, see-through as well. Superplastic steel could transform the automobile industry as drastically as titanium alloys revolutionized the airplane industry, allowing an entire car chassis to be molded like plastic. Cermets could make golf clubs dent-proof and presidential limousines bulletproof. Piezo-electrics could serve as burglar-alarm sensors, light switches, hearing aids or miniature speakers. Liquid crystal displays could revolutionize billboards and make the mechanical window shade a thing of the past.

In some cases, such applications are already proceeding quite nicely. One car company, for example, is at work with cermets to provide terrorist-proof cars for anxious executives, and the liquid crystal displays are now available to turn glass walls into privacy screens in office boardrooms. But such developments are almost invariably occurring without the assistance of the designers whose business it is to tailor such products for customer use. "Very few design firms are sophisticated in truly advanced materials," admits Charles Mauro of Mauro and Mauro Design in New York City. "And I don't know if they ever will be."

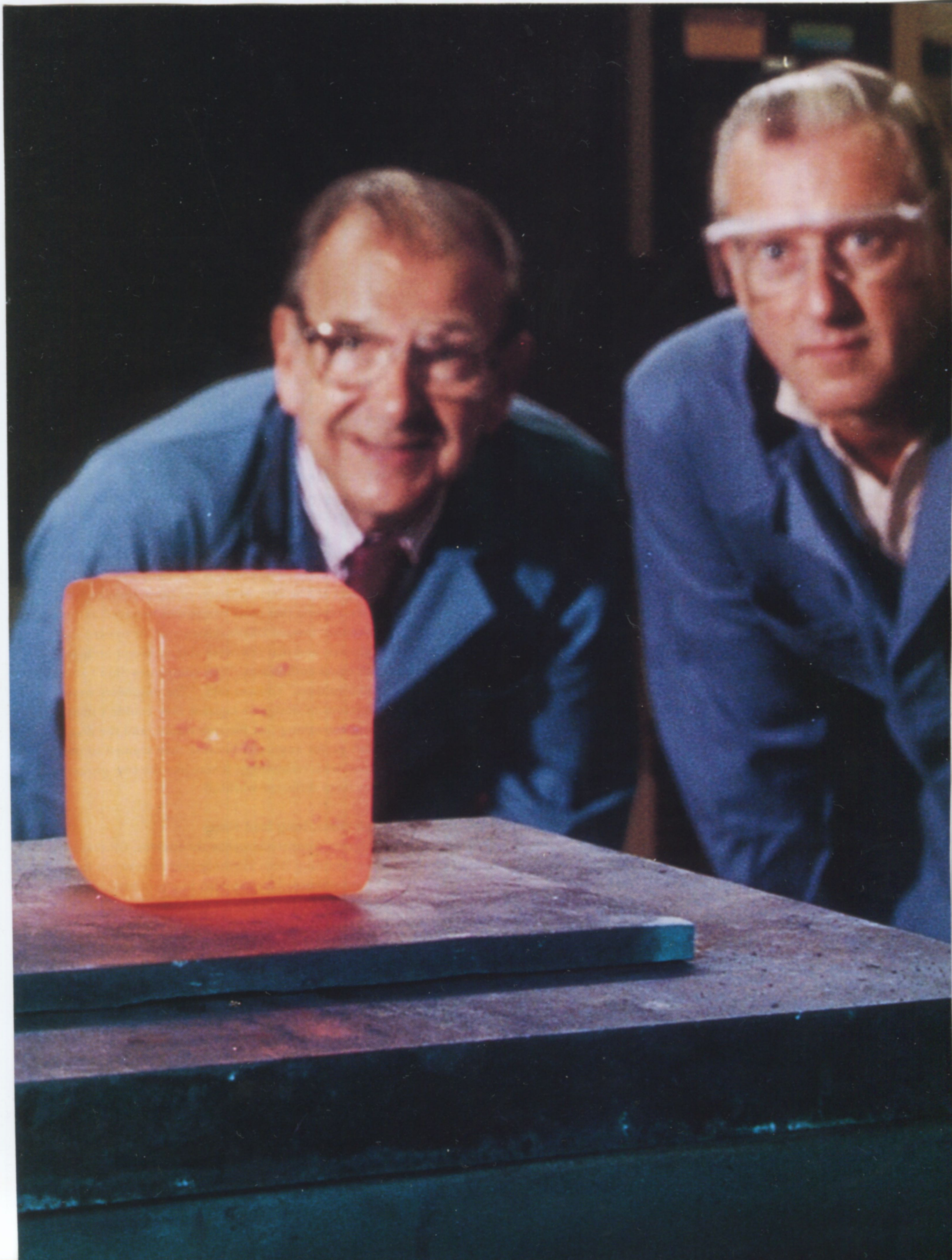
Few design firms are involved

Precious few designers come into regular contact with new materials, and the ones who do are largely concentrated in the automotive and housing industries, where the scale makes new materials affordable. But even there, designers rely far more on existing plastic, glass and sheet steel than on any exotic new substances. And they rarely work with material scientists and mechanical engineers to shape such new materials to certain product specifications, no matter how much this might speed up the development process.

The truth is, despite the heavy publicity given to the current spate of exotic materials, relatively few truly new materials come down the pike. "Those sorts of lightning-bolt discoveries are very few and far between," says Greg Jones, chief designer for General Electric's automotive plastics division in Southfield, Michigan. "At this point, it's hard to come up with a brand-new polymer. Typically, all we get is a new blend with a few new properties."

It doesn't help, he adds, that the design shop stands at the far end of the product development path, a long way from the materials lab. Design's position in his company is roughly analogous to its physical area of interest in the car — on the outer surface, mediating between the desires of the customer and the capabilities of the engineers. Jones, for example, calls himself "an advanced scout to hear the voice of the customer," and he refers to the new-materials division rather distantly as the "ivory-tower, white-lab-coats people."

Mark Roemer, a former General Motors industrial engineer now with the Silicon Valley design firm IDEO, believes that automotive designers are too detached from the basic issues of manufacturing to really help make a better car. "It's a major downfall of automobile design that design and engineering are separate entities," he says. Designers, he argues, are off in their own little world, woefully oblivious to the engineering implications of their designs. As an example, he cites the large, low-angled windshield that designers dreamed up for GM's line of mini-vans. The windshield



looked great, but it drove engineers crazy trying to maintain the car's crash-worthiness, air-conditioning systems, engine power and fuel efficiency. "There was a whole cascade of things started by that one design detail," Roemer grumbles. Ronald P. Nimmer, a mechanical engineer at General Electric's Southfield research and development center which develops a number of new materials for the automotive industry, complains that designers are unwittingly taking on structural engineering functions — without knowing nearly enough about the subject.

A fundamental ignorance

The transformation stems from the gradual shift in the materials going into today's vehicles by which plastic bumpers, for instance, are coming to replace metal ones because of their superior moldability. Designers see the plastic bumper as a design element, overlooking its important structural function. "The designers can't make their designs based on style alone," Nimmer says. "I wish they had a greater appreciation of the engineering issues involved." Occasionally, of course, designers do use new materials and use them ingeniously. Designers at David Kelley Design (now part of IDEO) thought to use tough, lightweight magnesium as a support in the Dynabook portable computer, and Jack Harkins of Ciba Corning in Hollis, New Hampshire employed rotationally-molded polyethylene, a substance normally reserved for children's outdoor furniture, in a portable incubator used to test water purity along remote stretches of the Amazon. But such instances are rare. The question inevitably arises: why are designers so little involved with the development and use of new materials in American industry?

To begin with, although industrial designers have themselves complained for years about industry's gross misunderstanding of their functions, they continue to suffer from it. Over two dozen material scientists were contacted for this article; not one of them knew what an industrial designer did. None had ever met one, and none had ever heard of anyone who had used one. Most guessed that an industrial designer designed industrial products, and were surprised to learn that wasn't really the case. Such fundamental ignorance obviously creates giant obstacles for designers who would like to make their way into the laboratory.

Then again, it might help if industrial designers themselves could agree on their own job description. Are they stylists solely concerned with the outer shape of mass-market products? Or do they delve deeper into the inner mechanical workings of the product because these dictate exterior appearance? Greg Jones of GE thinks designers should do a bit of everything: not just aesthetics and engineering, but marketing as well. To him, a designer's potential stems from the breadth of his or her professional interests and expertise. If designers were multi-talented, they "would then become key figures in the industrial enterprise, and

New software programs by GE simplify the design of products made from structural plastic foam, a material that combines high strength and light weight. One of the first of these products is this intricately shaped pallet for jet engine components.

they would be far more visible in the nation's laboratories than they are," he says.

The age-old art vs. science problem has also kept designers in a box. Engineers and designers aren't separate species, but it's safe to say the two groups don't always see eye to eye. Mark Glusker, a former designer at David Kelly Design who is currently exhibit hall manager at The Tech Museum of Innovation in Silicon Valley, reports that most companies betrayed an innate bias either toward DKD's design staff or toward its engineers, and that few were able to accept both parties with equal enthusiasm. "The companies didn't know whom to trust," Glusker says. "The engineers were suspicious of designers because they couldn't imagine doing something just for appearance, and the designers didn't go for engineers because they seemed so preoccupied with technology. It was like the two groups were from different worlds."

High costs, long lead times

Designers compartmentalize themselves, Glusker adds, often recoiling from anything that smacks too heavily of hard science. This can lead to a profound ignorance about materials. "You don't see many designers leafing through trade journals on engineering or plastics," he notes. And designers are inclined to dismiss certain new materials like the super-insulating aerogels as having merely an engineering function, without realizing that engineering functions can have important design implications.

But, truth be told, there are some good reasons why engineers and designers would not necessarily work side by side in the laboratory, cooking up new materials. For one thing, designers operate on a far shorter time frame than any laboratory researcher. Typically, designers need to complete their work on a product before the next trade show, which is usually just a few months away. Materials scientists might tinker with a

A materials technologist at Lawrence Livermore National Laboratory moves a glowing block of cermet, a composite material made up of boron carbide and aluminum. The composite, which is lighter than aluminum and stronger than steel, derives its name from its parts — a ceramic and a metal. This block has been heated to about 800 degrees C inside a ceramic sintering furnace. The material was produced by a unique process called molten metal infiltration, which allows cermets to be made at much lower temperatures than the typical 1700 degrees C required by conventional methods to fabricate ceramic materials.

Stanford University's Oleg Sherby (left), a pioneer in the creation of new materials, and Richard Landingham of Lawrence Livermore Laboratory look over a block of superplastic steel before a forging press is used to form the ultra-high carbon material, which has been heated to about 900 degrees Celsius. The two scientists are leading the efforts to develop ways to process this steel, which is as moldable as plastic and much more durable than conventional steel, on a commercial, high-tonnage basis.

new material for a decade or more — an eternity as far as most designers are concerned. Oleg Sherby, a professor of metallurgy at Stanford University who is credited with the discovery of superplastic steel, achieved his breakthrough sixteen years ago, and researchers are still fiddling with the formula in an attempt to find an application for the product.

There can also be bureaucratic constraints against bringing a designer on board the research team. Richard Landingham, a materials scientist at the Lawrence Livermore National Laboratory in California who heads up the group developing cermets, points out that the government funding on which so much of the new materials research depends usually makes no provision for a designer. Where would his or her salary come from? Even though the government recognizes that the laboratory depends on licensing agreements to cover at least some of its research costs, it provides no funding for anyone like an designer to facilitate product development. Why doesn't the government provide grant money for that purpose? "That's a very good question," Landingham says.

In private industry, the development of new materials is so expensive that it is only workable for the most sure-fire, mass-market applications; such applications are rare, especially in a recession. As it is, materials vendors refuse to make some existing materials available to many smaller industries because of the production costs. With the extra risks and start-up expenses involved with new materials, these vendors are even less likely to make them widely available.

Sticking to familiar territory

For many new materials, the development process is so complicated and uncertain that it may be difficult for most designers to make much of a contribution anyway. Caterpillar, Inc. has been working for some time to develop Oleg Sherby's superplastic steel for use in molding steel tractor parts. At present, Caterpillar's researchers have finally established the steel's superplasticity, but in the process they have somehow lost its steelness — its toughness and durability. "We're still in the jungle jumping from swamp to swamp," says Egon Wolff, Caterpillar's manager of advanced materials research in Peoria, Illinois. "We haven't gotten to the point where we can draw any useful conclusions about the material. We haven't generated enough knowledge for a designer to come in and tell us how to use it." Wolff supposes that an engineer might be able to guarantee certain minimum properties to allow a designer to consider the material, but even so, nothing compares with holding the substance in your hands. It's like buying a car, he says. It's one thing to see the service department, and another to get inside and smell the upholstery. Wolff concludes: "All we have right now is a sheet of cardboard with a dream written on it."

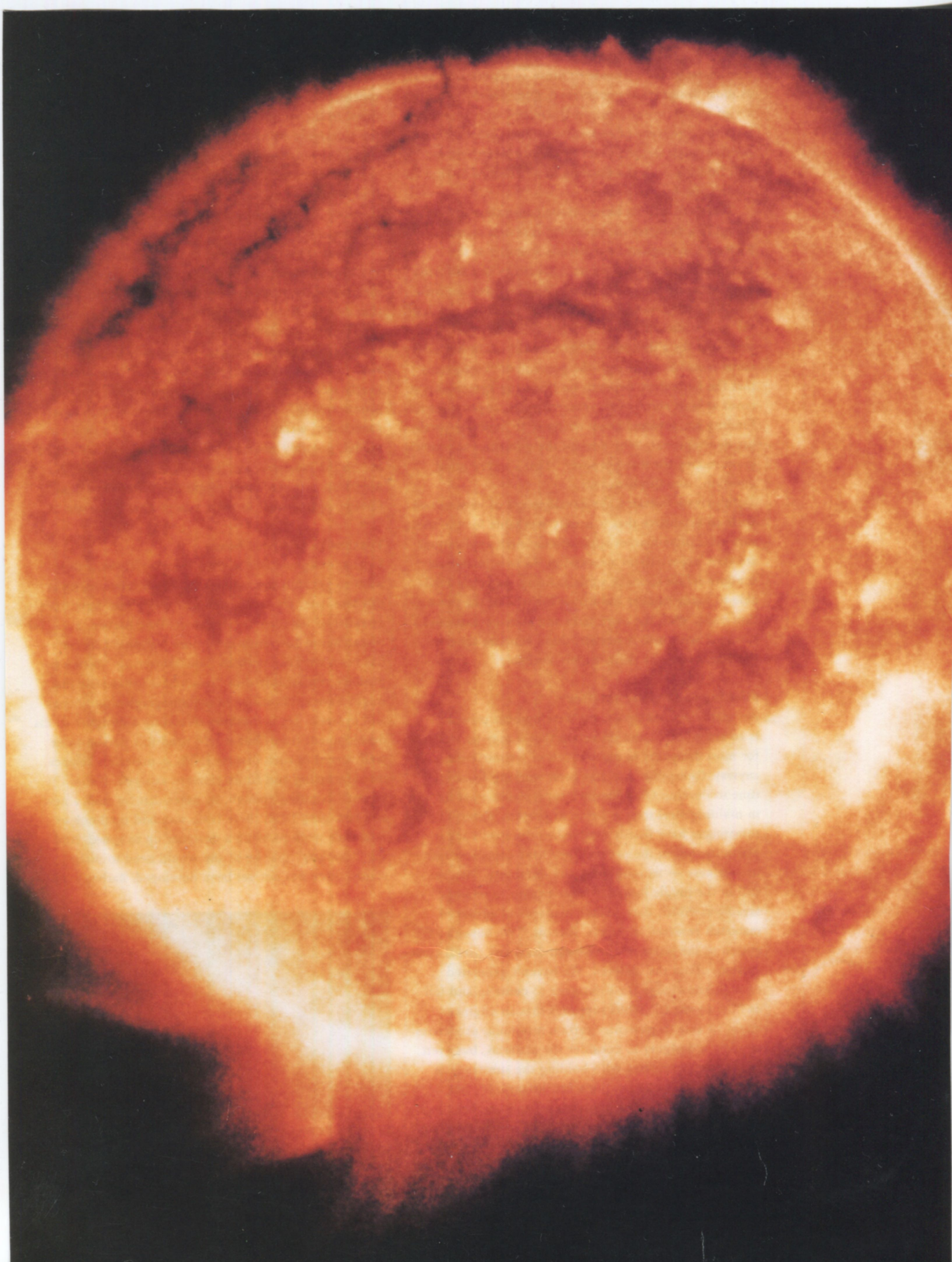
Currently, most designers do reasonably well with a relatively short list of materials, and so have little incentive to scour the countryside in search of new ones. In the computer industry, for example, it is rare for a designer to have to reach much beyond ABS plastic and sheet steel. "Those are the default materials," says Roemer. For the most part, this suits designers just fine; like anyone else, they prefer to stick to familiar territory. "You tend to work with your list of knowns," Roemer says.

When apportioning responsibility for the limited use of new materials, one should not overlook the dictates of the marketplace. Caterpillar's Wolff believes that despite Americans' supposed love for the new, they are far more conservative and practical-minded than their European counterparts. "Europeans have an obsession with the latest gadgetry," he says. "They don't care nearly so much about reliability and performance as Americans do." He adds that the Japanese don't share Americans' wariness of the first edition of a new car model, possibly released before all the bugs are out of it. "To the Japanese, the first one is the best one." So American manufacturers might be slower than their foreign competitors to make use of new materials.

Textbooks and tool boxes

Finally, designers face a steep learning curve if they want to get into the nation's materials laboratories at this late date, for few systems or guidelines have been established for their involvement. Troy Barbee, a researcher at Lawrence Livermore National Laboratory, has been working with an "ion-sputtering" device to produce remarkably thin "nanophase" materials that might have applications in mammography, telescopes and eyewear. He is thinking of adding a designer to his development team, but would need this person to be well versed in such diverse fields as materials science, manufacturing and finite element analysis. If that weren't daunting enough, he notes that for such a new and changing field, there is no standard textbook or reference work to bring a designer up to speed. And the "tool box" that he or she would need to make a contribution has not yet been developed. Barbee admits

Exploring the uses of new plastic resins, Baldwin Piano Co. will employ Heavy Valox resin to give its keys the touch, feel and appearance of ivory, while also ensuring chemical resistance and durability.



that the designer who could operate amid such uncertainty "probably doesn't exist." In short, just as the new materials are being built from scratch, so would any designer who sought to make use of them.

Targeting specific markets

Yet, despite all the impediments, the need is there for designers to help out in the laboratory. Many engineers and materials researchers declare that they would be delighted to have a designer assist them in bringing their material to the marketplace. All of them recognize the importance of speeding up the technology transfer process for new materials in order to recoup the research investment more quickly. And a number believe that even without an engineering background, designers could help tailor a new material to a specific application early in the development process, saving time and money.

Martin Cooper, Lawrence Livermore's licensing agent for aerogels, points out that like many new materials, the aerogels have a broad range of properties that could be developed depending on their eventual application. They can provide thermal insulation or dialectic insulation; they also filter out ultra-violet light, giving rise to the possibility that aerogels might even be developed as suntan lotions. "Tell me what you're trying to achieve," he says, "and we can work the right properties into account." Cooper claims he could use an in-house designer to help facilitate the licensing process. Because of the cost of aerogels, household refrigerator companies have expressed little interest in the material, but the makers of specialty cooling vessels find it attractively priced. "These companies ask me how to shape it — is it done by cutting or molding?" he says. "They very quickly get involved in design questions."

Similarly, Richard Landingham points out that his cermets consist of a broad family of materials with wide-ranging properties. He believes that designers could help to target his investigation into specific product markets, and he is not at all apprehensive about their possible lack of engineering expertise, or their inability to speak in the technical terminology of ergs and angstroms. "You don't have to be steeped in the material," he says. "I'd have loved it if someone had told me early on, 'Well, geez, if you change the color here, or the hardness there, or the strength there, then you could use cermets in this whole other application that you haven't even thought about.' You can make those kinds of changes easily in the early stages. It gets a lot harder later on."

This photograph of the solar corona of the sun was taken with a space telescope whose optical reflective portion was made of a multi-layer material consisting of molybedenum and silicon. One of the highest resolution spectrally-resolved images of the sun ever taken, the photograph came from a sounding rocket launched from White Sands Missile Range in New Mexico; it suggests some of the possible benefits of developing applications for the new materials already in existence.

As it is, Landingham is now dealing with a representative of a sporting goods company to devise a cermet to toughen the head of a golf club, and he has found this interaction rewarding. "It isn't a question of expertise so much as desire and motivation," he says. "If one person has a material and another person has a need, the chances are good that you are going to come out of the room with something useful."

Only two to three times heavier than air, ultra-low density silica aerogel is the lightest known transparent solid; these pieces of the gossamer-like material come from the Lawrence Livermore National Laboratory.

Oleg Sherby, inventor of superplastic steel, concurs: "If a designer had come to me sixteen years ago, I'd have welcomed it. Superplastic steel can flow like molasses or blow up like a balloon. It has lots of properties. A designer could have told me what I could do to take the fullest advantage of the material."

The need for designers

Is there anything designers can do right now to make themselves more useful in the laboratory? There are, unfortunately, no remedial courses for designers in materials science, and no companies offer training programs. Such developments are still years off. For now, designers might start by renegotiating their industrial roles. They will have to stop being thought of — and thinking of themselves — as cosmeticians, the industry equivalent of Hollywood hair stylists who whip in at the last minute to touch up the star's coiffure. Instead, they must present themselves as the architects of new products. The look and feel of a product are certainly important, but designers will have to develop a greater sophistication about the engineering that lies behind it.

After all, even if a new material is buried deep in a product's engineering viscera, it still has important design ramifications. Aerogels, for example, would most likely be embedded inside the walls of any refrigerator they might come to occupy, but their nature would dictate a "fundamental redesign" of the refrigerator, in the words of Edwin Berkowitz, president of Thermalux, Inc., which is marketing aerogels as insulation. Designers alone would not take on the entire task, but they would certainly be called upon to make an important contribution.

As with aerogels, so too with many other new materials. They may not yet require designers' attention, but they will eventually, and they should. The pace of change in materials is quickening, and designers had better be ready — both for their own sake and for the American economy's.