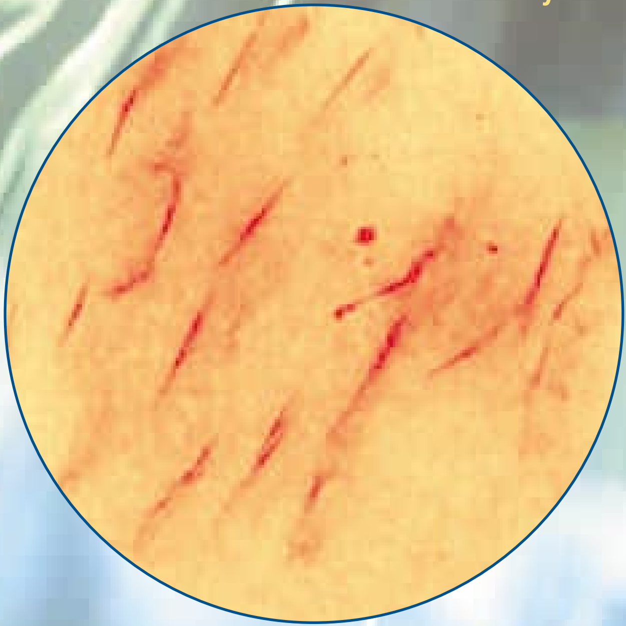
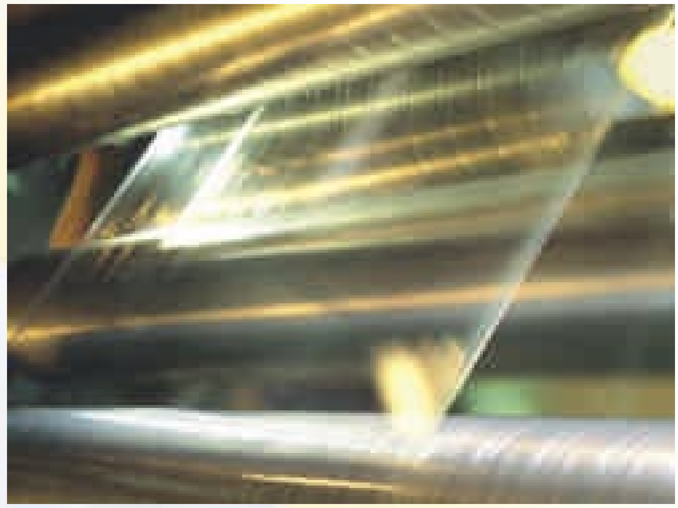
Nanoparticles make Durethan® films airtight and glossy

Securely wrapped

The primary purpose of food packaging films is to protect their contents from moisture, drying out and oxygen. Researchers at Bayer Polymers are now making plastic packaging even more airtight using new nanoparticle technology. The miniature barriers prevent the infiltration of liquids and gases, meaning that meat and cheese stay fresh longer.



Engineer Wolfram Littek checks the quality of the plastic films, because even the minutest irregularities in the distribution of the nanoparticles (inset) would impair performance.



After extrusion, the paper-thin plastic films are fed over deflection rollers before finally being wound.

It really isn't apparent at first glance what nanoparticles have to do with the shelf-life of packaged meat and cheese. However, delving deeper into the world of molecules quickly makes the relationship become clear: miniature silicate platelets incorporated in a plastic the right way can decisively improve the properties of packaging film. Welded airtight, the enhanced films make sure the smell of Swiss cheese doesn't mix with that of salami in the refrigerator unit at the grocery store, and they keep food from going rancid. Researchers at Bayer Polymers have now developed a plastic referred to as a "hybrid system" that is enriched with an enormous number of these silicate nanoparticles. When processed into thin films, the plastic does a better job of preventing food from going bad on the shelf.

Packaging films all look alike on the surface. But their make-up varies just as much as the requirements imposed on their performance. "Every film is specifically adapted to its application and to the package content," explains Dr. Ralph Ulrich from the polyamide research department of Bayer Polymers. Packaging manufacturers exploit the advantages of various plastics, combining them into multilayered systems: three-ply films for simple applications; five, seven or even more layers for tougher demands. Polyethylene is considered to be the plastic of choice for acting as a barrier against water vapor. It frequently lines the inside of food packaging films, making sure that moisture can neither escape and let the cheese or meat inside dry out, nor get inside and make it soggy.

Packaging film with built-in oxygen barrier

The substance most feared among food packaging engineers is oxygen, because it spoils the fat in meat and cheese and turns them pale. Only two plastics were available in the past to prevent these unwanted reactions: inexpensive but somewhat more permeable polyamide 6 for less sensitive foods, and expensive but more airtight ethylene vinyl alcohol (EVOH) for sensitive products. "Film manufacturers can combine the different barrier plastics as needed," explains engineer Wolfram Littek from Bayer Polymers Business Development. The new film material with nanoparticles unites the advantages of these two common plastics: it is inexpensive but still very airtight; not as good as EVOH, but much better than simple polyamide 6.

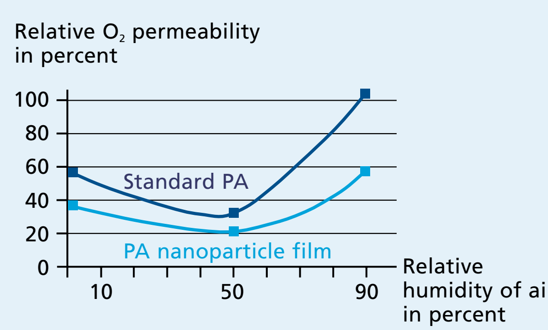
The embedded particles – which are only a few nanometers thick – prevent gases from penetrating the film, and moisture from escaping. With a maze-like arrangement in the plastic, they act as barriers, making it difficult for unwanted substances like oxygen to pass through the packaging. They increase the distance the gas molecules have to travel on their way through a film; oxygen molecules literally have to zigzag around the silicate platelets. This effect is so strong that it cuts the permeability of the film by half compared to conventional polyamides. "The plastic is most airtight at fifty percent humidity. Its permeability rises again in drier or moister air," Ulrich explains.

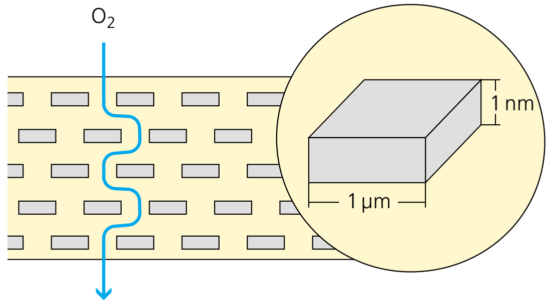
Silicate nanoparticles keep foods fresh

The silicate platelets not only make the new plastic – which has been named Durethan® KU 2-2601 – more impervious to gases, but also enhance its gloss. "The minute particles influence crystallization of the plastic, acting as nuclei for crystallization of the polymer and thus improving the microstructure of the film. The diffusion of light, which makes a film look cloudy, is reduced as a result," Ulrich says.

Twice as tight

The new hybrid plastic, comprising polyamide (PA) and layered silicate barriers, makes it much more difficult for oxygen to pass through to the packaged goods than conventional films made of PA.





Oxygen detour
Just a few nanometers (µm) thick and one micrometer (mm) wide, the layered silicate particles embedded in the plastic film present a barrier to oxygen. O_2 molecules first have to take a long detour around the nanoparticles before reaching their destination.

Small particles = Big effect

Plastics expert Dr. Ralph Ulrich with the innovative nanoparticle film.

For Durethan® KU 2-2601, the Bayer researchers chose polyamide 6 as the base polymer and chemically modified layered silicates as the nanoparticles.

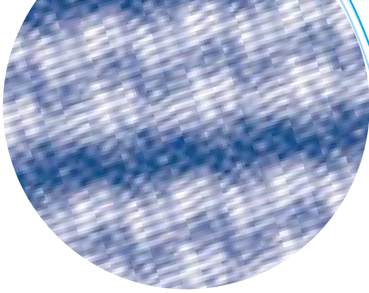
The food industry has been using polyamides for decades to make films, and recently also to plastic-coat paperboard containers. Polyamides are strong, transparent and they protect against gases and odors.

Ingredients: layered silicates and caprolactam are added to the polymerization process to produce the plastic.

Layered silicates comprise stacks of individual silicate platelets held together by metal ions, such as magnesium and aluminum. A few technical tricks are necessary to ensure uniform blending of the polyamide and the layered silicates. A process known as compounding – meaning the kneading of the silicates into the viscous plastic melt – has proved to be rather unsuccessful up to now. It is very difficult not only to separate the individual layers of the silicates, but also to distribute them homogeneously in the polymer "dough". Consequently, the Bayer researchers mix the silicates in the polyamide base material. This is a great advantage, because caprolactam – the starting material for polyamide 6 – is fluid and quickly penetrates the small spaces in the silicate stack. Once the chemists initiate polymerization of the plastic, the viscous polymer that forms scatters the individual platelets. In order to facilitate diffusion of the caprolactam, the silicates first have to be chemically modified: the metal ions that form strong bonds between the platelets are replaced by an organic acid, which increases the distance between the individual silicate stacks, making them more vulnerable. Bayer obtains the pre-processed raw material from U.S.-based Nanocor, which works closely with Bayer in this field.

The result of mixing is clearly visible under an electron microscope: the silicate stacks are broken down virtually completely and the individual platelets are distributed uniformly in the polyamide. If the plastic is subsequently extruded into a film, the platelets orient themselves parallel to the surface, forming a kind of patchy intermediate layer inside the film. The platelets are extremely thin in relation to their surface area: at a size of 1,000 x 1,000 nanometers, they are just a few nanometers thick. That is a major advantage: "If the silicate platelets were any thicker, we couldn't use them for plastic films, because they would make the films too rigid," Ulrich explains.

The Bayer researcher envisions several potential applications for the new hybrid plastic. "The barrier effect of Durethan® KU 2-2601 is between that



Self-assembled structure
Some molecules, like this strand of DNA, form ordered structures automatically, without any direct, external influence. Scientists exploit self-assembly forces to generate new nanostructures.

of polyamide 6 and EVOH. Durethan® KU 2-2601 would be suitable for applications in which conventional polyamides are too permeable, but EVOH too expensive," Ulrich says.
He thinks the application of Durethan® KU 2-2601 as a plastic coating for paperboard juice containers is very promising. The gastightness of the new Bayer plastic could protect highly oxygen-sensitive package contents, such as orange juice, at much lower cost. But Ulrich is also considering entirely different applications. Chemists traditionally fine-tune the properties of plastics, such as heat resistance and shrinkage, by adding fillers and reinforcing materials like minerals and glass fibers. Thanks to the "nanoeffect", minute amounts of nanoparticles can achieve the same advantages as large quantities of conventional mineral fillers. For example, the addition of just five percent layered silicate particles increases heat resistance, strength and rigidity to the same degree as thirty percent of a conventional mineral. This effect could be exploited in applications for the automotive industry, for example in plastic parts for the engine compartment that have to be highly heat resistant.

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More detailed information on the subject of nanocomposites and potential applications.

"The medical field will benefit most from nanotechnology"

What opportunities and risks are associated with nanotechnology for consumers? *research* spoke with chairman of the Nanotechnology Competence Network Professor Wolfgang M. Heckl of Munich University.

When will consumers begin to notice nanotechnology?

Products will stay the same at first. They will look virtually the same on the outside, except maybe for the label that says "powered by nanotech". But they will offer a great deal more on the inside. When you use toothpaste in the morning, you won't even notice that it's the nanoparticles that are making your teeth especially white. You won't have to clean clear plastic glazing as frequently any more, because the nanostructure on the surface lends it dirt-repelling properties. And once we acquire a better understanding of how to control surfaces and materials on the atomic level, entirely new products will probably emerge that are inconceivable to us today.

How will nanotechnology change people's lives?

All spheres of life will be affected by it, but particularly the field of medicine. That's because life itself is applied nanotechnology. In the course of billions of years, evolution has learned to optimally exploit its materials on the atomic level. Modeled after this principle, for example, are DNA chips for diagnosing diseases, or biocompatible implants. I would venture to predict that no branch of science will remain unaffected by the impact of nanotechnology in the next 50 to 70 years. And that in turn will be good for the man in the street; not only because he can buy more effective products, but also because this technology creates secure jobs for the future.

Will nanoproducts initially be very expensive for consumers?

The opposite is more likely to be the case, because the nature of nanotechnology is to achieve effects with tiny amounts of material. That minimizes our dependence on raw materials and offers advantages in terms of recycling and disposal. The decisive question, however, will be whether we can succeed in replicating the production principles of nature and transferring them to the technical world. Living beings have innumerable nanomotors and nanogrippers. In nature, they aren't produced by machines, but by the principle of multiple, parallel self-assembly, controlled by proteins and genes.

Does nanotechnology also harbor risks for humankind?

Any new technology is associated with risks. Stone age man discovered the hand axe to cut materials, but the tool was also a powerful weapon. But nanotechnology doesn't pose any greater threat than other established technologies. In any case, there's no sense in elaborating frightening scenarios that are just as misleading as naive promises that "the whole thing's harmless." It would be more effective for the development of this new technology to be accompanied by information, education and critical examination.