Material World

An enthusiastic exploration of our man-made surroundings, from stone tools to polyester shirts.

STUFF
The Materials the World Is Made Of.
By Ivan Amato.
Illustrated. 294 pp. New York:
Basic Books. $25.

Blocked due to copyright.
See full page image or
microfilm.

By Marcia Bartusiak

THE specialness of humans is not in our ability to fashion tools from the things found naturally around us. Certain animals do that. It's in our insatiable drive to go nature one better. Not satisfied with carving out gourds to make drinking vessels, we invented pottery. Animal skins were replaced by fabrics woven out of wool, cotton and artificial threads. Ever the tinkerers, we can now fashion materials that are 50 times stronger and run engines that are 100 times hotter than those made just a few decades ago, and electronic components made now may be only a millionth of the size of the smallest ones possible a generation ago. The first fiber optics — cables of glass as fine as hair — couldn't move a beam of light down a city block; now such fibers regularly carry signals across entire oceans. With "Stuff: The Materials the World Is Made Of," the science writer Ivan Amato makes us marvelously aware of our unnatural surroundings: the metals, alloys, plastics, polymers, fabrics, glasses and ceramics that we take for granted (but would dearly miss if suddenly gone). "Mined ore becomes metal becomes wire becomes part of a motor," Amato points out. "Drilled petroleum becomes chemical feedstock becomes synthetic rubber becomes automobile tires. . . . Natural gas becomes polyethylene becomes milk jugs."

Each year 15 billion tons of raw resources are transformed into something else — something designed and forged by materials scientists, the heroes and heroines of this engaging tale. As the author puts it, they are the "architects of the future's commonplace miracles." These everyday wonders have been springing up since the dawn of the Stone Age. Amato likes to think of the first materials scientist as a "Paleolithic Edison" who struck rock against rock and discovered how to make sharp-edged tools far superior to stones flaked by accident. Slowly, over some 2½ million years, the descendants of proto-Edison diversified, making an assortment of scrapers, hammers, axes and choppers. As soon as our ancestors learned to control fire, their cleverness quickened. Malleable clay was turned into pottery, and metals were extracted from ores. Perhaps more important to the average peasant was the introduction of plaster, brick and mortar. The Romans pioneered a volcanic-ash-and-calcium-carbonate mix, used in such structures as the Pantheon, that wasn't reproduced again until 1824, as Portland cement.

By the second half of the 19th century we entered the age of mass production. Steel, initially a specialty item limited to 50-pound batches, could at last be made in bulk owing to the ingenuity of Henry Bessemer. It allowed skyscrapers to sprout on the urban landscape, huge bridges to span our waterways and more lethal cannons to operate on battlefields. Aluminum, formerly as precious as platinum and used for adornment by the affluent, became common enough to wrap sandwiches. The first commercially successful plastic — celluloid — made its appearance when John Wesley Hyatt, an Albany printer and mechanic, was trying to find a substitute for billiard-ball ivory, then coming into short supply.

Originally operating by trial and error — trying a little of this and a little of that — material craftsmen started to be more methodical in their formulations. By the turn of the century, they began to study the physics and chemistry of their materials and to use new tools, like X-rays and electron microscopy, to analyze atomic structures. "The ultimate task, after all," Amato writes, "is to understand how a common palette of about 90 types of atoms — the periodic table of the chemical elements" — can make such countless materials.

At the same time, lone inventors came to be replaced by institutional laboratories, hastening the transition from lab to market. Polymers became a boom business, introducing us to such novel entities as polyvinyl chloride, polystyrene, Plexiglas, Lucite and Teflon. One of the biggest success stories was nylon, whose inventors were inspired by the chemistry of silk.

Amato relates this history with a winning style, and I would have enjoyed his lingering in the past a bit longer. But he places his stress on the present, taking advantage of his years of covering materials science for such publications as Science and Science News. He introduces us to the field's "different tribes, prides and packs." Here we find the race to make extended forms of synthetic diamond for use as the ultimate semiconductor material, as well as a lifelong lubricant, coating and surgical implant material. Other researchers are devoted to "biomimetics," the attempt to exploit and improve on the structures already found in nature. An abalone, for example, can take simple calcium carbonate, the stuff of chalk, and weave an iridescent yet tough shell. It might be possible to mimic the abalone's designs in making superhard ceramics for lining the piston in a car engine or in producing steels that "heal" themselves when cracked.

IN the last third of his book, Amato focuses on two case studies. The first involves a Bell Labs materials designer, Federico Capasso, who would very likely offer quite different advice to Dustin Hoffman in "The Graduate." The future, he would say, lies not in plastics but in molecular beam epitaxy. With M.B.E., atomic masons are spray painting atoms, one by one, onto surfaces to create materials for specific functions, like the tiny lasers that act as the phonograph needles in our CD players. "M.B.E. is now so good," Amato notes, "that a square centimeter of crystalline real estate — an enormous expanse of over one quadrillion atoms — can have as few as three atoms out of place." This section is a tour de force in solid-state physics, and Amato does a superb job in explaining how it all works.

Greg Olson, a Northwestern University researcher who has "mind-melded with metal," the author says playfully, hopes to make similar progress in steel production, which in many ways is still more an art than science. He seeks the rules in making lighter and tougher steel alloys, whose uses might not be readily apparent to the layperson. "For every pound shaved off of a gear that goes into a commercial airliner, for example, the economic payoff would be about $80. There are about two tons of gears on a Boeing 747," Amato says. Olson's analytical approaches can also be used in designing the perfect ice cream.

The author convincingly argues that humanity is now entering a new age of toolmaking, having secured an unprecedented power "to understand, control and manipulate the material world." Materials scientists are guided by new theories, new methods of synthesis and new levels of computational capability that allow them to design materials in virtual space. Indeed, the country with an edge in these abilities could gain enormously in geopolitical power.

Of course, as Amato cautions, there are sometimes "trends du jour" that never fulfill their promise. And that is the book's weakness. "Stuff" would have been enhanced by both more depth (less magazinelike breeziness) and more critical analysis. Amato examines all too briefly the potential downside to this new era in materials science. Chlorofluorocarbons, once so promising as refrigerants and aerosol propellants, endangered the world by destroying our atmosphere's protective ozone layer. How concerned are the new atomic architects at unknowingly constructing similar hazards? The issue is not fully aired, for Amato is more caught up in the wonders of these technological advances. Yet his enthusiasm is infectious. While molecular biologists and planetary astronomers grab science news headlines these days, it doesn't hurt to be reminded that it's the materials scientists who produced the printing press, the paper and the ink. □

Marcia Bartusiak, a contributing editor of Discover magazine, regularly writes on physics and astronomy. Her latest book is "Through a Universe Darkly."