



Nanotechnology in automotive tyres

Driven by a growing demand for fuel efficiency, combined with strict automotive standards for safety, durability and noise, as represented by the new EU tyre label, automotive tyre manufacturers are continuously seeking to create better and more ecological tyres. For decades, rubber fillers, like carbon black and silica as nano-structured materials, were the drivers of improvements in tyres. Recently, the innovation trend is moving down the supply chain to the material suppliers, with new additives and nanomaterials making their appearance, promising to expand further the 'magic triangle' of tyres. Green tyres have nowadays a market share of about 30% and the demand for tyres of lower rolling resistance, lower weight and superior performance is likely to grow with the market uptake of electric cars.

The drivers for better tyres

As consumers become increasingly environmentally aware, and pressured by rising gasoline prices, together with increasingly stringent fuel-efficiency regulations (the new EU tyre label), rubber manufacturers see a lucrative market for 'green' tyres, which deliver on environmental performance via increased fuel efficiency. Popular green tyre models include Goodyear UltraGrip Ice+, ContiEcoContact 5, Michelin Energy Saver, Pirelli Cinturato P1.

The expansion of the tyres 'magic triangle' has been the holy grail of automotive tyre Original Equipment Manufacturers (OEMs) for decades. The magic triangle is basically the representation of a tyre's performance in three major indicators; rolling resistance/fuel efficiency, abrasion resistance/tyre life, and wet traction/safety. The challenge here is that improving fuel efficiency by reducing friction has a negative effect on safety.

The new EU label for automotive tyres has been a catalyst for innovation, with many OEMs aiming for "A" or "AA" label tyres with enhanced attributes on wet grip, rolling resistance, and noise. The new rules will apply from the 1st November 2012 for all passenger car, light truck, and heavy duty vehicle tyres produced from 1st July 2012. The label is designed to show information regarding the three aforementioned criteria. However, there are other important performance factors that also require high standards including; resistance to aquaplaning, driving stability, handling and steering po-

sition on wet and dry roads, durability, braking performance on dry roads, and capabilities in winter conditions. Some drivers for tyre innovations, as identified by industry executives, include:

- **Consumer:** Safety; Fuel consumption (pushed by rising fuel prices, combined with pressure on personal income by the crisis); CO₂ emissions reduction – eco-sensitivity.
- **Industry:** Availability and cost of raw materials
 - a) the recent steep rise in natural rubber price,
 - b) crude oil price (from which many raw materials for the tyres are made, including synthetic rubber) is rising; interest in biomass-based products; reducing overall carbon footprint of products by downsizing; or improving recyclability.
- **Policy:** EU label (fuel efficiency, safety, noise) drives improvements on these factors, but it does not monitor the tyre's wear behaviour.

What nano-enabled functionalities can offer

A modern car tyre tread typically consists of natural and synthetic rubber, fillers (traditionally carbon black and silica), additives, linkers and reinforcement (steel, textile or nylon cord).

Each area of the tyre may have a different research focus. For example in the body area tear resistance may be more important, while in the tread area rolling resistance and braking/grip may most likely drive innovations.

A successful story of a nanotechnology application in tyres is synthetic rubber and specialty chemicals manufacturer Lanxess, which has been developing a new family of nanorubber nanoparticles, trademarked as **Nanoprene**, aiming at expanding further the "magic triangle" by improving wet grip and abrasion resistance without affecting rolling resistance negatively. Nanoprene is a nanogel particle that consists of pre-crosslinked rubber particles (manufactured by LANXESS in an innovative patented emulsion process) and an outer coating of hydroxyl groups. These groups interact with the polar ingredients in the rubber compound, such as

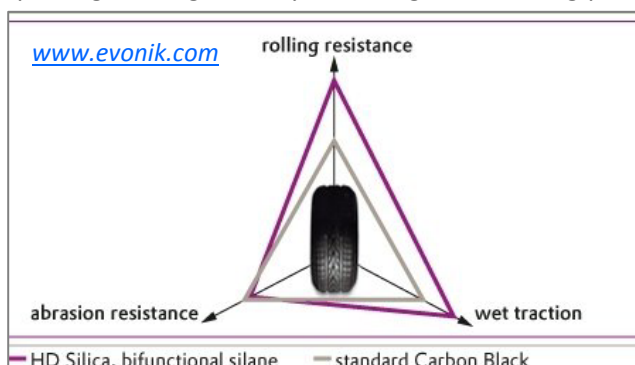


Figure 1: Tyres magic triangle

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silica, via dipole interactions and hydrogen bonding. With particle sizes ranging between 40nm and 200nm, Nanoprene has a large specific surface area, which leads to improved distribution and joining of the silica filler to the polymer matrix.

Different Nanoprene grades can be used to satisfy different requirement profiles for tyres (e.g. summer and winter tyres, green or high-performance tyres) and various tyre components (tread, side wall, carcass, etc.) in line with their glass transition temperature. Lanxess recently began commercial production of the material. Its first customer, Toyo Tire & Rubber, will use it in winter tyres.

Other cases of nanomaterials used in tyres:

- Nanobase: a nano-molecular structure at the bottom of the strong cap of the tyre, improving grip and steering properties, while also reducing heat emission and therefore rolling resistance; used in the Nokian WR A3 tyre;
- NanoPro-Tech (Nanostructure-Oriented Properties Control Technology), a nano coating for the tyre tread, which reduces heat generation; used in the new Ecopia tyre range of Bridgestone;
- Tyres enhanced with CNT (carbon nanotubes) appear to have improved mechanical properties, such as tensile strength, tear strength and hardness of the composites, by almost 600%, 250% and 70% respectively, comparing with those of the pure SBR composites (styrene-butadiene rubber)³;
- A nanoclay containing BIMSM (brominated isobutylene-co-para-methylstyrene elastomer), developed and commercialised by ExxonMobil, shows increased air retention properties that exceed those of halobutyl rubbers by about 50%;
- Lamellar nanomaterial organoclays e.g. Montmorillonite Clay (MMT) developed by Pirelli give the tyre an isotropic behaviour (equal performance in longitudinal and lateral directions) and a better trade-off between handling and comfort, while also exhibiting higher stiffness, better thermoplastic stability and reduced decay;
- Polyhedral Oligomeric Silsesquioxanes (POSS);
- Nano Oxides (Silica, Alumina);
- Carbon Nano Fibres (CNF);
- Graphene (delaminated Graphite); and
- Poly(alkylbenzene)-Poly(diene) (PAB-PDM) nanoparticles (polymer nano-strings)

For more information on nanofillers, please also refer to the ObservatoryNANO Briefing No.21¹⁵.

Impact

Economic/Industry

Most nanotech adhesives probably are used in high performance or green tyres (according to Continental green tyres take up about 1/3 of sales) where the requirements for exceptional characteristics are stronger; however, it could be foreseen that in the future a majority of the tyre products will include at least some nanotechnology in them.

The global tyre market was around €100 billion in 2009, dominated by 5 major OEMs with a combined share of more than 50% (Bridgestone, Michelin, Goodyear, Continental, Pirelli). The global tyre sales grew in 2010 driven by a recovering global economy, with manufacturers reporting sales increase of 12% (Bridgestone) and 25% (Continental) over 2009. The trend is expected to continue in 2011, with global sales of passenger-car tyres forecast to grow 6.1% this year from 2010, while commercial vehicle tyres sales to rise 11% (International Rubber Study Group forecast on Jan. 26.).

This market growth, together with an increasing focus of OEMs in innovative R&D (e.g. Continental reported €1.4 billion investment in R&D in 2010), is likely to fuel more nanotech applications in tyres in the next few years, around 50% in an electric car¹⁶. Reducing rolling resistance has therefore a very big impact of the driving range of an electric car. Ways of improving rolling resistance is by improving the dispersion of the filler inside the rubber or by reducing the heat generated by the friction with the road.

Similar importance has the air pressure of the pneumatics for the fuel consumption; applications that improve air retention would be expected to be attractive for drivers.

Looking at the tyre production chain, we could identify a tendency in where the innovation happens: while OEMs tend to create new rubber mixes and investigate the chemistry in process, the newest nanotech materials seem to be developed and sourced directly from the material suppliers.

With a view to 2020, electric mobility provides for new performance requirements that tyres would need to reach. Tyres cause 20% of the fuel consumption in a conventional fuel driven car and reducing the weight of tyres by replacing or reducing the amount of "heavy" materials by using

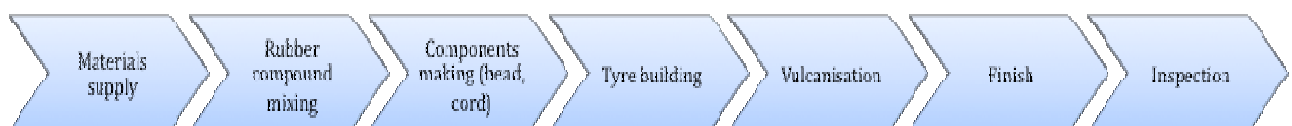


Figure 2: Tyre manufacturing process

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nanomaterials with similar characteristics is also a continuous challenge for OEMs. Less material contributes to the damping effect, which may lead to improved energy efficiency and better handling.

Technology Readiness Levels

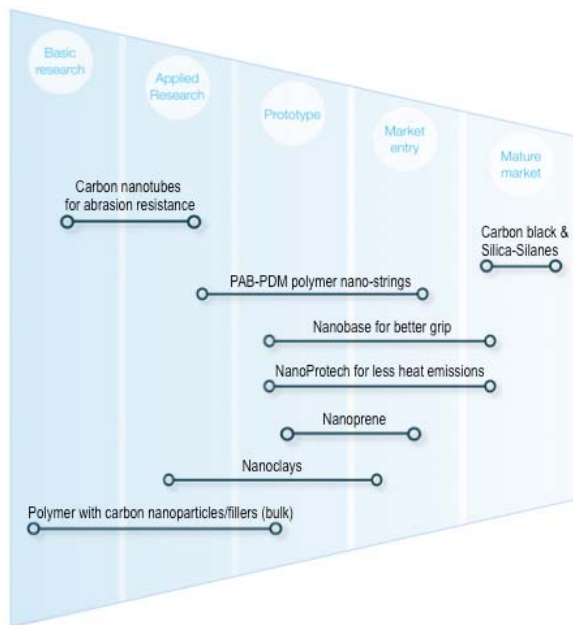


Figure 3: Technology Readiness Levels for nanotechnology developments in automotive tyres.

Impact on European citizen

The term ‘green’ tyres emerged in the tyre industry in the 1990s when tyre engineers discovered that if they used silane-treated silica as reinforcing filler in tread compounds, instead of the traditional carbon black tyres, rolling resistance was improved. A Life Cycle Assessment by the European Association of the Rubber Industry (ERTMA, 2000/2001) determined that ‘green’ tyres reduce the impact on human health and the environment. Studies have shown that ‘green’ tyres provide better traction on wet and icy surfaces and can reduce stopping distances by as much as 15%. Tyre rolling resistance is reduced by up to 20% compared to an equivalent standard tyre, which reduces vehicle fuel consumption by up to 5%. Widespread use of these green tyres could save millions of barrels of oil per year and reduce carbon dioxide (CO₂) emissions significantly¹⁰. As 25% of all CO₂ emissions are generated by road traffic and about 20-30% of a vehicle’s energy consumption can be attributed to tyres alone, measures to improve the rolling resistance are likely to become a top priority¹¹. Nanotechnology could provide the potential to improve the tyres rolling resistance and therefore the increase the cars’ fuel efficiency further.

Additionally, nanotechnologies that improve braking and steering performance can have a positive impact on human safety, a value that, according to OEMs like Continental, is still considered as top priority among manufacturers and a determining

factor of consumer product choice.

Challenges

Environment, Health & Safety

There is reluctance by a number of industry executives to discuss nanotechnology in tyres, in an effort “to avoid any possibilities of misinterpretation and misunderstanding”. This reluctance seems to relate to the argument that the reinforcing fillers used for the production of rubber articles should not be categorised as nanomaterials, since they are practically always sourced and handled in aggregated forms and their dimensions range from approximately 0.1 mm to several millimetres. According to tyre OEMs, the only moment that carbon black and silica are broken down to short-lived intermediates is during the tyres’ vulcanisation process; in this minimal time the reactions and bonds between the rubber, the fillers, and the additives take place in the nano-scale.

According the related ERTMA position paper: “Due to the strength of the bonding forces between individual particles in an aggregate, and between the polymer and filler in rubber compounds, it is not physically or chemically possible to obtain individual nano-object forms during rubber article life cycle. As a result, there is no human or environmental exposure to nano-object forms of carbon black or amorphous precipitated silica used as fillers to reinforce rubber.”

Moving away from carbon black and silica, new materials are starting to be introduced into tyres, which do fall into the definition of ‘nanoparticles’ with sizes smaller than 100 nm. Such materials (Nanoprene, CNTs, etc.) would therefore need to be controlled throughout their lifecycle, from the production until the use and disposal of the tyres.

As in other industries, when applying engineered nanomaterials employees’ safety is a concern to which the precautionary principle should be applied. It is the employer’s duty to prevent exposures which may cause health effects. Unless effective control measures are used there is the potential for exposure to occur during manufacture. Such control measures include always handling nanomaterials in a specially closed vessel or in a liquid solution, preventing the nanoparticles from ‘flying’ into the environment.

In summary, the main environment, health and safety issues relating to use of nanomaterials in tyres are: the potential for exposure to workers involved in manufacturing of the tyres; and the potential release of nanomaterials into the environment during and after use via tyre abrasion or disposal and the impact this could have on human health and the environment⁹.

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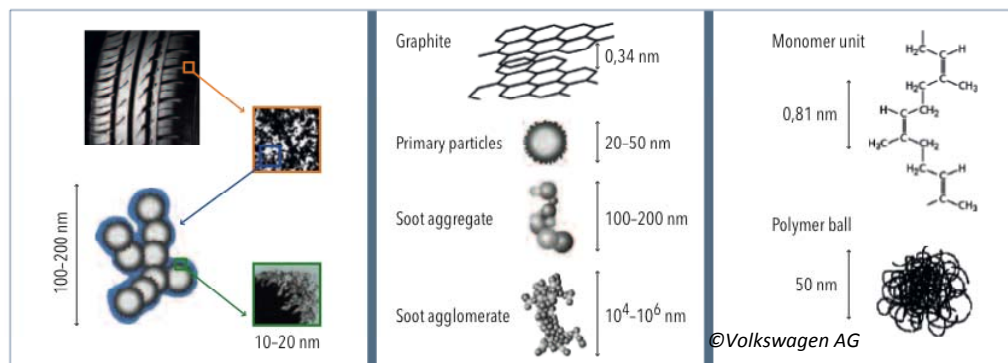


Figure 4: Layout of a tyre running surface with comparison of size between individual components.

EU Competitive Position

The automotive tyre sector in the EU appears to be very strong. Three out of five major tyre OEMs are European (Michelin in France, Continental in Germany, Pirelli in Italy) with a combined global share of about 25%¹². In Europe, 12 tyre corporate companies have production lines in 91 tyre plants situated across 20 European countries¹³. Chemical giants Evonik (Germany) and Rhodia (France) are also based here, while Lanxess in Germany is one of the leaders in nanotech innovations for tyres. With Nanoprene, its new line of rubber nanoparticles, Lanxess hopes to secure a very competitive position in the European and global tyres market.

Outside Europe, Asia and the US also have well-known names such as Bridgestone (Japan) and Goodyear (USA). It is worth mentioning that more than 90% of world natural rubber supply comes from Asia; the three largest producers being Thailand, Indonesia and Malaysia. At the same time, China is becoming the largest and fastest growing market of automotive tyres, driven by a growing trend in personal mobility. China's investment in nanotech research jumped to second place, reaching the equivalent of \$1.11 billion, compared with the US at \$1.57 billion¹⁴.

Summary

- Green tyres using carbon black and silica-silane fillers have been on the market for decades, providing lower rolling resistance and thus increased fuel efficiency.
- Nanotechnology applications can have a role in stretching further all three corners of the tyres' 'magic triangle', meaning rolling resistance, durability and wet grip.
- The new EU tyre label is an important driver of innovations, permitting consumers to choose the better performing tyres in efficiency, safety and noise, while focusing and intensifying the research efforts of the tyre OEMs.
- Many tyre OEMs already use different types of nano-enhancements in their products, such as Continental, Pirelli, Bridgestone, and Toyo.

- Qualities that nanotechnology can improve in tyres include improved dispersion of the filler in the polymer that affects rolling resistance, reduced friction and heat emissions that cause energy losses and rapid wear of the tyre, improved air retention, lower weight by reducing the amount of heavy materials, hydrophobic surfaces for wet grip, and more durable tread for longer life.

Contact information

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