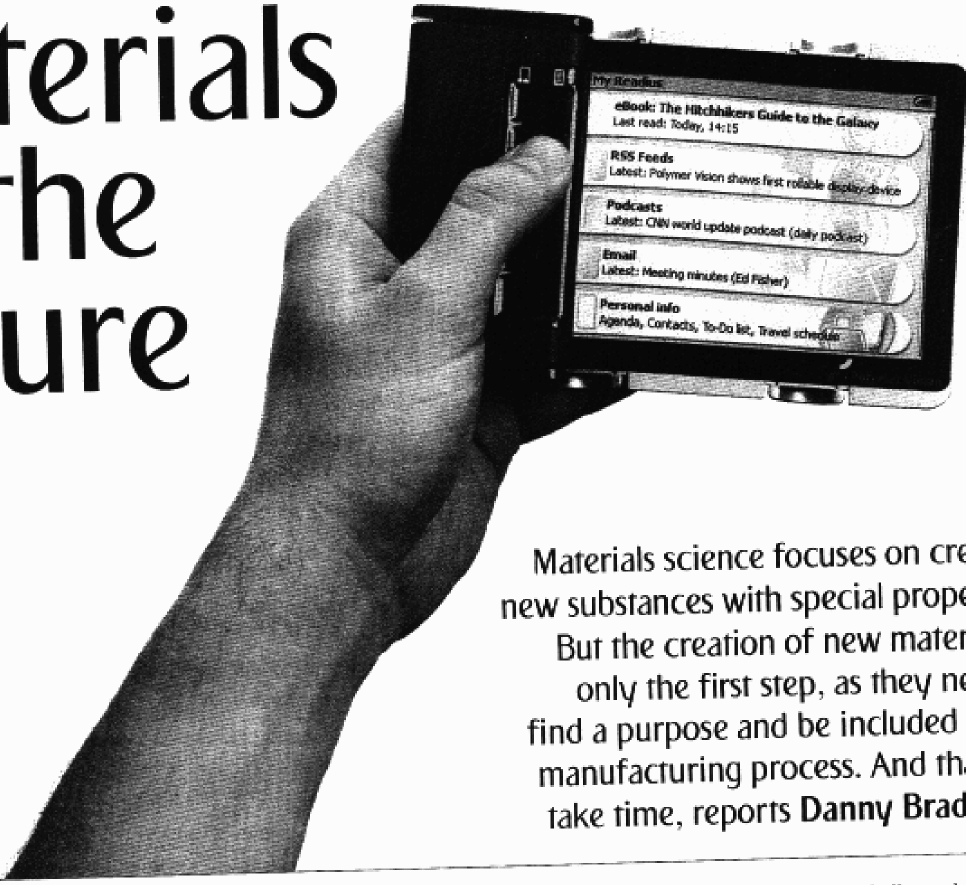
Materials of the Future



Materials science focuses on creating new substances with special properties. But the creation of new materials is only the first step, as they need to find a purpose and be included in the manufacturing process. And that can take time, reports Danny Bradbury.

Right now, you're reading *Open Skies* on conventional paper, but one day, you could be reading this using a single sheet of electronic paper on which the images change before your eyes. That paper – which would use hardly any battery life at all – could be charged using electricity gathered by solar paint, applied to your roof with a brush. Such technologies are closer than you might think (indeed, electronic paper already exists commercially in a primitive form, in everything from mobile phones to electronic book readers).

These developments and many other new and innovative commercial products rely on materials discovery, a complex and multi-disciplinary process that takes ideas from a scientist's brain, through a myriad of different laboratory processes, and finally through to manufacturing and retail. Without materials science, the polymers and other innovative substances that make up the airplane that you are sitting in wouldn't exist. The developments that make substances lighter, stronger, and more effective at what they do would never have happened, and our way of life would be substantially different.

The ideas for new materials may start off in a laboratory beaker, but they end up in the most unusual and unexpected places. One material ended up in the palms of thousands of tennis players. Babolat, which manufactures tennis equipment, now has a lighter, stronger racquet based on advanced nanotechnology materials. "The nanotubes have amazing properties," says spokesperson Robin Ashmore. "This racquet is stiffer than a carbon racket, and it's a lot lighter." Because the racket is stiffer, it is able to resist torsion, which is an effect that causes the head of the racket to twist imperceptibly upon impact. "That is the kind of thing that causes tennis elbow," says Ashmore. "What happens is that the vibrations travel through the grip of the racket and up the forearm to your elbow." Reducing torsion also helps to improve the strength of a tennis player's return shot, because less energy is absorbed upon impact.

Babolat's NS series of racquets uses carbon nanotubes, which are sheets of carbon molecules rolled into a hollow tube so small and thin that they are just tens of atoms in diameter. This gives them a number of unique properties, including making them very good conductors of heat (because their small size makes them free of structural defects that could impede the flow of energy). They are also incredibly strong – orders of magnitude stronger than steel, for example. Consequently, nanotubes are being proposed for a wide variety of future applications, including futuristic buildings, and even 'space elevators' – connectors anchored to the ground and stretching all the way up to space stations in orbit, that could eliminate the need for expensive, polluting rockets to ship cargo into space.

The application for materials based on carbon nanotubes could stretch even further, says Bryan Scott, CEO and chair of research at development company Nanotailor. His company is working with one partner on a carbon nanotube-based material that can be used to produce electricity. This carries particular relevance in solar panels, he

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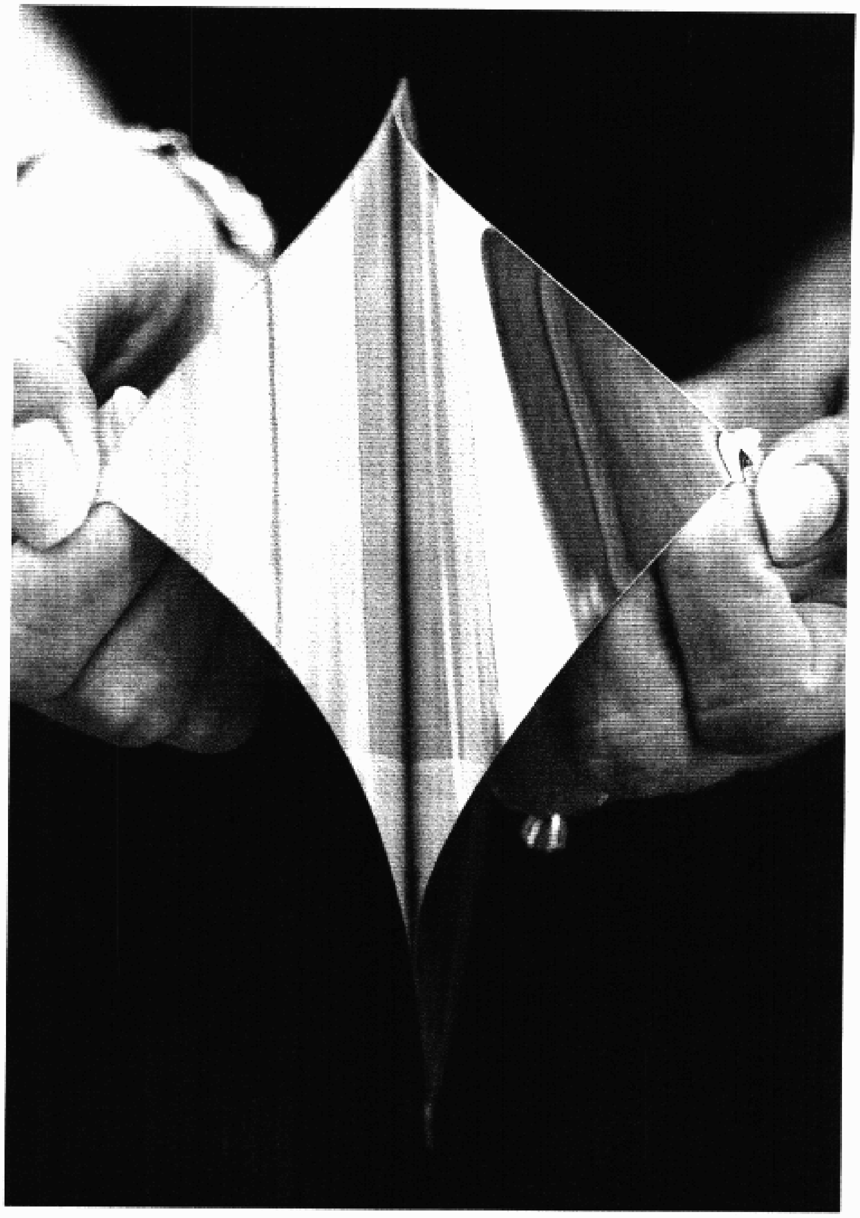
says, which are currently expensive because they have to be created using silicon-based materials in a clean room environment.

"Envision going to a hardware store, buying a bucket of material and spreading it like a tar on your roof, before putting some wires into it. Now, you have a huge solar panel on your house," he says.

But while such visions are tantalising, getting such materials to market is far from easy. New polymers – mixtures of different materials incorporating specific properties – must be created to suit a particular application. That requires an intimate commercial understanding of the various steps in the value chain, and the stakeholders involved.



"WE KNOW that the raw material has these great properties, but let's say we have a baseball bat that we'd like to put it into to make it lighter and stronger," says Scott. "The company integrating the materials together has to talk with the manufacturer to understand how the new material may fit into an existing production process that may already be churning out hundreds of thousands of baseball bats each minute. And the manufacturer also has to check that these properties can be created at a price that the customer wants," he says. "Incorporating this new material into that production process is a significant part of the whole process."

Nanotailor was formed on the back of a deal with NASA, which licensed a process enabling the company to refine the production of carbon nanotubes, says Scott. He claims that the process can help to reduce the number of chemical treatments needed to extract carbon nanotubes from raw materials, which are initially produced by applying electricity to carbon-based substances. Ultimately, he hopes that this will significantly reduce the cost of carbon nanotubes, and in turn drive down the economies of scale and help to promote the use of the material in the wider market.

Repurposing material to suit different applications is an integral part of the materials discovery process, explains Sian Bronock, materials business manager at Oxonica. The company took five years to bring a product called Optisol to the market. Based on research done at the university, Optisol is a UV absorber that has been doped with a chemical additive to stop the material breaking down and becoming ineffective (as often happens with traditional sunscreen solutions). Originally developed for personal care, the material has since been adapted for use in other applications, such as UV protection coatings for glass and paints.

But as with most material discovery processes, it requires people with many different skills for the material to be developed in the first place. "We are a very cross-disciplinary company. We have chemists, physicists and bio-chemists and you have to share knowledge from different areas to help you create these solutions," says Bronock.

While Scott works at refining the materials integration and production process and Bronock works on finding new markets for materials, Graeme Purdy is focusing on speeding up the initial research phase for materials science. Purdy co-founded a spin-off company from Southampton University called Ilika, which has developed a device to speed up the prototyping of various material substances during the early phase of their development. Rather than selling the device, the company is using it to provide a prototyping service to researchers.

"Scientists have traditionally taken a sequential approach to experimentation," he explains. Scientists would produce a sample of a proposed material that wouldn't perform as they had hoped, and would then have to go back and redo everything while tweaking certain parameters. "What this means is that the length of time to turn a new material from a twinkle in a scientist's eye into a prototype could be 10 years. These days we don't have the patience for that," he says. Instead, Ilika has automated the tweaking process so that thousands or even tens of thousands of different samples can be produced simultaneously.

Perhaps that could have helped e-Ink, a Boston-based company formed by MIT research in 1997. The company was trying to develop an electronic paper substance as an alternative to traditional LCD computer displays. The problem with today's flat screens is that they use electricity at an alarming rate. To maintain an image, the screens require a constant flow of power, and many of them also need power for the backlights that enable people to read the display.

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E-INK took several years to develop an alternative display technology that only drew power when the image on the screen changed. The technology uses a series of tiny microcapsules containing a collection of microscopic black and white particles suspended in a clear fluid. When a positive or negative charge is applied to the microcapsules, the black particles rise to the top and white ones fall to the bottom, or vice versa, creating a black or white dot on the display. The result is a monochrome display that needs hardly any battery power, and which has a higher resolution than traditional computer displays.

The microcapsules can be printed on to a variety of different materials, says Dave Jackson, director of marketing and planning at e-Ink. "Our material is very flexible. There are eight different companies or consortiums around the world developing flexible screens," he says, adding that one company – Polymer Vision – recently announced the Readius. The mobile computing device has a roll-up display that unfolds from its body like a piece of paper.

With several other companies working on electronic paper, it is easy to envisage a future when displays can be printed on materials such as fabric, paving the way for shirts that tell you your body temperature, backpacks that tell you the time, or perhaps hats that display a message when you are near a WiFi hot-spot.

Some materials, such as Optisol, are based on using well-understood chemicals in new configurations to achieve new behaviours. Others, such as polymers based on carbon nanotubes, are using much newer technologies (the basic technology behind nanotubes was only discovered in the early 1990s). But all of these material advancements affect us in ways that we may never even be aware of, and enable us to do things that we take for granted, but which our ancestors would have marvelled at.

The most promising aspect of materials discovery is that as we develop more materials, we can use them to cumulatively advance our research in new and interesting ways, ultimately increasing the pace of development. Today's world may differ markedly from the world that our parents inhabited, but the world that our children and grandchildren inherit will bear even less resemblance to the one we know today. ■