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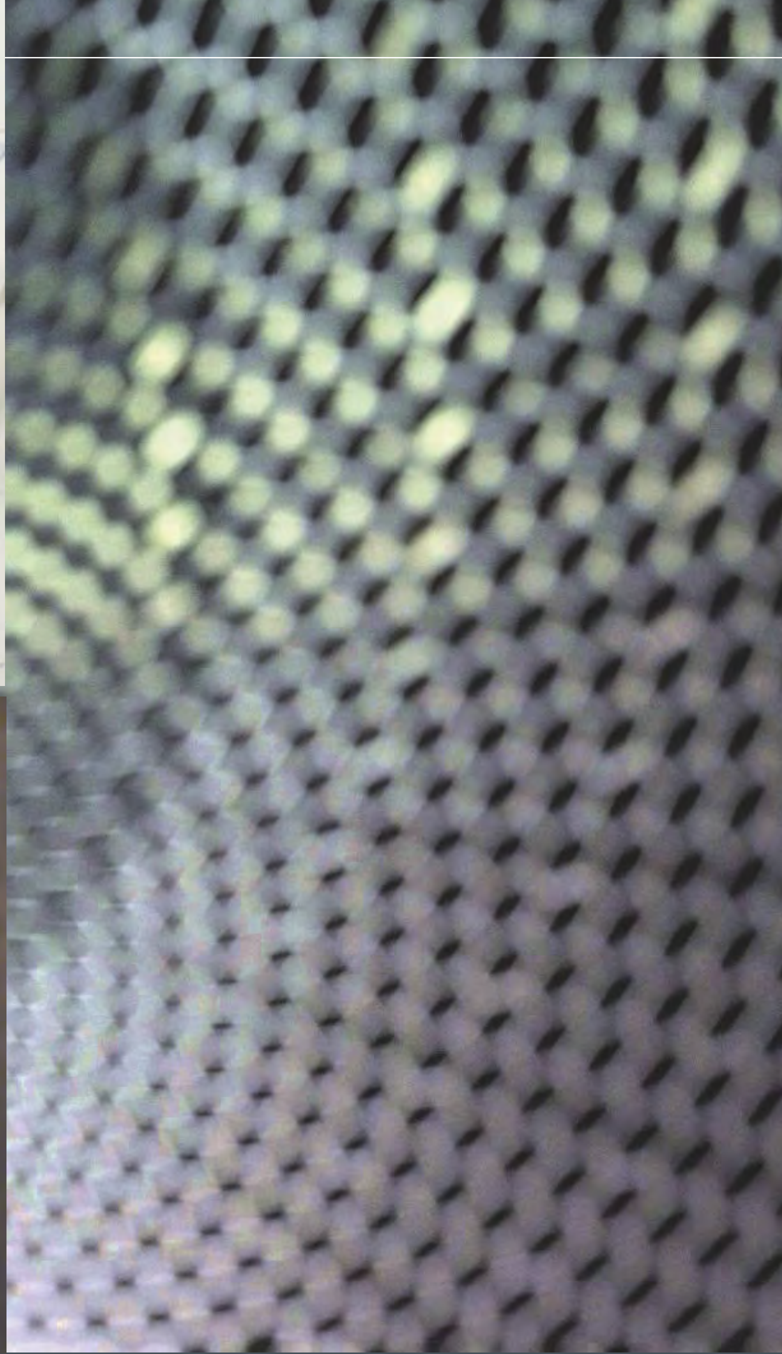
The future has "materialised"

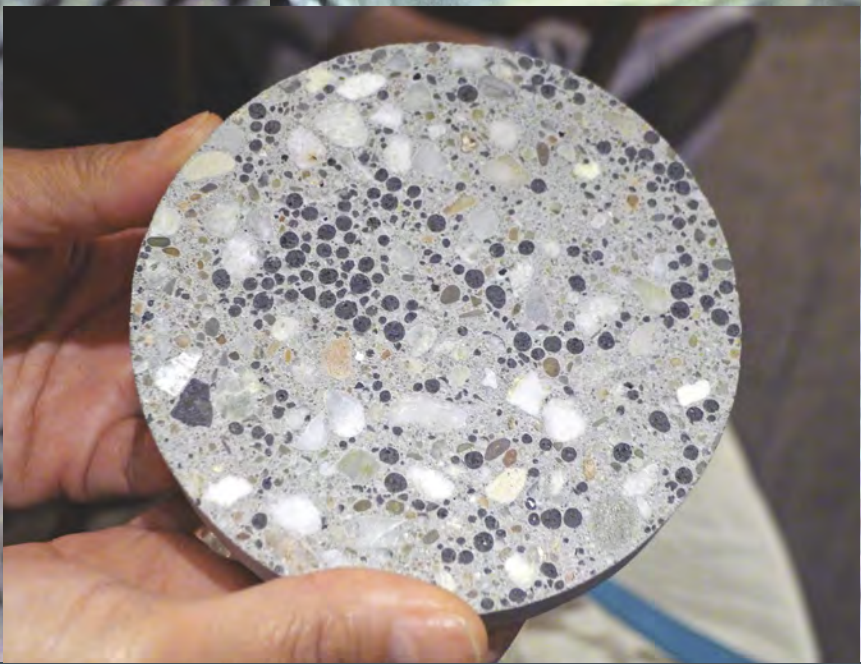
Hydrophobic supermetal, aerographite, graphene, bullet-proof polymers, self-healing bio CONCRETE and bone polymer are six promising materials worth studying. MaDec, the design materials research centre of the Milan Polytechnic, looked at them and saw great potential.

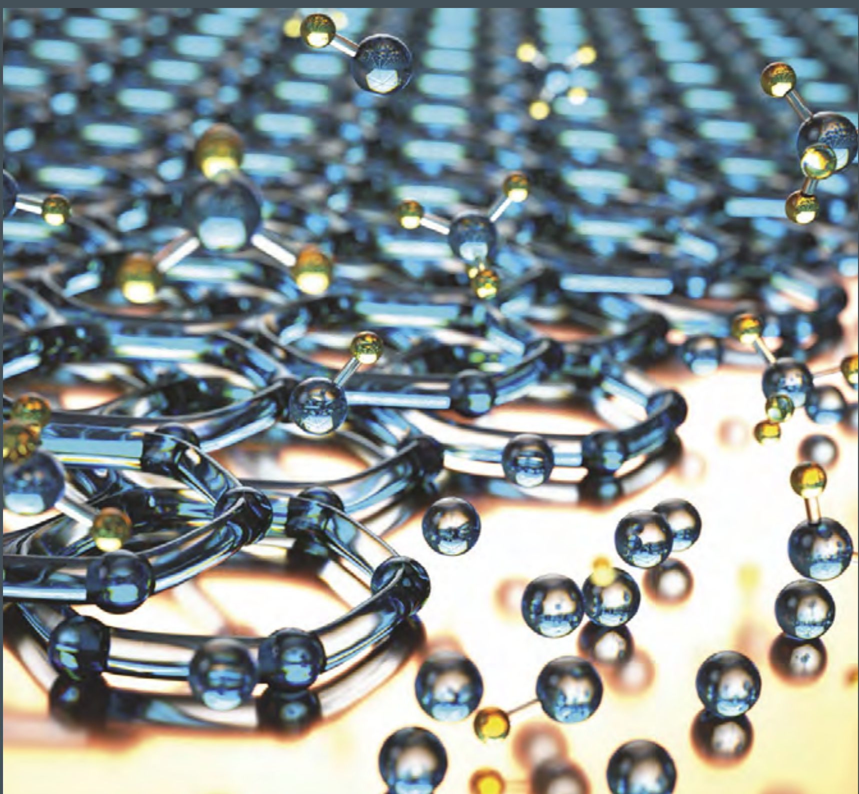
Materials actively affect the design of new product families that will change the way we live. MaDec's aim and responsibility here are to stimulate those seeking new design instruments who want to revolutionise the way of conceiving the function of traditional objects.

The hydrophobic supermetal

From the United States comes the super-water repelling metal produced by Chunlei Guo and Anatoliy Vorobyev, scientists at the Institute of optics of the University of Rochester in the USA. Water repellency, or water impermeability, is the well-known but obsolete property these scientists have developed. They succeeded in developing a metal, or rather a surface treatment for it, that not only makes it impermeable to water but also repels water (if water drips onto the material, the drops bounce away before they can wet it). In their study published in the Journal of Applied Physics the two inventors explained that the effect is obtained physically using laser technology (engraving particular textures with dimensions of around 1 millionth of a millimetre) that is different from old and traditional chemical surface coating methods because it lasts forever



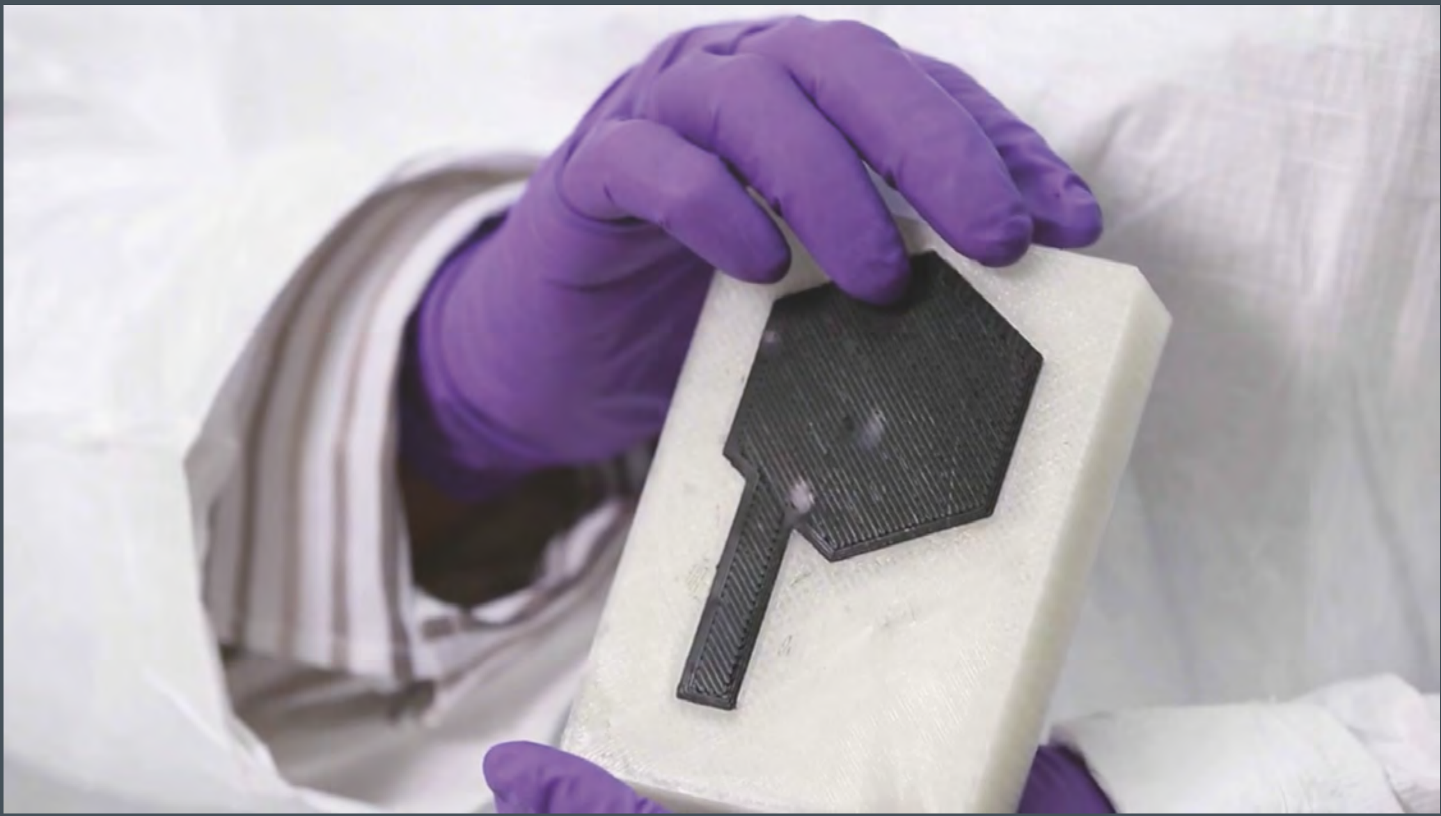




Bacillus bacteria are inserted directly into the concrete while the calcium lactate is contained in capsules that open on contact with water.

The mechanical method for obtaining sheets of graphene known as the “scotch-tape” method.

Atomic diagram of carbon in graphene formation.

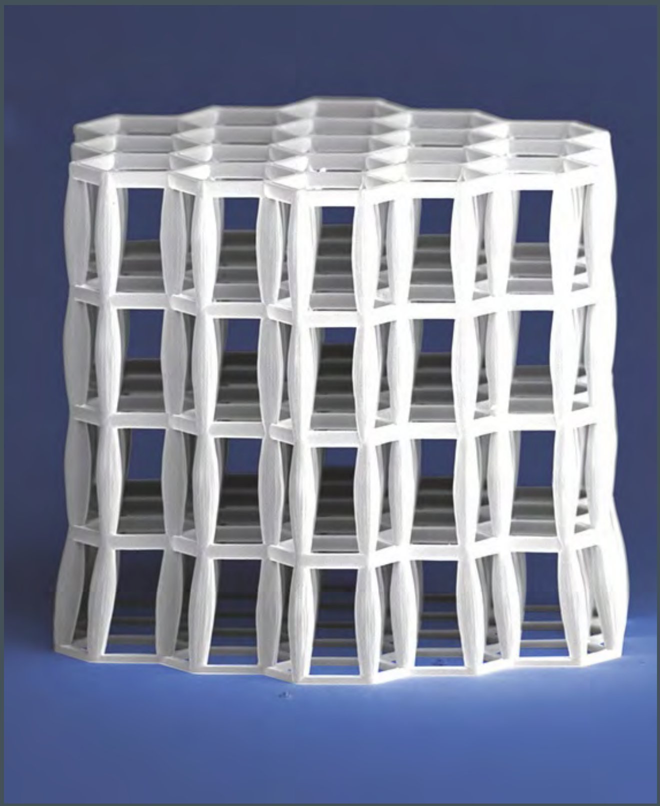


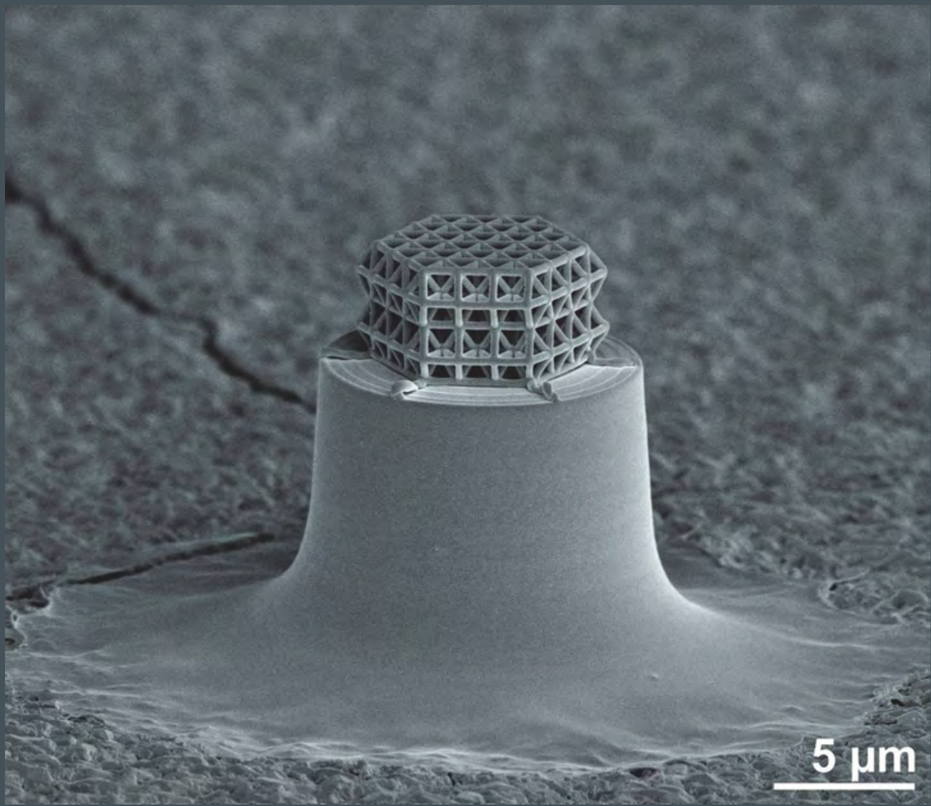
Product obtained using filaments of carbon printed in 3-D.

on the material. The scientists obtained this material by treating an alloy of platinum, brass and titanium with an ultrafast laser beam (with a speed of a few quadrillionths of a second). This technique alters the structure of the metal on a nanometric scale, creating a series of invisible grooves and ridges which can, depending on their layout, make the material super hydrophilic (able to absorb and retain water on its surface) or super hydrophobic (repelling the water completely). The laser creates on the surface of the metal micro and nano structures that in addition to repelling the water make the metal able to absorb solar rays – this leads us to think right away of applying these metals to solar panels, increasing their efficiency and self-cleaning properties. Not even Teflon is this effective compared with this innovative metal. In fact with Teflon a slope of 70° is required to allow the water to slide off, while with the new metal just 5° are enough. The water not only bounces off the surface but takes with it what it finds there, from dirt to dust, leaving it clean and dry. These particular characteristics make this metal suitable for infinite applications: to avoid the formation of rust on ice especially, for example, on the fuselages and wings of aeroplanes, as a more effective nonstick coating for pans, smart phones, tablets and televisions, or the bodywork of cars, to increase the efficiency of rainwater gathering in developing countries or in health structures to prevent illnesses due to poor cleaning of the environments. And just think of the boats sector… All that remains to be done is to overcome the time factor: etching one square inch of metal takes an hour. So the researchers are working on speeding up the times and looking at applying this method to nonmetallic surfaces.

Aerographite

This is carbon foam, the lightest in the world: it weighs 0.2 mg/cm³. German researchers at Kiel University and the Hamburg University of Technology have invented the lightest material in the world: 75 times lighter than polystyrene and six times heavier than air. A kilogram of this material has a volume of 5 m³. Aerographite is a black material made up of a nanoscopic weave of 99.99% air and 0.01% of hollow carbon nanotubes. Besides being an ultralight material it is also super elastic, opaque, ductile, water repellent, can absorb most light rays and is an excellent conductor of electricity. This material also has a special property, resilience: it can support tension of 1000 times its weight and can be compressed up to 95% without changing its form and structure, returning to its original dimensions (a property related to the interconnected structure of the porous tubes of which it is made). It is made starting from zinc oxide, which is transformed from a powder to crystals by heating it to a temperature of 900°C. This crystal functions as a skeleton, since it is made up of a series of structures known as tetrapods,





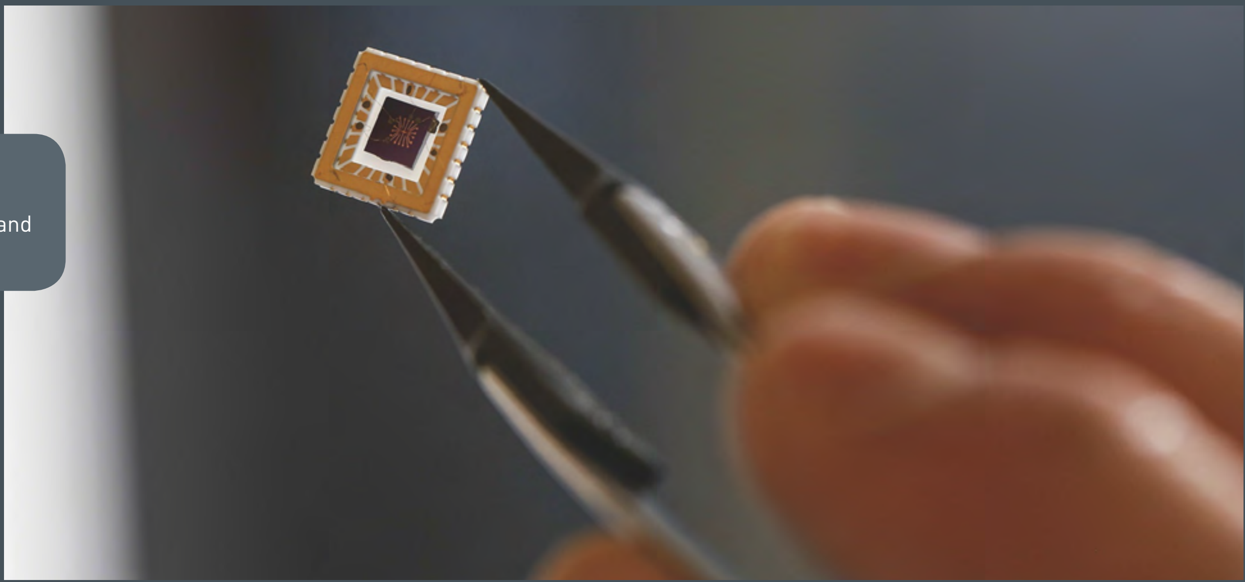
which provide the base for forming the network of nanotubes in aerographite. The crystal is then placed in a reactor to synthesise the material in a process known as chemical vapour deposition. Carbon is sprayed in a gaseous form leading to the deposit of thin layer of graphite, often only a few atoms thick, on the tetrapods of the crystal. At the same time, hydrogen too is injected into the reactor and, when it reacts with the oxygen in the zinc oxide, it liberates vapour and zinc in a gaseous form. It crumbles the skeleton around which the graphite has been deposited and creates the new material, which may be more or less porous (and so more or less light) depending on how the chemical processes carried out. Aerographite has characteristics that make it ideal for being integrated in the electrodes of lithium ion batteries, making them ultralight for use in mobile devices and electric cars. Its network structure can be exploited for purifying air or water. Its resistance would make it useful in environments subject to strong vibration, for example the electronic components of aeroplanes, probes, satellites and telescopes.

Graphene

Graphene is a nano material made up of a single layer of carbon atoms with an ultra-thin two-dimensional crystal structure. This innovative "two-dimensional material" is the basic structure used to build the five allotropic forms in which carbon is found in nature (diamond, graphite, fullerene, carbon nanotubes and graphene) and is seen as the "wonder material". In all five structures each atom of carbon is bound to the other three forming a series of planar structures, held together by weak intermolecular forces. Besides being thinner than existing materials, it has strengthened rigidity superior to those of steel (by 100 times) and an electrical conductivity superior to that of any other substance (from 10 to 100 times that of traditional conductors). All this is possible thanks to the strategic layout of the carbon atoms due to the strong bond between them and the flexibility of this bond which allows it to be stretched by up to 20% of its original dimensions. The structure of graphene allows electrons to travel long distances without meeting disturbance, thus permitting conductivity far superior to that of normal conductors. And it was not discovered long ago. Konstantin Novoselov and Andre Geim of the University of Manchester showed in 2004 that a single layer could be isolated and transferred to another substrate and that it was possible to effect an electrical characterisation. For this they receive the Nobel Prize for Physics in 2010. The isolation of the sheets of graphene was initially achieved with a not very elaborate method, using a mechanical technique known as the "scotch tape" method, using adhesive tape to remove fragments of graphite from a crystal. The only unfavourable side of using this material lies in the extraction process.

A hexagonal structure can withstand overall loads of 550 kg/cm².

The Nanoscribe 3-D printing system uses a polymer that reacts when exposed to light and laser that can be focused on a point with the help of lenses.



Microchip combining graphene and silicon.

The two main methods of synthesising graphene, not suitable for industrial production, are mechanical and chemical preparation. Yet the uses of graphene are innumerable, from high-frequency electronics to the construction of touch screens, solar cells, flexible sensors and high-performance composite materials. The first of the many applications of graphene, which will be launched on the international market, is its use for making flexible touchscreens that can be printed on sheets of plastic since it is transparent not only to visible light but also to infrared and ultraviolet. Solar panels currently being developed have photovoltaic cells sandwiched between two layers of graphene. Light passes through the layers and strikes the photovoltaic cell, generating electricity that is then carried by the graphene. Plastic materials in which graphene or other nanostructures based on it has been inserted show extraordinary improvement in several properties such as electricity conduction, thermal stability, elastic modulus or resistance to stretch. Graphene can also be used as a super condenser to accumulate electrical energy produced by solar cells. Finally its particular molecular structure makes it possible to create holes of any size on its surface, creating a kind of molecular sieve or filter membrane that can act as a barrier against liquids and harmful gas (useful, for example, for desalinising water). Drinking water for millions in developing countries, strengths, flexibility, lightness and conductivity of fabrics, ultrafast charging of mobile devices and electric cars, targeted administration of drugs, ultrasensitive sensors that can detect minuscule dangerous particles, sci-fi, faster transistors, new generations of semiconductors and flexible telephones are some of the many applications of this special material. Andre Geim, one of its discoverers, speaking of the uses of graphene, said: “I don’t know. It’s like giving a piece of plastic to someone a century ago and asking him what you can do with it. A bit of everything, I think”. All you need is creativity to achieve added value.

The bullet-proof polymer

Scientists at Rice University in Texas have created an ultra-thin polymer that can stop a 9 mm bullet and seal the hole behind it, without collapsing or cracking. It has the hardness of glass and the elasticity of rubber (it is made of alternating layers of rubber and glass 20 nm thick), it is strong but also ductile, and absorbs shocks without breaking or folding thanks to its great ability to dissipate energy. When the bullet strikes the polymer the material melts and then solidifies, surrounding and blocking the intruder.

The material could revolutionise traditional clothing and components of means of transport, such as bullet-proof jackets, aeroplane fuselages and the rotating blades of engines, or be used to protect satellites from meteorites and other space refuse.

Self-healing bio concrete

The bacillus bacterium, which is by nature endophytic (it can grow inside rocky and alkaline materials and can survive in hostile environments), could solve once and for all the problem of infiltration in concrete structures. Concrete has always been known for its strength and versatility, but also for its most stubborn defect, its proneness to cracks that threaten its stability. In 2006 a Dutch microbiologist, Henk Jonkers of the Delft University of Technology, helped by Eric Schlangen, a specialist in concrete development, discovered the fruitful combination of the two elements, the bacterium added to the concrete. Although they remain latent for years, these bacteria are reactivated by contact with water that filters into the cracks, producing spores that can survive for decades without food or oxygen and fill the spaces formed by the cracks, blocking the infiltration of the liquid. For this reason it can be defined as bio concrete, a material that can regenerate itself automatically in the case of fractures or cracks, avoiding the problem of infiltration. These bacteria feed on calcium lactate, a crystalline salt (which is easily converted by the microorganism's metabolism) that is present in the concrete mix in capsules of biodegradable plastic that open in contact with water, producing calcium carbonate (lime). In this way the calcium combines with the carbonate ions to form the calcite that seals the cracks. Once the crack is repaired, humidity, water and chemical agents can cause no further damage to the structure. The potential of this technology is huge and could lead to a revolution in the construction industry, though the cost of the material is still too high for the market.

Bone polymer

A material as light as water but strong as steel, with a nanometric structure similar to our bone tissue, has been created by a group of scientists of the Karlsruhe Institute of Technology in Germany, thanks to a new 3-D printer, the Nanoscribe. Jens Bauer, a researcher on the team, used 3-D laser lithography to print the structures using a mix of polymer and ceramics coated with a thin layer of aluminium oxide. The Nanoscribe system uses a polymer that reacts when exposed to light and laser that can be perfectly focused on a small point with the help of lenses. The printer is so precise that the laser touches only the points in which the material must be solidified, making it possible to create materials with complex internal structures. However, this material is not yet sufficiently strong, so it is coated with a film of aluminium oxide 15 nm thick that increases not only mechanical resistance but also the density of the material. The material obtained is better than all natural and artificial materials lighter than 1000 kg/m^3, because it can withstand a pressure load of 280 MPa. Even if for now the objects made can only be produced in micrometre ranges, this material is very promising for insulation, shock absorbers and filters for the chemical industry. These materials were not discovered from nothing, but synthesised starting from known substances. When we think of futuristic materials and their application that today may still seem far-off in time, we must think that in reality everything already exists but in a form that is not yet "recognisable" and to make it recognisable all we have to do is sapiently combine, mix and condense together elements we already know. As Antoine Lavoisier said of the conservation of mass: "Nothing is created, nothing is destroyed, all is transformed". We hope that designers will quickly and with curiosity model these materials to transform them into useful objects, and, who knows, perhaps it will be Madec that stimulates the innovators to give life to new applications.