VIAVISION

VOLKSWAGEN GROUP • SHAPING THE FUTURE OF MOBILITY

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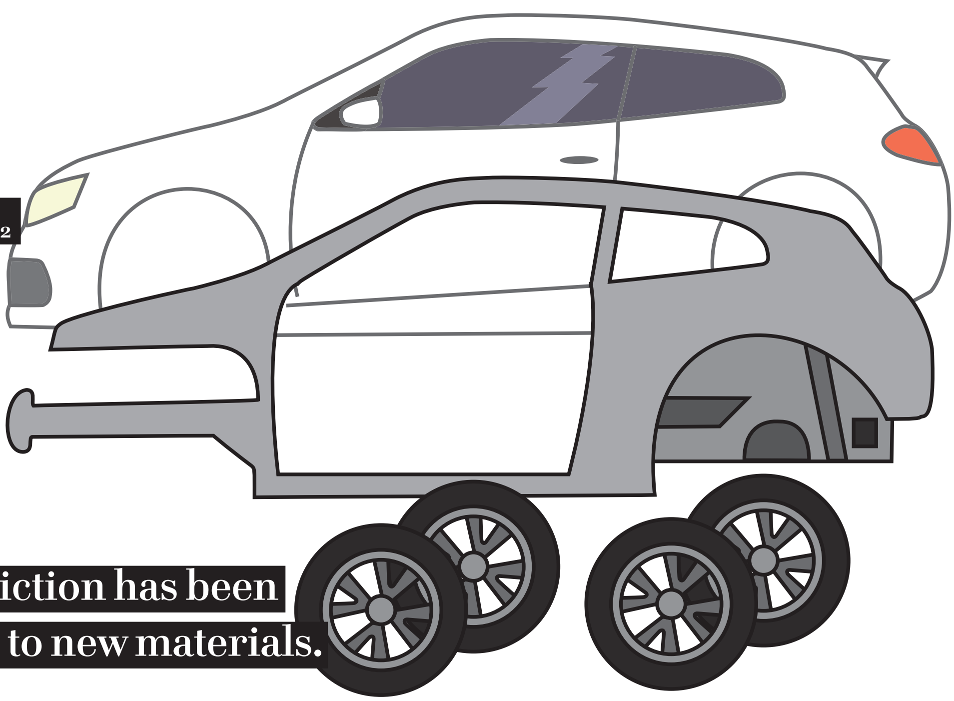
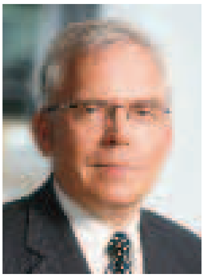
Substance Science
The Potential of Materials



3.5 grams of CO_2 are reduced per car per kilometer if its weight is reduced by 100 kilograms.

30 percent of tire rolling friction has been reduced thanks to new materials.

Editorial



Dr. Ulrich Hackenberg, Member of the Board of Management of Volkswagen Brand with responsibility for Research and Development.

There are many roads to sustainable mobility. The choice of materials used determines how efficient a car is, too. In this edition, VIAVISION explains which materials can help reduce consumption and thus CO_2 emissions. Also, you will find facts about the numerous materials used in automobile manufacture – from exterior lacquering to bodywork and tires.

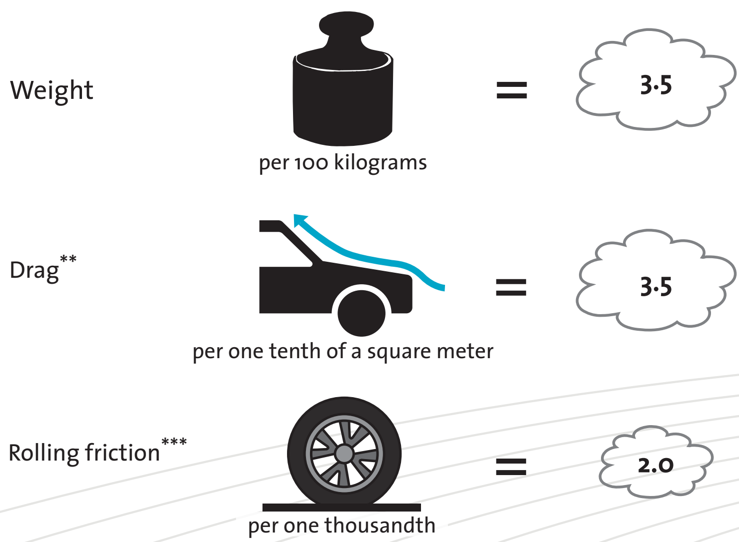
Happy reading.

Hardware Counts

The Properties of Today's Materials

Steel bodywork, rubber tires and a choice between two lacquer colors – the number of materials was rather manageable at the dawn of mass mobility. Today, with new materials being added constantly, the situation has changed. They can help cars gain new properties and reduce CO_2 emissions: Light bodywork reduces weight, new tires reduce rolling friction and, in the future, drag optimized lacquering will render the car more aerodynamic. Additionally, research on intelligent materials that adapt to their environment is on the way: Lacquers, for example, that change color or bodywork parts that soften in the event of rear-end collisions.

The potential of driving resistance related CO_2 reductions:*
(in grams of CO_2 per kilometer)



* All data applies to medium-class vehicles with gasoline engines.

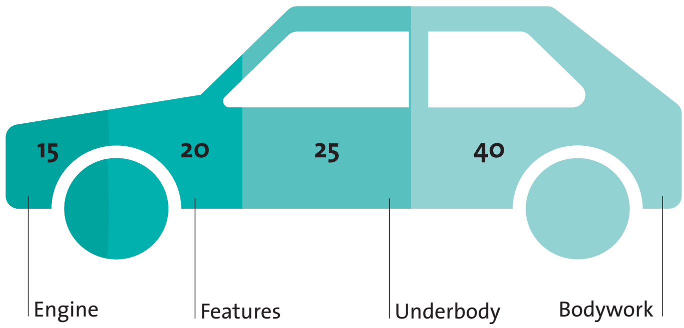
** Drag is the mathematical product of the flow resistance coefficient, determined in the wind tunnel, and the face surface of the car – that is the area that is frontally exposed to the airflow.

*** Rolling friction is measured in thousandths of weight force. The latter is the product of weight and gravity.

Efficient engines are key to reducing CO_2 emissions. Another important parameter is new materials: Rolling friction, as well as the energy costs of acceleration, are reduced when light construction materials lead to the weight reduction of the car. A reduction in weight of 100 kilograms results in 3.5 grams less carbon dioxide emissions per kilometer. Aerodynamic bodywork design helps to limit drag and thereby saves CO_2. Additionally, low friction tires play an important role in reducing the rolling resistance.

Source: Volkswagen AG

Heavy weight bodywork – Car parts and their share of total weight:
(in percent)



The bodywork and underbody account for the lion's share of the total weight of an average car. In this context, it is especially worthwhile to deploy light materials to reduce weight and rolling friction in order to save gasoline and CO_2.

Source: German Association of the Automotive Industry (as of 2011)

Extreme materials

The XL1 by Volkswagen fully utilizes the potential of new materials.

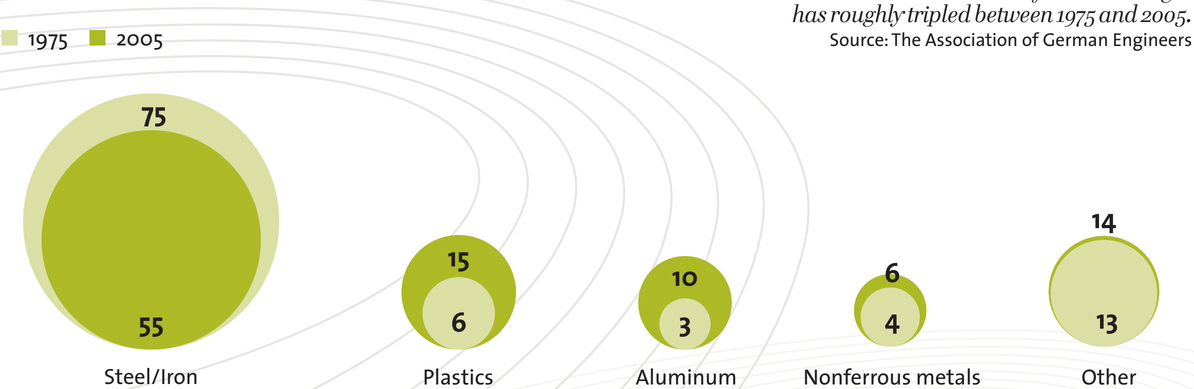
21 percent of the prototype is made of carbon fiber, 22 percent of light metals and only 23 percent of iron and steel. Total weight: 795 kilograms. Consumption per 100 kilometers: only 0.9 liters of fuel. The hybrid engine emits only 24 grams of CO_2 per kilometer.

Source: Volkswagen AG

The car's material mix – Now and then:
(in percent of total weight)

The use of steel and iron in car manufacturing has continuously declined since the '70s. Lighter materials like plastics and aluminum are more and more often being deployed instead: Their share of the car's weight has roughly tripled between 1975 and 2005.

Source: The Association of German Engineers



The Best Protection

Lacquering Is More Than Just Color

100 to 120 minutes is how long it takes to lacquer a car, from applying the first layer of lacquer to drying.

16 to 17 kilograms of lacquer are carried around by a passenger car.

Source: BASF Coatings (both)

Be it the car wash, cat claws or even bird stools – modern lacquers have to endure a lot in every day usage. It is their task to protect the bodywork of the car that is usually made of materials that are susceptible to weather damage, like aluminum and steel, from detrimental environmental effects. Although only seven percent of lacquer production is conducted by the automobile industry in Germany, research in this field is particularly active. The reason for this is contemporary car drivers' high demands: The new lacquers should be scratch-proof and resistant, look like new after ten years and, in the future, maybe even be able to change their color at the press of a button.

Reasons for buying a car:
(in percent)

Design, that is the combination of the form of the bodywork and the color of the lacquer, scored fifth place in terms of buying incentives for car customers – despite the tense economic situation. Source: Study by Aral, "Trends beim Autokauf"

Liquid and powder coating

There is a distinction between lacquers that are made into a liquid before application (liquid coating) and those that are applied as a powder (powder coating). Liquid lacquers are applied to the car parts in dip tanks, while in the powder process the lacquering particles are electrostatically attracted to the material to be colored. They are then melted into an even layer in ovens.

Source: Fraunhofer Institute for Manufacturing Engineering and Automation

Nano lacquer

Nano lacquer is a clear coat that is mixed with minute ceramic particles. Not only does this increase the cohesiveness of the material but it also makes it three times as resistant. The result: The prevention of small flaws, such as those that occur after using a car wash.

Source: TÜV Nord (as of 2009)

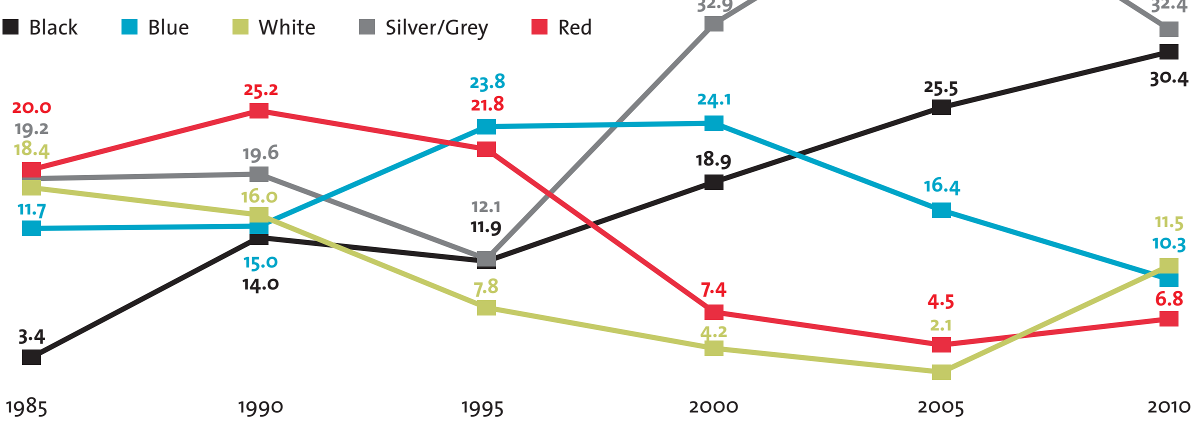
Self-healing lacquer

Is what clear lacquers, which strive to emulate the human skin's ability to heal, are called. The lacquer closes up minor damages in the top coat autonomously. The healing process is initiated either by warmth or due to the damage itself. The lacquer contains microscopically small capsules which burst when damaged and which close up the scratch using the ingredients they contain.

Source: Deutsches Lackinstitut (as of 2011)

Spoilt for color choice – The most popular car colors:
(in percent)

The Germans like it plain and simple: In the past five years, more than 60 percent of them preferred gray or black cars to those that are brightly candy-colored.
Source: Federal Motor Transport Authority



Changing Colors

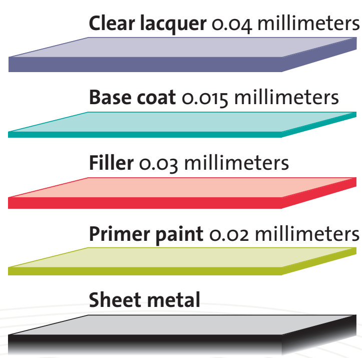
The Lacquer of Tomorrow

There really is only one must-have when it comes to current trends in lacquering: Matt finishes all the way. Whereas high gloss was the most popular choice in past years, this summer it is all about the dull color effect. This mainstream success reflects the costumer's ongoing wish for an individual car look. Research too was inspired by these demands; it is, for example, developing a lacquer that can change color at the push of a button.
A conceivable process would involve mixing in tiny liquid crystals, which can, when given an electric impulse, change its color properties – comparable to a flat screen which can display any given image. While the nano lacquer necessary can be produced already, it is very difficult to apply a coat of this lacquer to bodywork. The conventional lacquering processes and the materials used for bodywork mean it is out of the question at present.

Sources: Fraunhofer Institute for Manufacturing Engineering and Automation; Forschungsgesellschaft für Pigmente und Lacke (as of 2011)

By a hair's breadth – The layers of car lacquer coatings:

On average the combined layers of a car's lacquer are no thicker than the breadth of a human hair. The primer paint protects the sheet metal of the bodywork from corrosion and the filler smooths out surface irregularities, before the actual coloring agent, the base coat, is applied. Finally a coating of clear lacquer protects the whole structure.
Source: BASF Coatings



Auto Light

Lighter Drives Cleaner

It is not sufficient to just make use of more efficient engines and environmentally friendly fuels in order to decrease CO_2 emissions. 100 kilograms of vehicle weight cost around 0.3 liters of petrol, which equates to 3.5 grams of CO_2. Weight reduction therefore is better for the environment as well as less costly for the car owner. Lightweight construction is the solution. It is made possible by new materials. Beside lighter metals such as aluminum, magnesium and stronger steels, there are great hopes for fiber reinforced polymers.

Aluminium is the third most common element on earth, after oxygen and silicon. It is dissolved from the sedimentary rock bauxite by chemical processes.

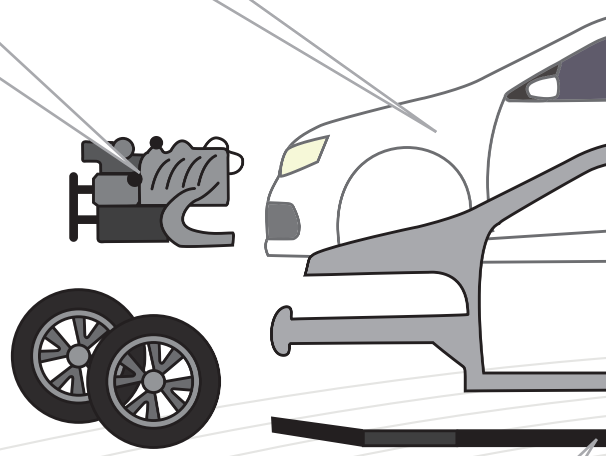
- ➔ Deposits: 7.6 percent of the earth's crust
- ➔ Density: 2.698 grams per cubic centimeter
- ➔ Cost:* 1,920 euros per metric ton
- ➔ Uses: Bodywork, exterior car parts
- ➔ Recycling rate:** 50 to 95 percent

Sources: Frankfurt Stock Exchange (as of July 2011); Gesamtverband der Aluminiumindustrie

Magnesium is produced from magnesium-chloride and magnesium-oxide, which are deposited in rock.

- ➔ Deposits: 1.9 percent of the earth's crust
- ➔ Density: 1.738 grams per cubic centimeter
- ➔ Cost:* 2,380 euros per metric ton
- ➔ Uses: Bodywork, exterior car parts
- ➔ Recycling rate:** 35 percent

Sources: Fakultät Technik und Informatik HAW Hamburg; Federal Ministry for the Environment, Nature Conservation and Nuclear Safety; IKB Deutsche Industriebank (as of July 2011)



Glass Fiber Reinforced Plastics (GFRP) are colloquially labeled fiber glass. Thin glass fibers are embedded in plastics, thus increasing stability.

- ➔ Uses: Underbody, shock absorbers
- ⊕ Advantages: Standardized process of production, high stability at low weight, very resistant to corrosion
- ⊖ Disadvantages: Heavier than carbon fiber reinforced polymers, low stiffness

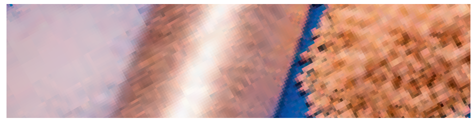
Source: Federation of Reinforced Plastics

Pictures (clockwise): DDP/Volker Hartmann; ThyssenKrupp Steel Europe AG; Fraunhofer IAP/Armin Okulla; cgb Carbon Großbauteile; comon/G. Heckel; Sanderwerbung for Gesellschaft für Metallurgie & Legierungshandel

Steel is produced from iron and a small amount of carbon. New production techniques increase its strength, which allow for materials to be made thinner, without compromising stability.

- ➔ Deposits (iron): 4.7 percent of the earth's crust
- ➔ Density: 7.874 grams per cubic centimeter (iron)
- ➔ Cost:* 670 euros per metric ton
- ➔ Uses: Bodywork, exterior car parts
- ➔ Recycling rate:** 90 to 95 percent*

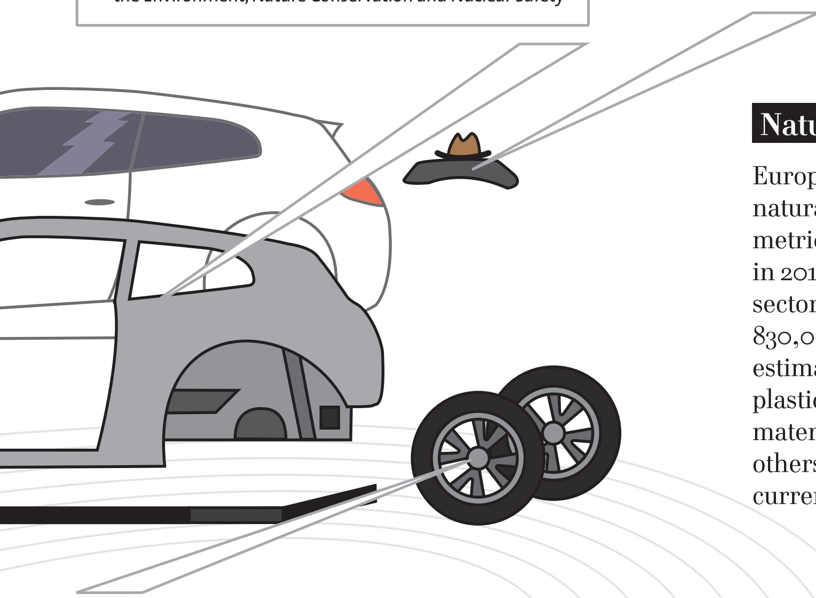
Sources: beschaffungswelt.de (as of June 2011); Fakultät Technik und Informatik HAW Hamburg; Federal Ministry for the Environment, Nature Conservation and Nuclear Safety



Natural fiber reinforced plastics (NFRP) are thin natural fibers made from hemp, sisals, flax, burlap, kenaf, ramie and occasionally wood. They are combined with plastics and thus allow for high stability.

- ➔ Uses: Non-supporting elements like door panels, dashboards and rear shelves
- ⊕ Advantages: Small carbon footprint, light and economical
- ⊖ Disadvantages: Not sufficiently stable for supporting components, not yet recyclable, less corrosion-resistant than, for example, fiber glass

Source: Federation of Reinforced Plastics



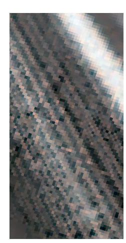
Natural fibers

European industry is increasingly using natural fiber reinforced plastics. 315,000 metric tons of these materials were processed in 2010; around 95 percent by the automotive sector. Consumption could rise to as much as 830,000 by 2020, according to industry estimates. Research on bio-polymers whose plastics component is made from natural materials, namely resins, which, among others, are produced from sunflower oil, is currently being conducted. Source: Nova Institut

Carbon fiber reinforced plastics (CFRP) are colloquially referred to as simply carbon fiber. They are made by embedding thin carbon fibers within plastics.

- ➔ Uses: Bodywork, rims
- ⊕ Advantages: Extremely light with high stability; larger components can be manufactured in a single piece, thus lowering both construction time and cost
- ⊖ Disadvantages: Costly production, not yet recyclable

Sources: Federation of Reinforced Plastics; Fakultät Technik und Informatik HAW Hamburg



* Exchange rate according to European Central Bank, 1 US dollar = 0.7543 euros (annual average 2010).
** Refers to the percentage of a raw material that is introduced into the recycling process.

Tire Evolution

Between Low Friction and Good Grip

Rolling friction

The tire deforms through contact with the road surface and due to the weight of the car, thus creating rolling friction. If the value is large, fuel consumption increases, because the engine has to work harder. A low rolling friction in contrast goes easy on the fuel tank but increases breaking distance because the tires have less grip on the road surface.

Source: German Association of the Automotive Industry

Silica

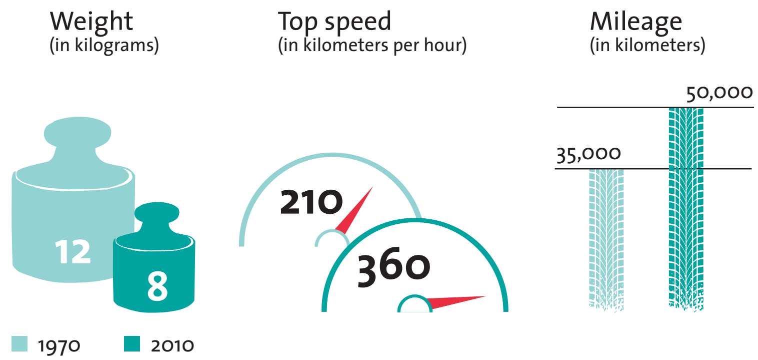
During the production of tires, fillers are applied which give the rubber certain properties. Silica makes it harder, thus lowering friction, whilst also improving grip, thanks to its molecular structure.

Sources: ATZ auto technology; Continental

Carl Benz's drive in the first motor vehicle in 1886 would not have been very comfortable: Its wooden wheels were covered with solid rubber, which made the car jolt over every stone, difficult to brake and awkward to steer. Just two years later John Boyd Dunlop came up with the idea of inflating the rubber tires, consequently improving not only the driver's comfort but also safety.

Tire manufacturers nowadays face the challenge of making car tires less fuel consuming. According to manufacturers, rolling friction accounts for up to 20 percent of fuel consumption. The material that is found in any modern, quality tire is called silica. Thanks to its help, rolling friction has decreased in the past 30 years by 30 percent.

Further, faster, lighter – Car tires in the past and today:



Car tires have become increasingly high performance and much lighter in the last decades. Source: Continental (values taken for standard passenger car tires)

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