End-of-life tyres including nanomaterials

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Francis Peters May 10th 2012

1. Nano materials for tires, today carbon black and silica

2. Project of new nano materials

3. End of life tires

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Although there are no nano particles in the factories which produce the mixtures to make tires, there are reinforcing fillers which are likely to be nano size inside the tires. They are linked in an irreversible way to rubber, and are essential for the performance of the tires.

Explanation…

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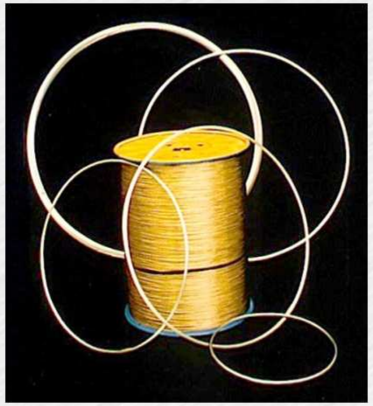
Explanation…

TIRE composition

METALLIC AND TEXTILE

- limit the deformation of the rubber mixes under air pressure and vehicle load,
- allow steering and movement on the road,
- ensure the fixing of the tire to the rim.

Metallic



Textile

TIRE :

A composite architecture based on :

Steel cord

Textile

Bead wire

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TIRE composition

RUBBER MIXES,

- allow to use the air as springiness (impermeability),

- **to absorb the irregularities of the ground (deformability),**
- **to deaden the shocks, to dissipate energy (viscoelasticity),**
- **to resist the various undergone deformations (mechanical cohesion).**

Elastomeres

Reinforcing fillers

Mineral and organic additives

And…

Mixes based on rubber and containing reinforcement fillers

THE INDISPENSABLE MATERIALS

ELASTOMERS

Gives the tire mixtures its source of hysteresis (or dissipation of energy): essential for the performance of adherence and mechanical resistance. Brings the impermeability.

REINFORCING FILLERS

Improve tire strength and abrasion, and increase the rigidity and the hysteresis (heating) of the mixtures.

ANTIDEGRADANTS

Ensure the chemical stability of the mixtures and the constancy of the performances

PLASTICIZERS

Improve mixing of the various ingredients and make possible to adjust rigidities

CURING AGENTS

Give to the rubber mixes dimensional stability and permanent elasticity

ESSENTIAL MATERIALS

RENFORCING FILLERS

They are « furnace » carbon black and amorphous silica.

« Furnace » carbon black: used since the beginning of the 20th century.
World production of carbon black "furnace" = 10 millions T/year

Silica used in the tire = only amorphous silica, never crystalline silica. There are many applications outside of tire manufacture for this silica.
More and more used in tire tread since 20 years to reduce fuel consumption and greenhouse gas emissions.
World production of amorphous silica = 1,4 millions tons including 1/3 for the tire.

Carbon black and amorphous silica are not in the nano particle stage when used in tire manufacture factories.

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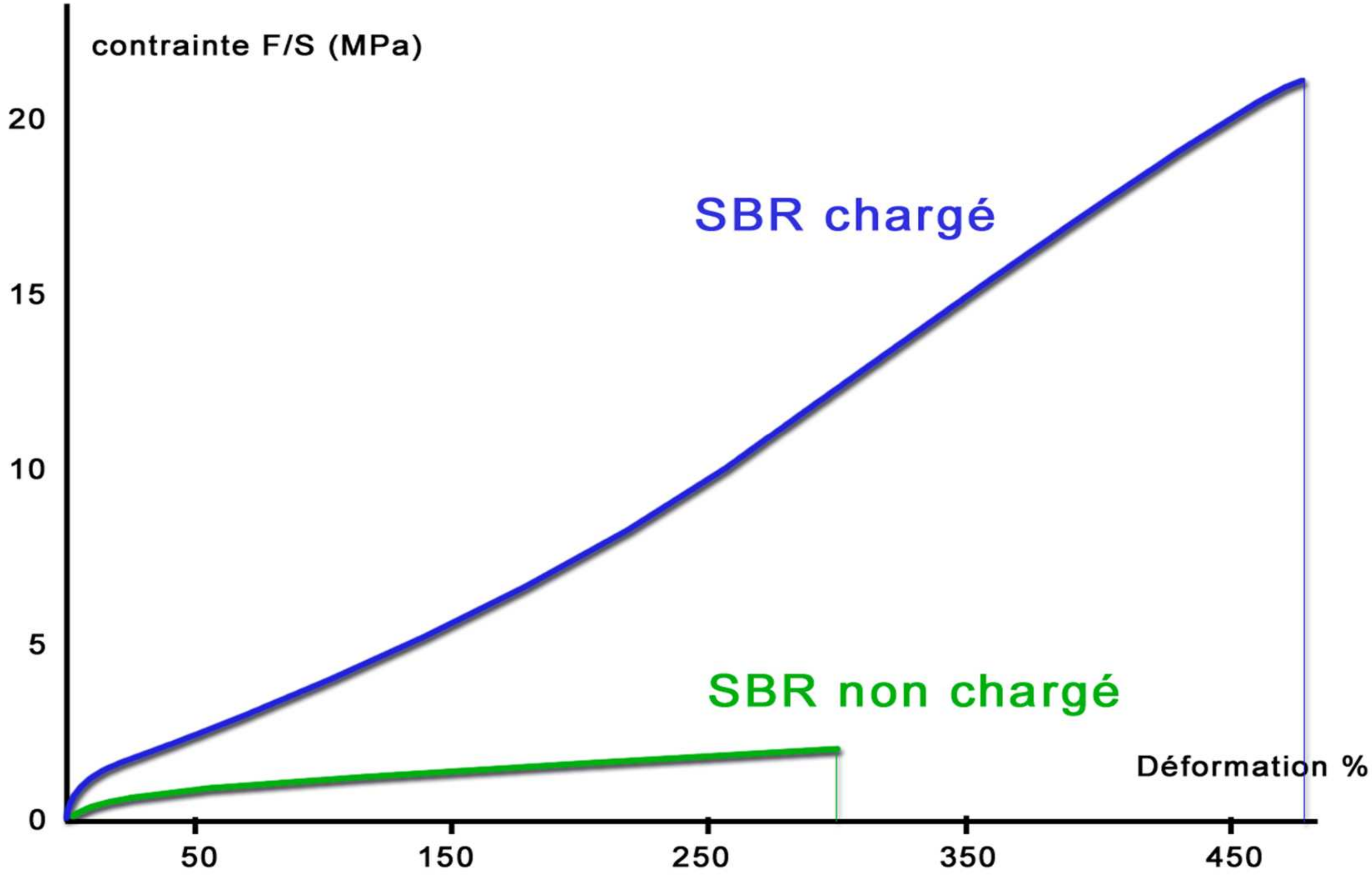
WHY IS A FILLER NEEDED IN RUBBER ?



Increase of modulus, the stress strain curve is standing up, breaking resistance is improved

There is no reinforcement if filler particles are not chemically linked to the molecules of the rubber

PRODUCTION PROCESS AND SIZE OF REINFORCING FILLERS USED IN TIRES

Carbon black

Obtained by incomplete combustion of a feed stock coming from distillation of crude oil with gas

Amorphous silica

Obtained by precipitation of a sodium silicate

Sodium silicate is obtained by melting of sand with sodium carbonate

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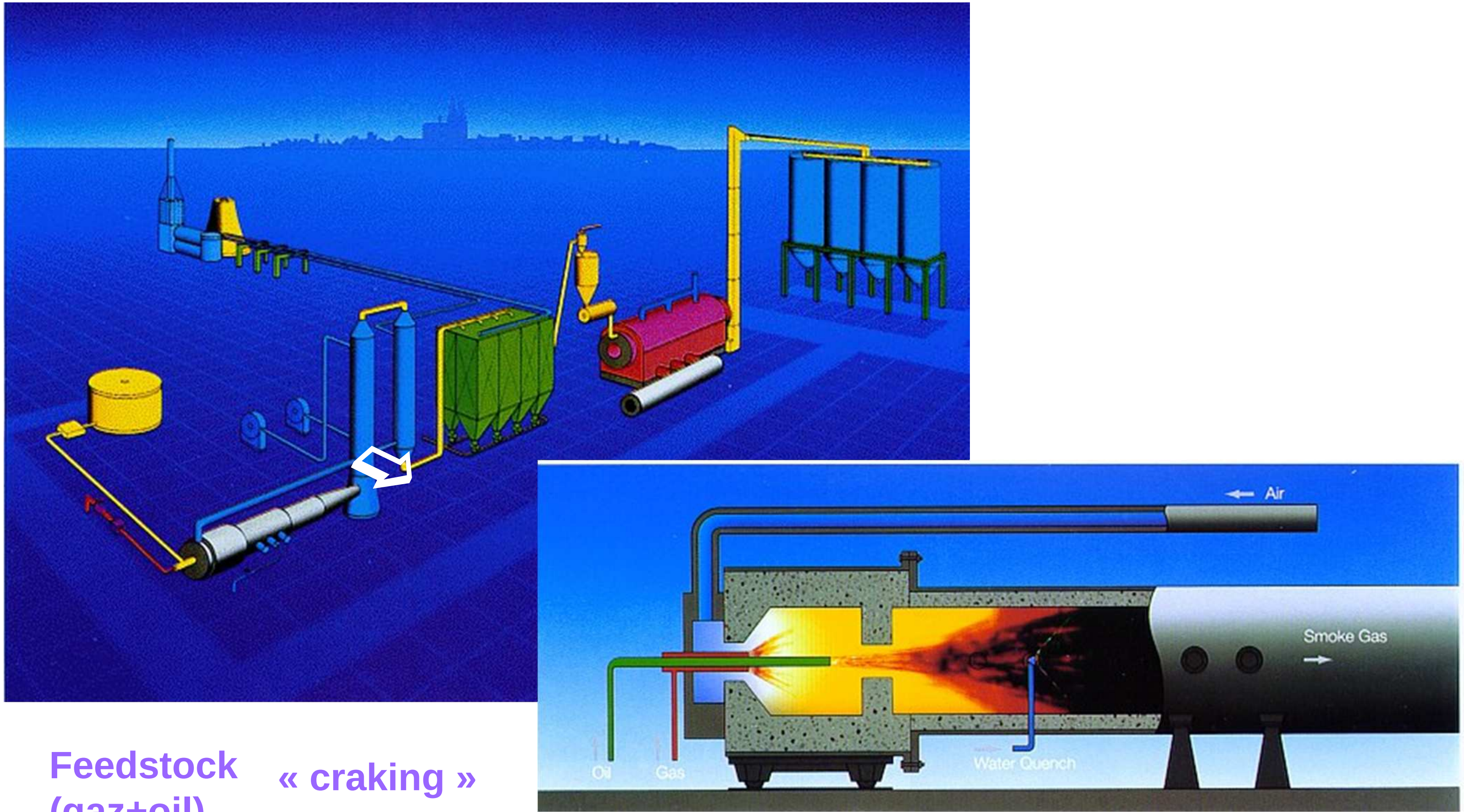
PRODUCTION PROCESS AND SIZE OF REINFORCING FILLERS USED IN TIRES

Carbon black

Applications of carbon black: printing inks, paintings, lacquers, varnished, plastic, fibers, ceramics, enamels, batteries, electrodes, brushes of electric motors, rubber articles, tires…

« FURNACE » PROCESS TO PRODUCE CARBON BLACK



Feedstock
(gaz+oil)

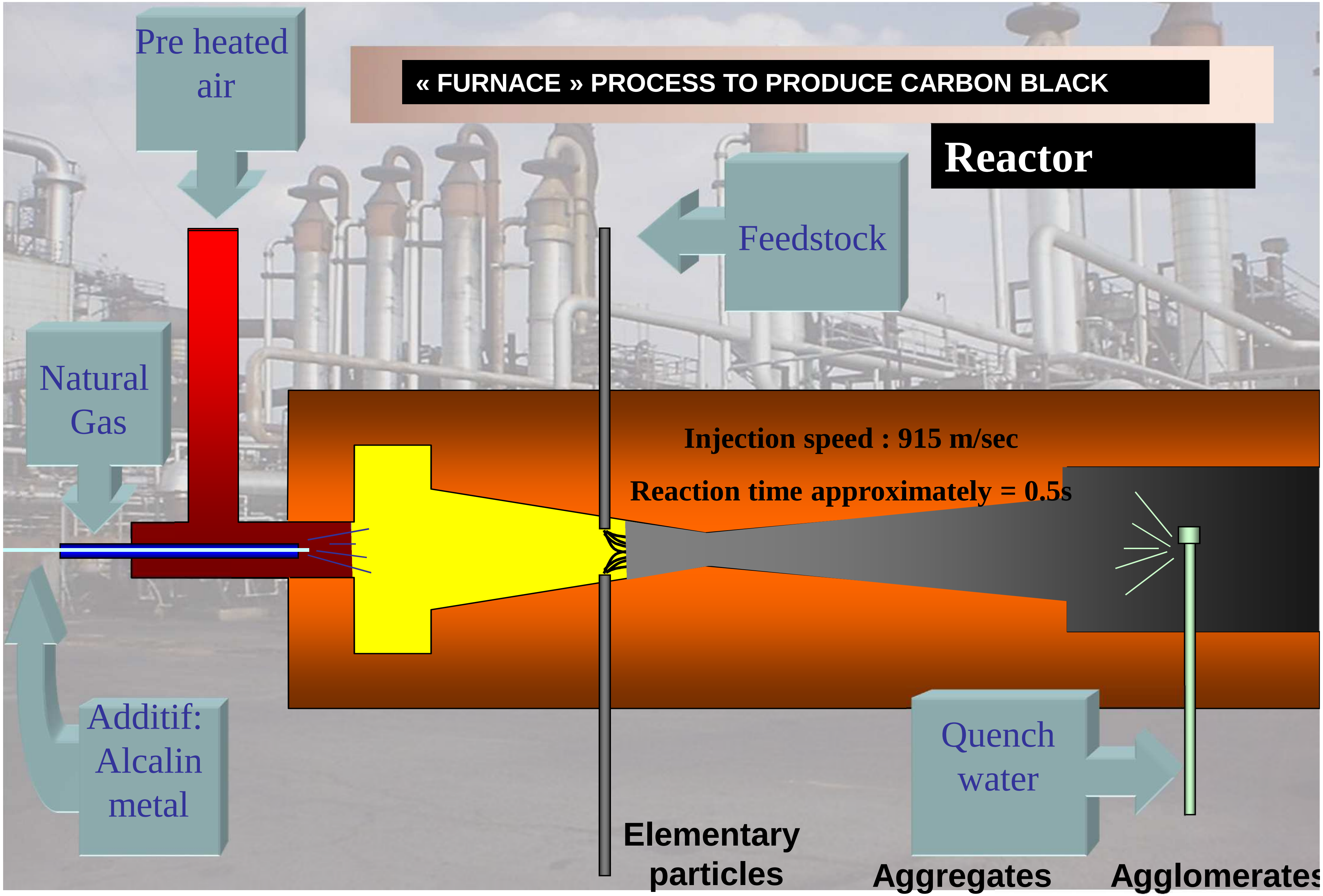
« craking »

Elementary particles

Aggregates

Agglomerates

« FURNACE » PROCESS TO PRODUCE CARBON BLACK



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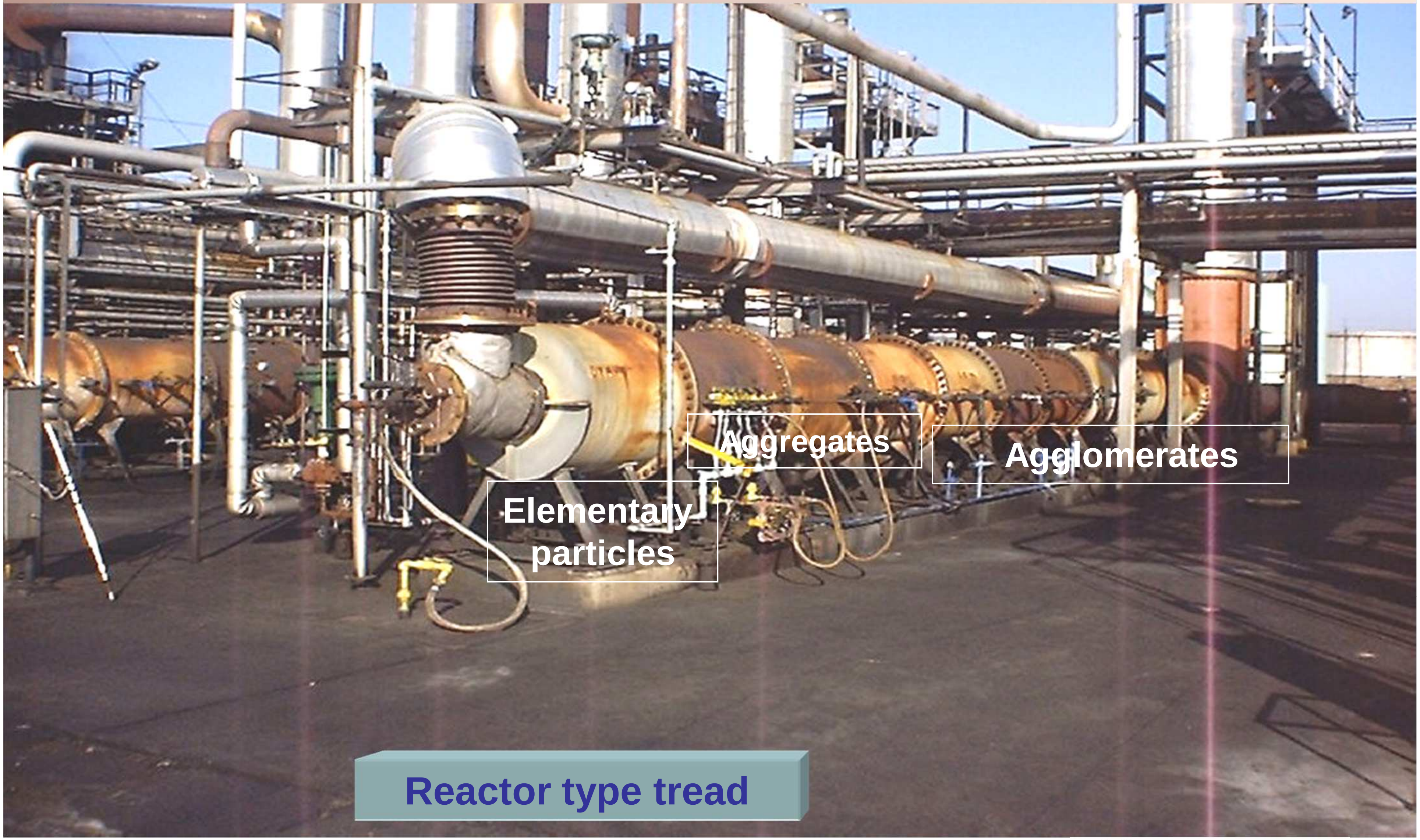
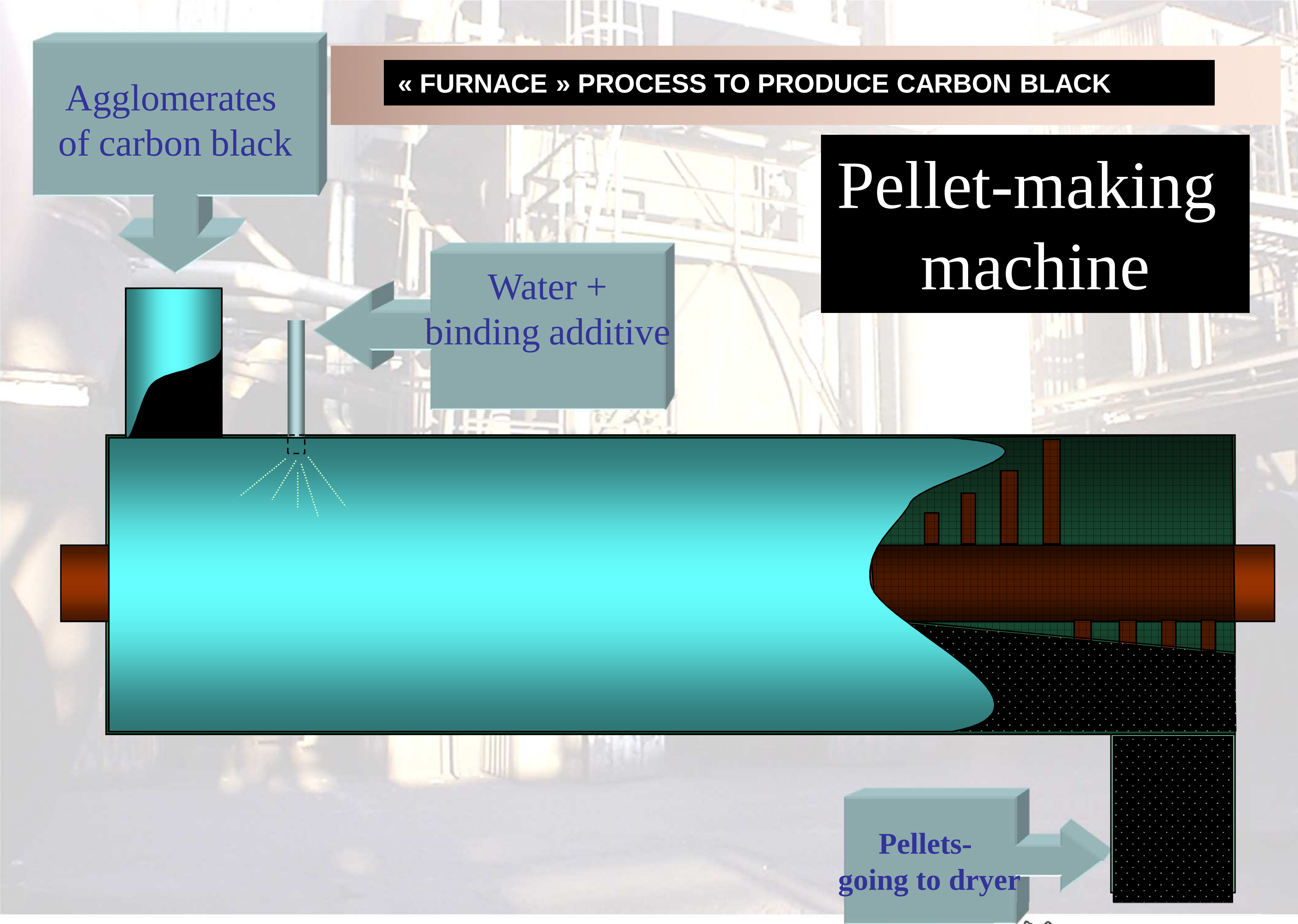
« FURNACE » PROCESS TO PRODUCE CARBON BLACK



« FURNACE » PROCESS TO PRODUCE CARBON BLACK

Pellet-making machine



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SIZE OF CARBON BLACK ALONG THE « FURNACE » PROCESS

At the end of the process : Pellets

Few millimetres

Commercial form of carbon black

A fraction of second after formation of aggregates : the agglomerates

From 1 to 50 microns

May exist in a free stage

Immediately after formation of nodules : the aggregates

from 100 to 500 nanometres
Do not exist in a free stage
After incorporation of carbon black in the rubber they exist being chemically link to the rubber molecules

At the very early stage of the process: elementary particles = « nodules »

From 20 to 110 nanometres

Do not exist in a free stage

CARBON BLACK USED IN TIRE FACTORIES ARE IN THE PHYSICAL FORM OF PELLETS

2 mm

Pellets are measured on millimetre scale

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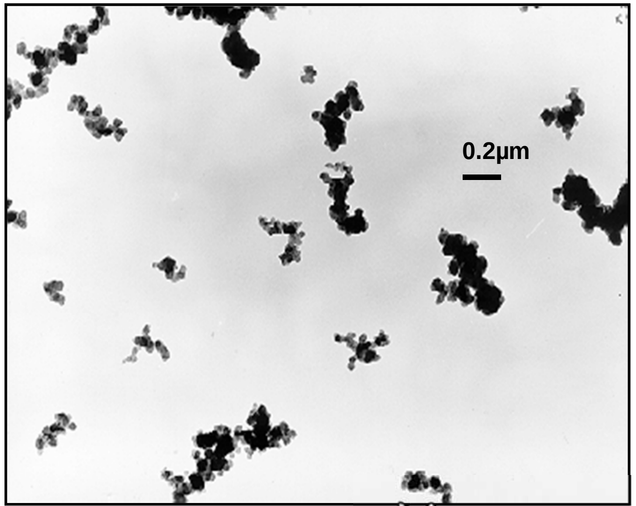
SIZE OF REINFORCING FILLER AFTER INCOPORTION IN RUBBER

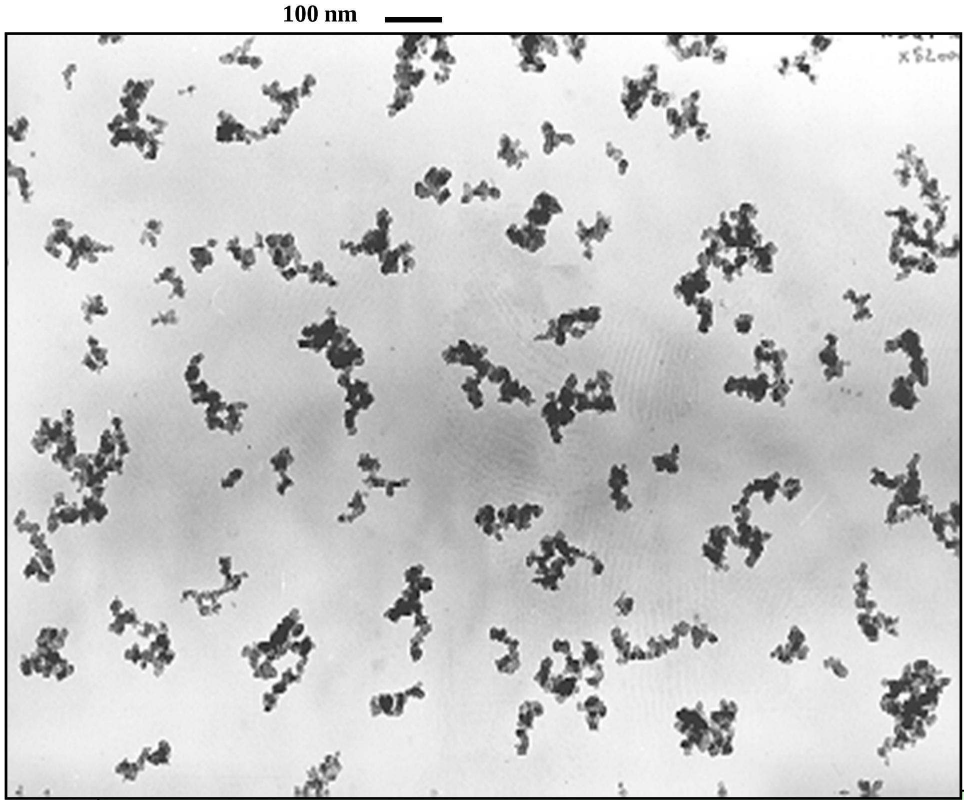
Plasticization of rubber needs very high level of energy. Internal mixers used for this mixing are equipped with very efficient engines (more than 1200 KW).

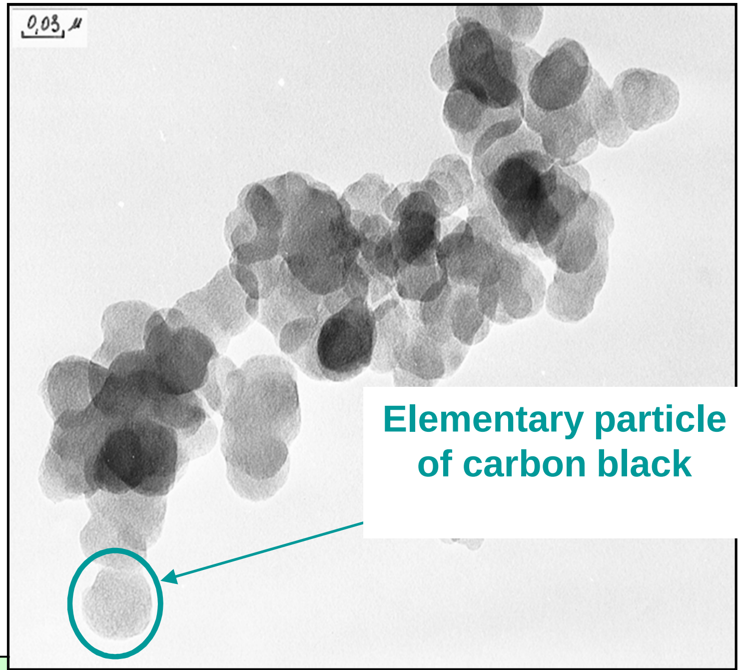
During the plasticization of rubber in the presence of carbon black, the pellets are destroyed, as well as the majority of the agglomerates.

The aggregates are released and immediately bonded on the rubber. These aggregates give the reinforcement thanks to their chemical links with rubber.



SIZE OF REINFORCING FILLERS AFTER INCOPORTATION IN THE RUBBER





The aggregates are the smallest particles in rubber. It is not possible to break them in elementary particles – the energy level which would be necessary is too high

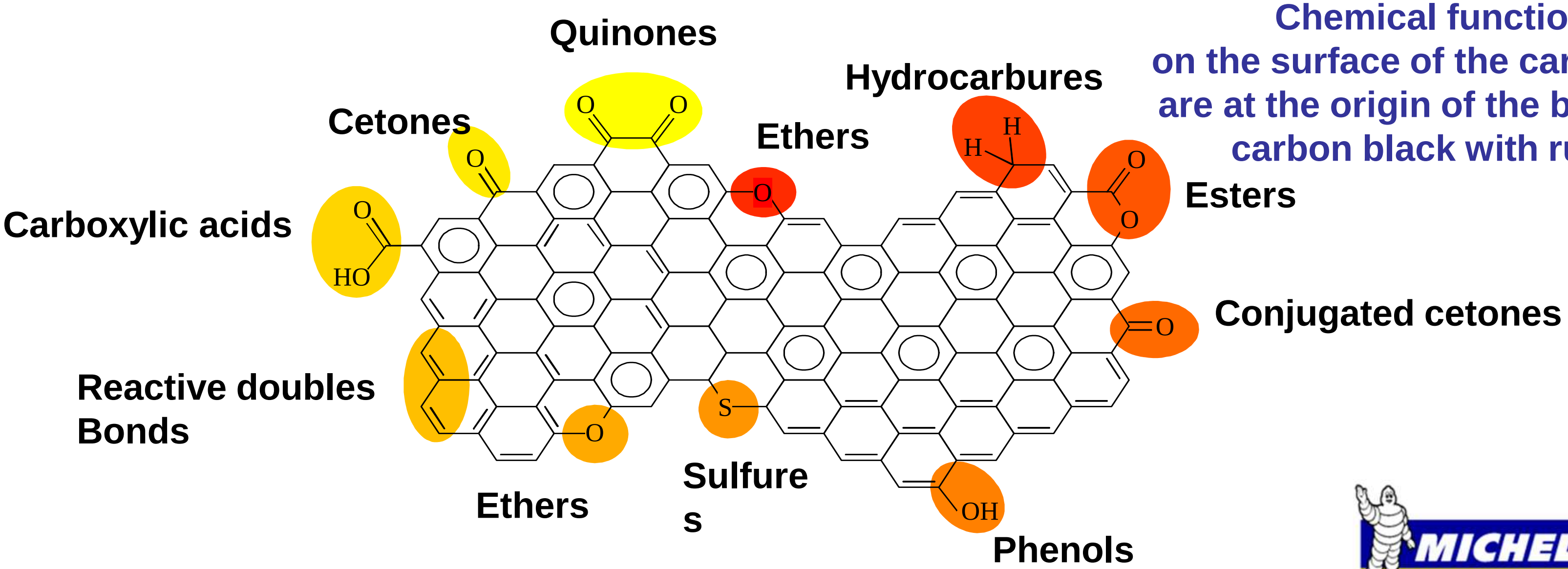
CHEMICALS LINKS: CARBON BLACK/RUBBER

The carbon black binds spontaneously with rubber by chemical bonds

Two assumptions for the generation of covalent bonds elastomer/carbon black…

During the mixing, radicals are formed and react with the surface of the carbon black

During curing, polysulphides bridges are created between the carbon black and the chains elastomers



Chemical functions on the surface of the carbon black are at the origin of the bonding of carbon black with rubber

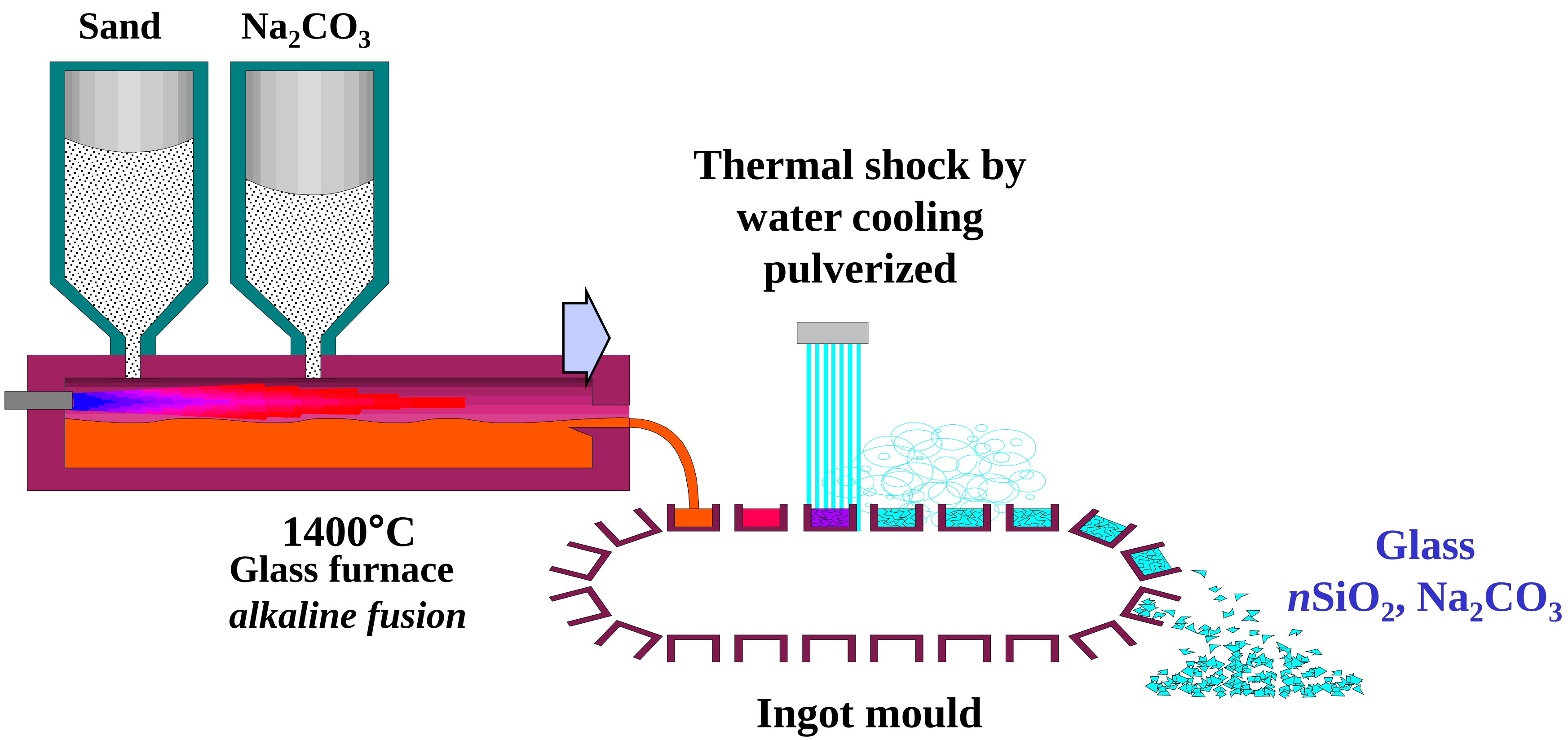
PRODUCTION PROCESS AND SIZE OF REINFORCING FILLERS USED IN TIRES

Amorphous silica

Applications of amorphous silica:
Toothpaste, paper, nutrition and health, articles out of rubber, tires

PROCESS TO OBTAIN AMORPHOUS SILICA

Preparation of water soluble glass



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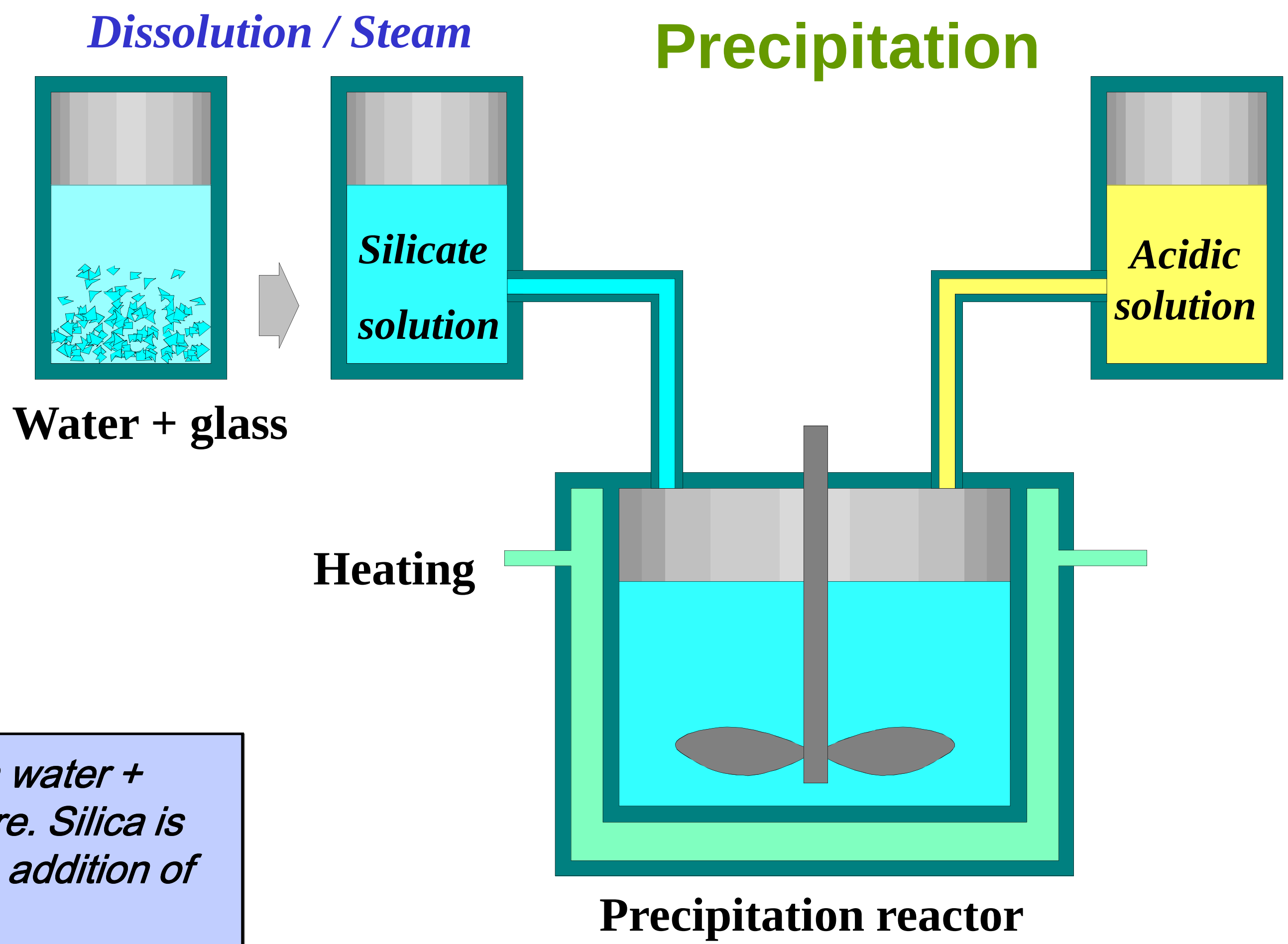
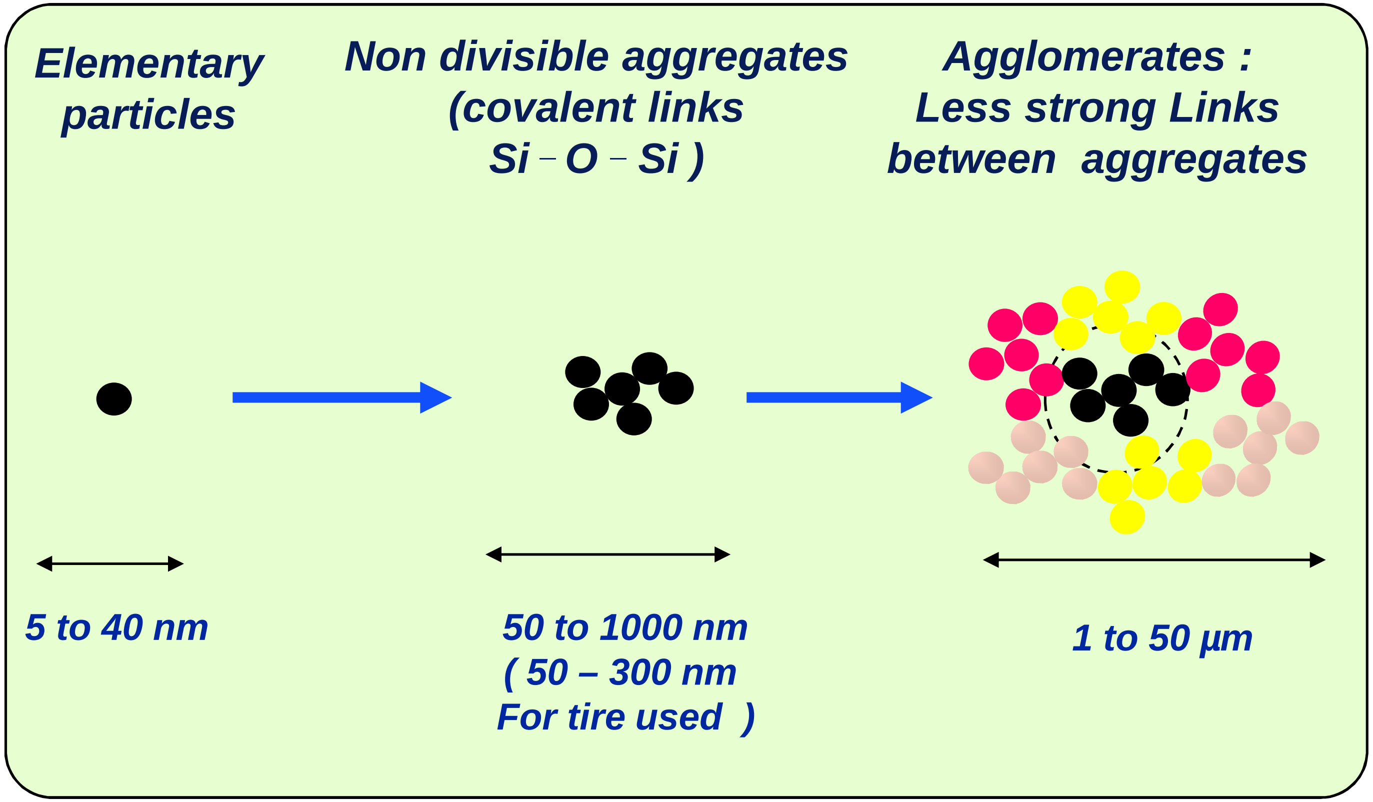
PROCESS TO OBTAIN AMORPHOUS SILICA



Glass is dissolved in water + steam under pressure. Silica is then precipitated by addition of sulphuric acid

PROCESS TO OBTAIN AMORPHOUS SILICA

Size of the objects at the stage of precipitation of amorphous silica



The structure of precipitated amorphous silica is generated at the stage of precipitation (chemical reaction silicate/acid)

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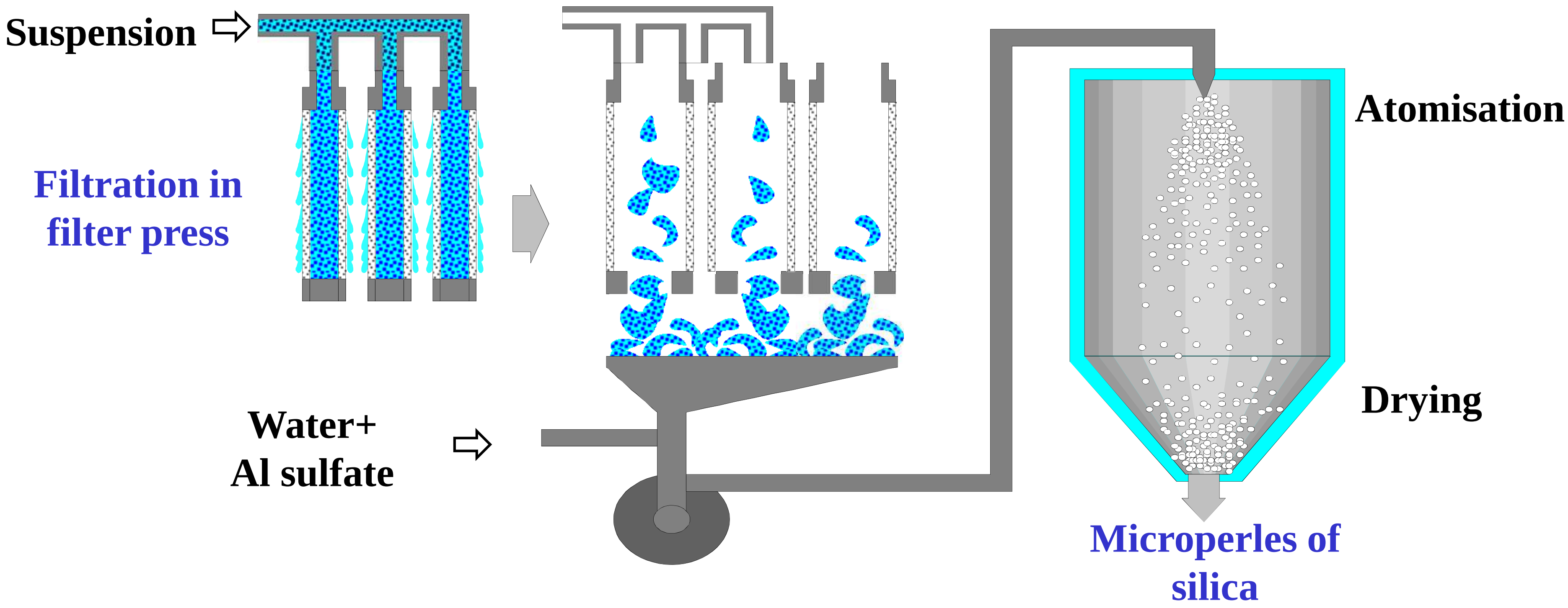
PROCESS TO OBTAIN AMORPHOUS SILICA

Silica – filtration / drying



The silica suspension is filtered on filter press and a "cake" is obtained which is falling apart in water + aluminium sulphate. The suspension obtained is injected under pressure in a drier.

SIZE OF SILICA ALONG PROCESS TO OBTAIN AMORPHOUS SILICA

At the end of the process : Micro pearl or granules

From 1/10 millimetres few millimetres

Commercial form of amorphous silica

A fraction of second after formation of aggregates : the agglomerates

From 1 to 50 microns

May exist in a free stage

Immediately after formation of nodules : the aggregates

from 50 to 300 nanometres
Do not exist in a free stage
After incorporation of carbon black in the rubber they exist and are chemically link to the rubber molecules

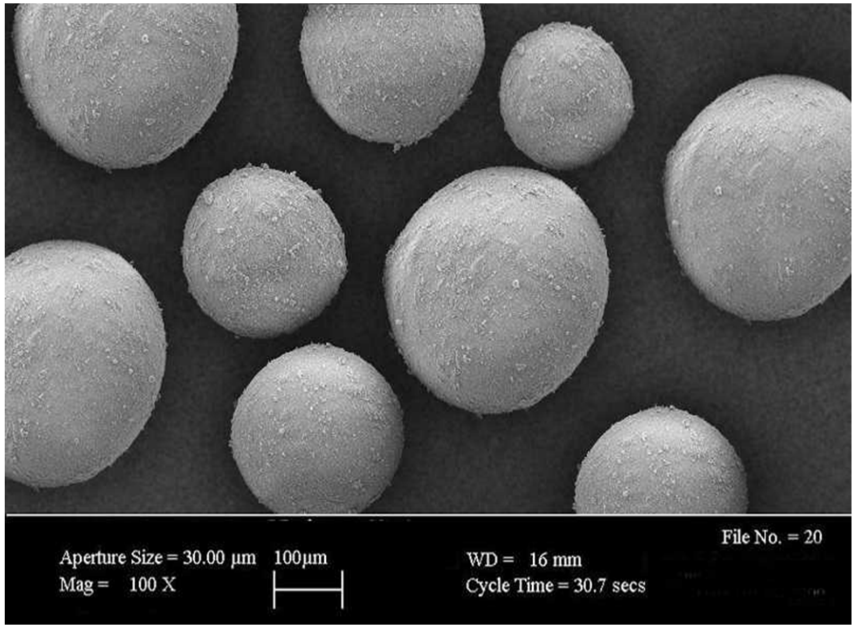
At the very early stage of the process: elementary particles = « nodules »

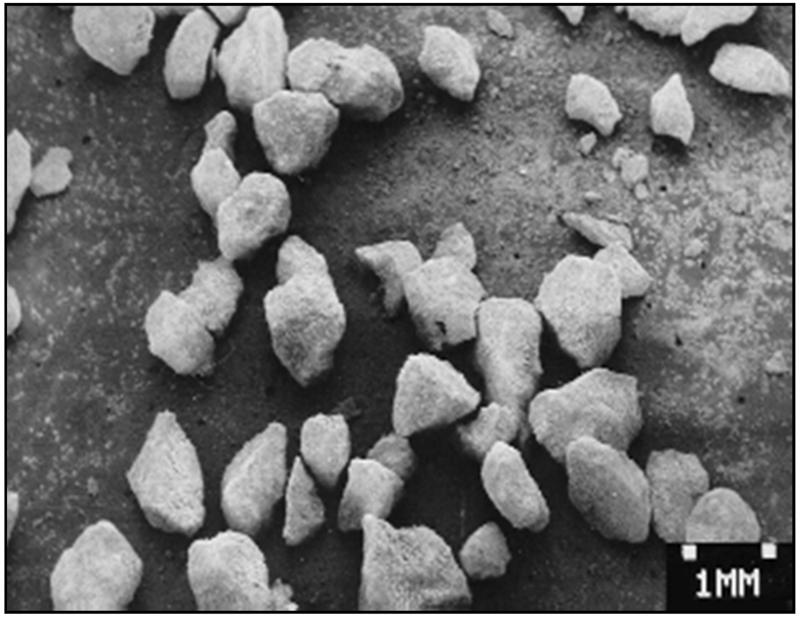
From 5 to 40 nanometres

Do not exist in a free stage

AMORPHOUS SILICA USED IN TIRE INDUSTRY ARE IN PHYSICAL FORM OF MICRO PEARL OR GRANULES

micro pearls	granules





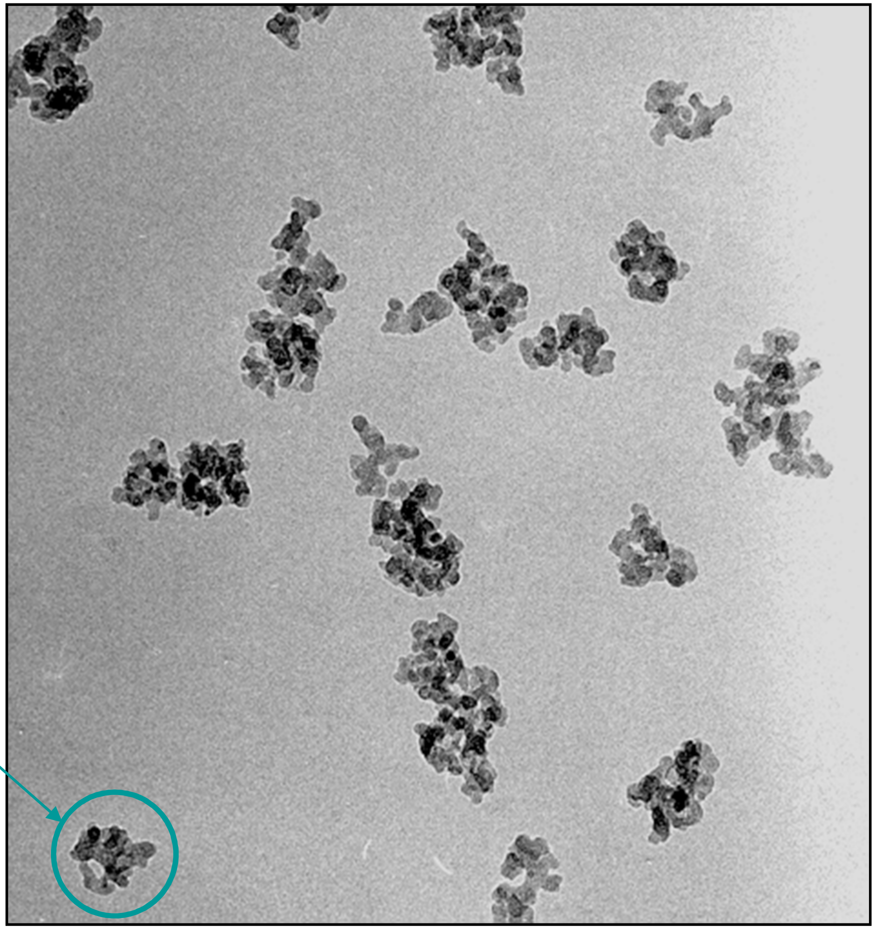
Micro pearls appeared as micro balls of very homogeneous size and shape

Granules are obtained by mechanical compaction between two striated cylinders and consist of angular fragments of some tenth to a few millimeters

SIZE OF REINFORCING FILLERS AFTER INCOPORTATION IN THE RUBBER

As for the carbon black, during the plasticization of rubber, micro pearls and granules are destroyed, as well as the majority of the agglomerates. The aggregates cannot be destroyed.

Aggregate of silica



In transmission microscopy silica have a morphology of aggregates very close to that of the carbon black.

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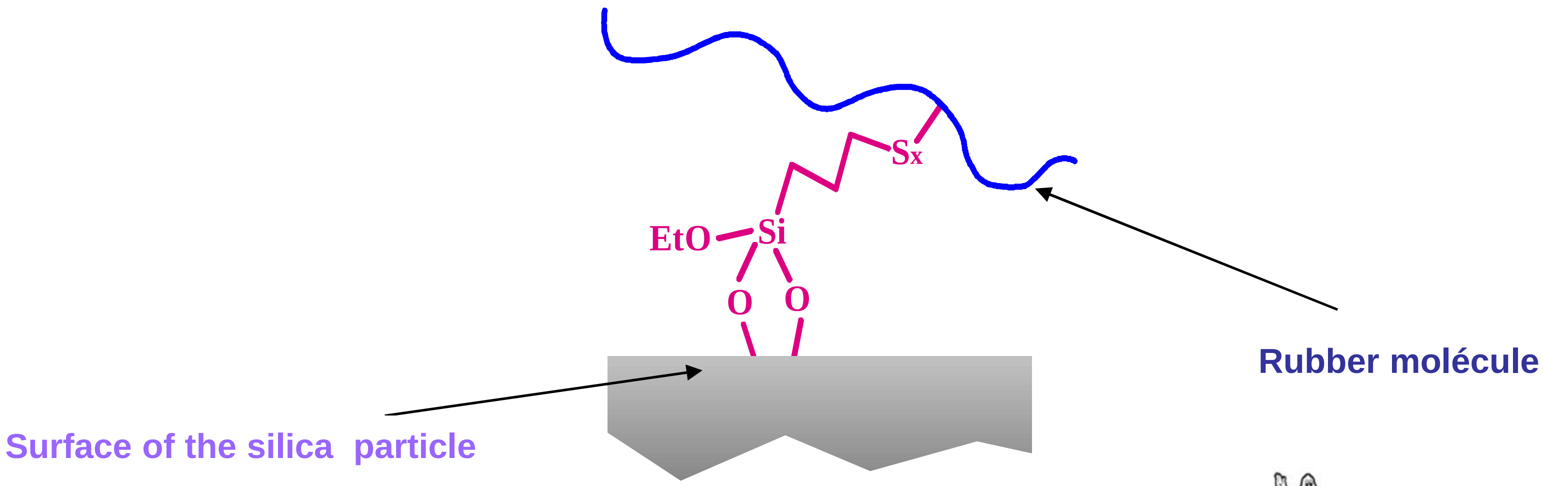
CHEMICALS LINKS AMORPHOUS SILICA/RUBBER

Silica is bind to the rubber by a chemical binding agent

In the case of amorphous silica, the link with the rubber molecules is not spontaneous as it is the case with the carbon black. it is ensured by a chemical binding agent which is added on the mixing stage. The chemical agent binds silica to the rubber molecules



1. Nano materials for tires, today carbon black and silica

2. Project of new nano materials

3. End of life tires

Why a strong interest from tire industry for new nanomaterials ?

Francis Peters May 10th 2012

In 1950 they were 50 millions vehicles on earth

In 2009 : They are 800 millions vehicles

In 2030 : experts estimation gives 1,6 billion vehicles, development mainly in emergent countries

Today the sector of the road transportation is at the origin of 18% of the emission of fossil CO2….

… and, because of the rolling resistance, the tires contribute for 20% to the consumption of fuel of a car (30% in the case of a truck).

Worldwide production of tires : 1,11 billion in 2008.

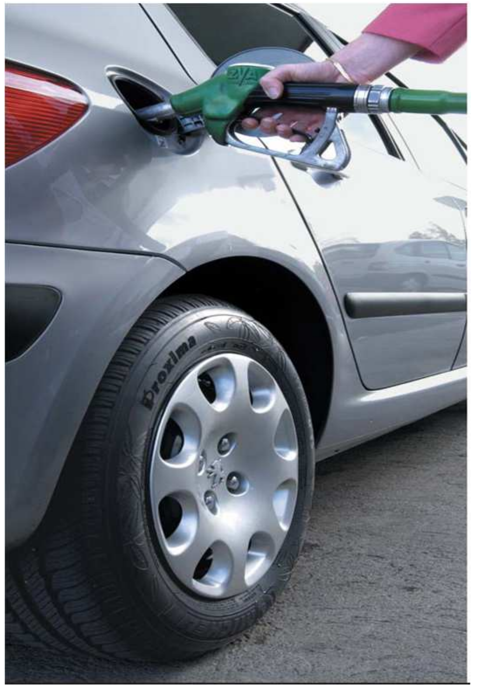
To double this production, without new technology , => need of two times more raw materials what seems not possible.

Goals

• To divide by two rolling resistance of the tires to not generate one gram of additional CO2 in spite of the increase in the number of tires

• To divide by two speeds of wear and to reduce the tires weight to not consume a gram of additional raw materials.

•Development of new nanomatériaux is one of the research way (nanotubes example of carbon, metallic oxides…)



•**There is an agreement between the eleven main producers of tires :** ***no development of nano materials which may generate a health hazard for human or for the environment*.**

Remark : Efficiency of new nanomaterials was already demonstrated : amorphous silica introduced in tires tread 20 years ago decreases rolling resistance and CO_2 emission (for example in first generation of tire with amorphous silica the CO2 emission of cars was decreased between 2% and 3% and further other significant improvements were obtained with amorphous silica).

- In 2005, CEOs from 11 Largest Tire Companies have taken the decision to joint there efforts for improvement of sustainable development (Tire wear particles (“TWP”), Tire materials, Scrap tires …)

- Tire Industry Project (TIP) launched in 2006 and organized as a sector project at the World Business Council on Sustainable Development (WBCSD)

- In 2010 CEOs concluded that development of new nanomaterials is a promising way for sustainable development But they won't make any development   which may present a risk for the human   health or for the environment.

- The OECD examine with TIP sustainable development and use of nanomaterials by the tire industry (WPN & WPMN)
    - A case study on societal advantages if tire industry develops and uses advanced nanomaterials
    - A guide on best practice for development and use of new nanomaterials in tires, taking in account all life cycle of tires including End of Life Tires
    - OECD report due October 2013

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End of life tires …

and nanomaterials

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What is an End-of-Life (ELT) and how many ?

A tire is considered at the end of its life when it can no longer be used, or re-treaded and used, as a tire.

ELT issues arise for all tires including passenger tires, truck, airplane, bicycle and off-road tires. On-road tires are the major source of ELTs.

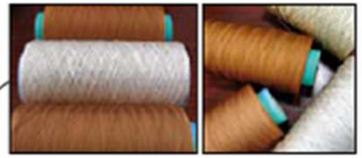
Approximately 1 billion ELT/year

	Millions of tires generated p.a.
Europe	300
US	299
Japan	100
South Korea	17
Canada	27.7
Australia	19.6
Israel	6.5
Iran	10
South Africa	12
China	112
New Zealand	4

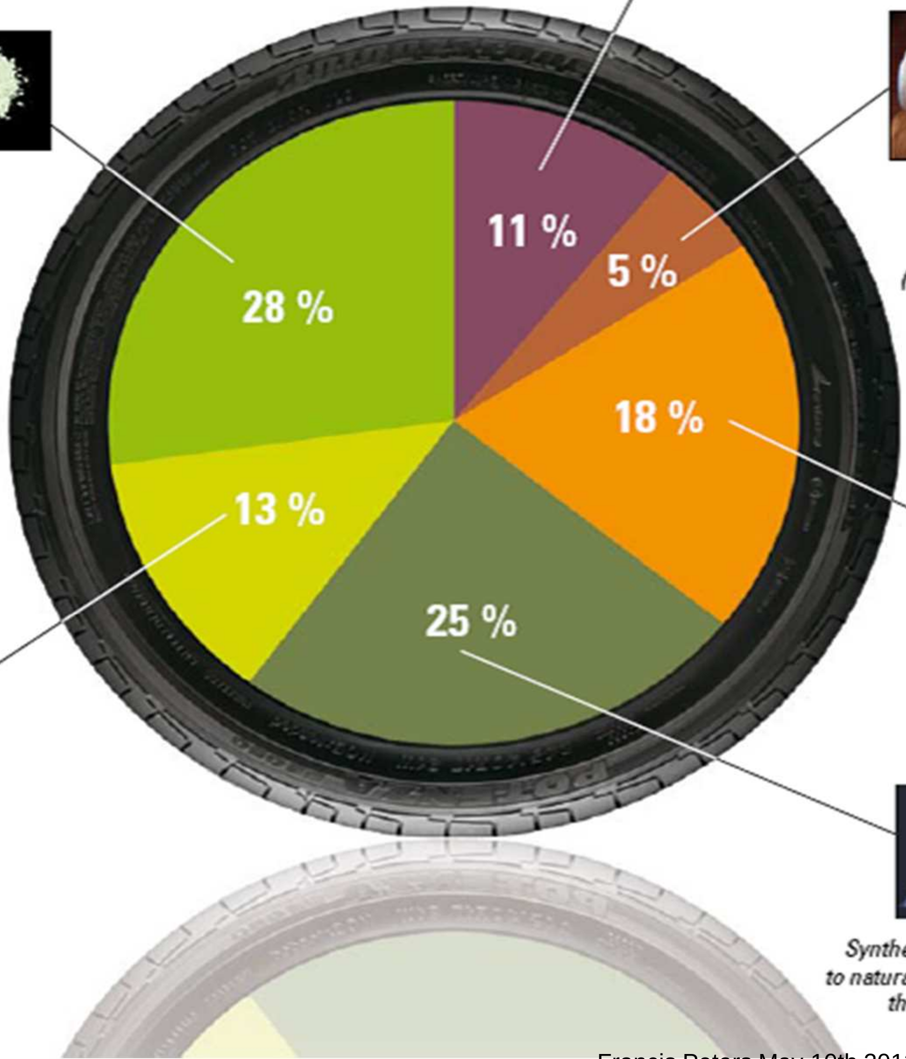
Composition of and average tire

High-strength steel cords are applied under the tread of passenger car tyres (and in the carcass of truck tyres) while other steel wires are located near the bead to assure adherence to the rim.

Carbon Black and silica are the basic tyre fillers, providing the necessary «structure» to the compound.



Passenger car tyres feature rayon or polyester cords radially disposed along the carcass (« radial tyres »), while nylon cords are placed under the tread or near the bead area.

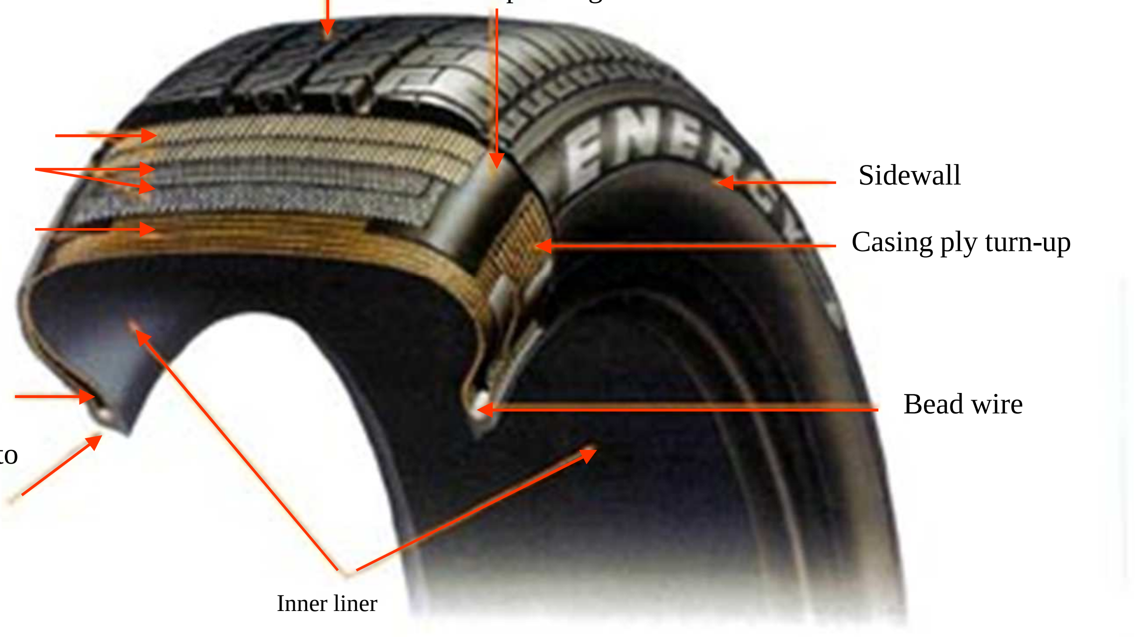


Natural rubber has unique elastic properties and is an essential element of a tyre. Truck tyres have even an higher content of natural rubber than passenger car tyres.

Other chemicals have various functions, like oils, sulphur, zinc oxide, or anti-degradants to protect the compound.

Synthetic rubber is added to natural rubber to achieve the desired elasticity.

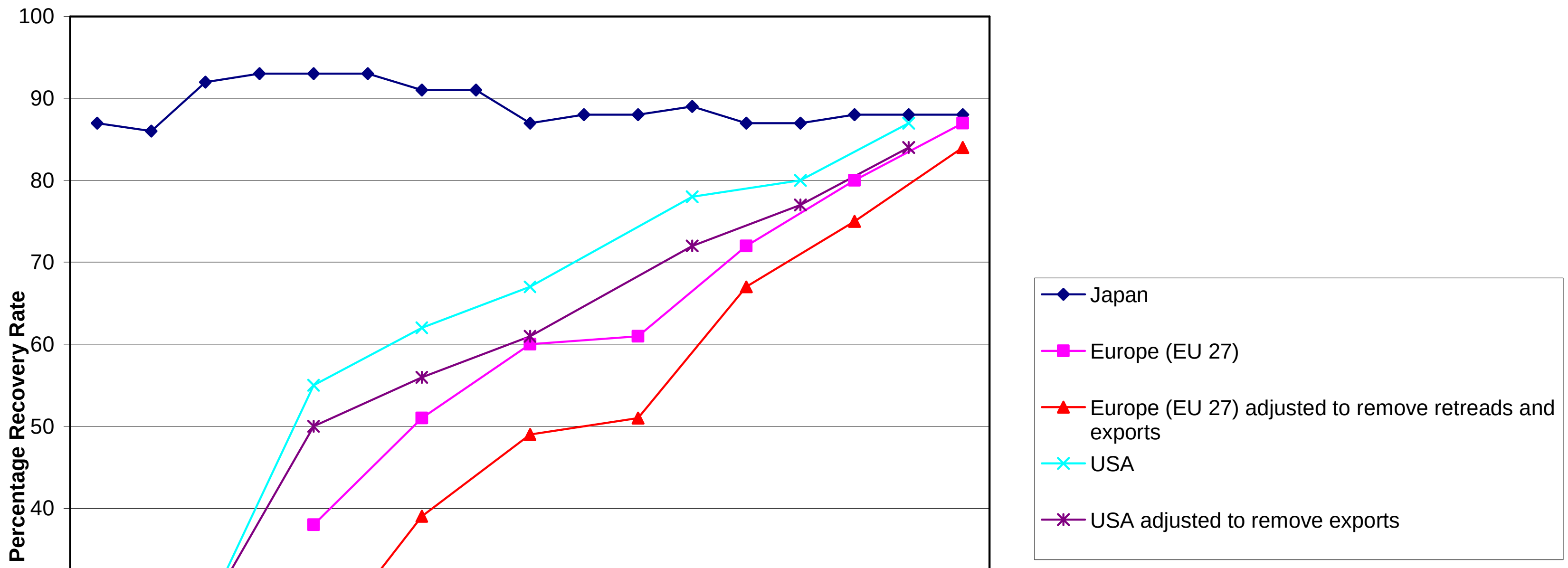
But there is an unknow aspect of a tire



A tire is more complex than it may seem …

and this exclude possibilities of recycling by regeneration of the initial raw materials used to make the tire

Recovery rates for ELTs have dramatically increased in Europe, South Korea and the US. Japan started recycling programs even earlier.
This shift shows that ELT-derived products can legitimately be recognized as a valuable secondary raw material or an alternative fuel.



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Comparison of tires recycling rate versus some others materials

Material	Recycling rate Europe (%)	Recycling rate US (%)	Japan
Tires	84	86	**85**
Glass	65	22	**90**
Car batteries	90 (UK)	99	-
Steel containers	63	63	**87.5**
Aluminum beverage cans	52	52	**92**
PET bottles	39	24	**66**
Paper/cardboard	**64**	**50**	**66**

Current uses for ELTs

Energy recovery

- Alternative fuel(mainly for cement
kilns, paper/pulp mills, thermal
power stations, industrial boilers, etc.)
- Substitute for Coal in steel plants (for example, electric arc furnace are an emerging use

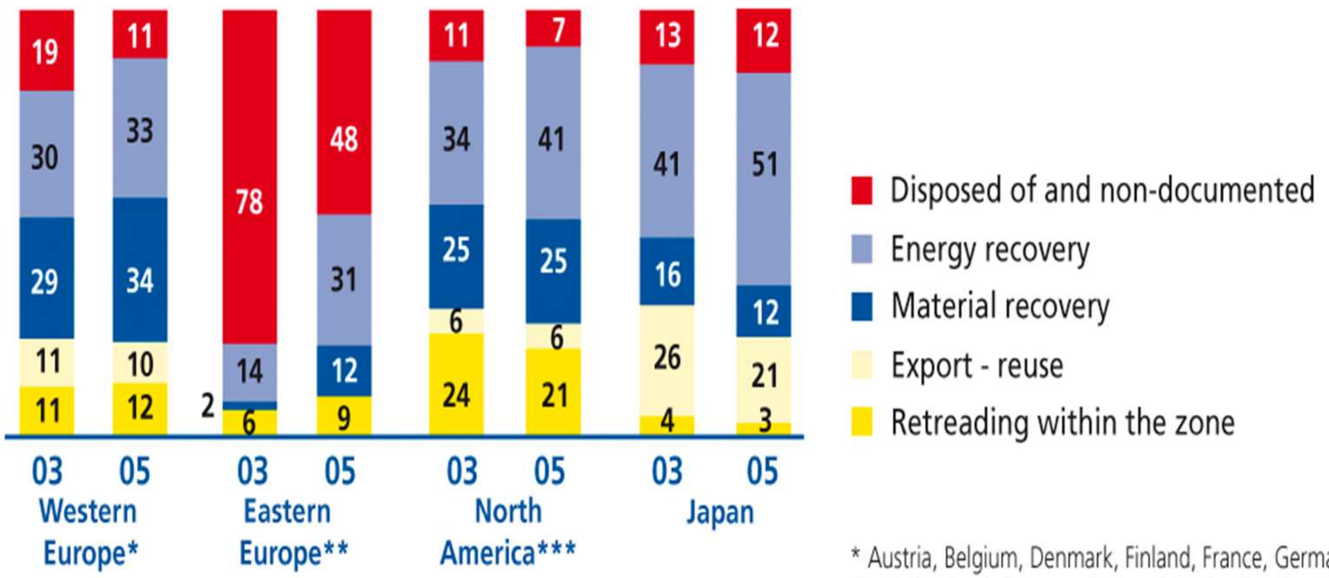
Material recovery

- Construction material
- Crumb or ground rubber applications (including molded products when combined with thermoplastics), reclaim rubbers

Rates of differents types of tires recovery

END-OF-LIFE TIRE RECOVERY RATE

(as a percentage of total volume)



Primary Sources: ETRMA (European Tyre and Rubber Manufacturers' Association), RMA (Rubber Manufacturers Association), JATMA (Japan Automobile Tyre Manufacturer Association).

2006 data to be available late 2007.

* Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom.

** Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia + Malta.

*** Canada, Mexico, United States.

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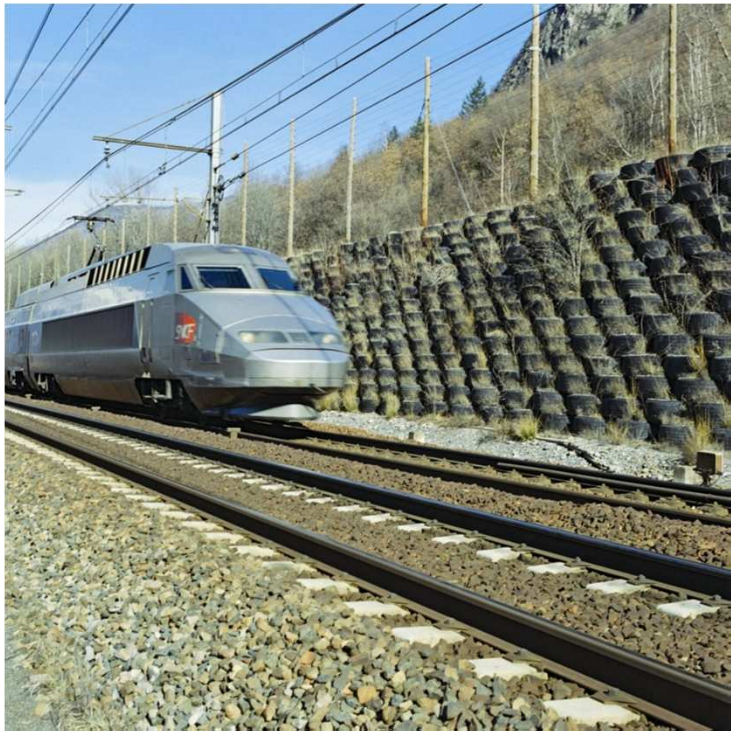
Energy recovery
Tire derived fuel (TDF)

	Total ELT (tires)	TDF usage	Facilities with TDF utilization
US	300 million	32% (2005)	Cement kilns, paper/pulp mills, boilers
Japan	100 million	54% (2006)	Cement kilns, paper mills, tire factories
Europe	250 million	41% (2006)	Cement kilns

Fuel	Energy (GJ/t)	Emissions	
		kgCO2/t	kgCO2/GJ
Tires	32.0	2,270	85
Coal	27.0	2,430	90
Pet coke	32.4	3,240	100
Diesel oil	46.0	3,220	70
Natural gas	39.0	1,989	51
Wood	10.2	1,122	110

Material recovery
Civil engineering use



Example : anti-scree wall in the haute Alpes, France

Material recovery crumb rubber, reclaimed rubber

Crumb rubber

ELTs are converted into ground or crumb rubber for use in rubber-modified asphalt, running tracks, sports fields, ground cover under playgrounds, molded rubber products and mulch in horticultural applications. Fine particles are produced by cryogenic grinding, using liquid nitrogen to cool the tires before processing.

Artificial turf on playing field, france

Reclaimed rubber

Reclaiming is a method allowing partial recycling and usage of waste rubber.
Steeps are grinding of rubber, removal of textile fibers and metals, and thermic, chemical or mechanical treatment of the vulcanized rubber.
The continuous thermo-mechanical method is now the most popular one. In this case reclaiming is performed in continuous screw in the presence of softener and destruction activator...
The reclaimed rubber is used in some application in combination or in substitution of new materials

Reclaimed rubber

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Introduction of new nanomaterials in tire brings new questions for recycling

Is there a risk of emision of hasardous nanoparticles during the recycling ?

For example in energy recovery could a nano material which did not burn go in the atmosphere ?

All the questions will be taken in account in the OECD tire project.

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Thank you

OECD Working Party on Resource Productivity and Waste

Survey of activities on nanowaste

Munich Workshop on Safe Management of Nanowaste

Munich, 9-11 May 2012

Mathias Tellenbach

Outline of the presentation

- Introduction
- The challenge of managing nanowaste
- Initiatives and actions on nanowaste
- Findings of the Survey
- Possible issues for future work

Objective of the study

- Survey
  - current and planned policy initiatives or actions addressing health and environment concern
  - Research and studies on nanowaste management
- Identify gaps
  - scientific information
  - policy framework for nanowaste
- Suggest possible issues to be addressed by WPRPW

Methods

What information has been available?

- Existing documentation on nanowaste at Terra Consult
- Work done by the author for the Federal Office for the Environment FOEN of Switzerland
- Contributions by members of the WPRPW
- Evaluation of survey articles and reports
- Internet search for nanowaste and nanowaste management

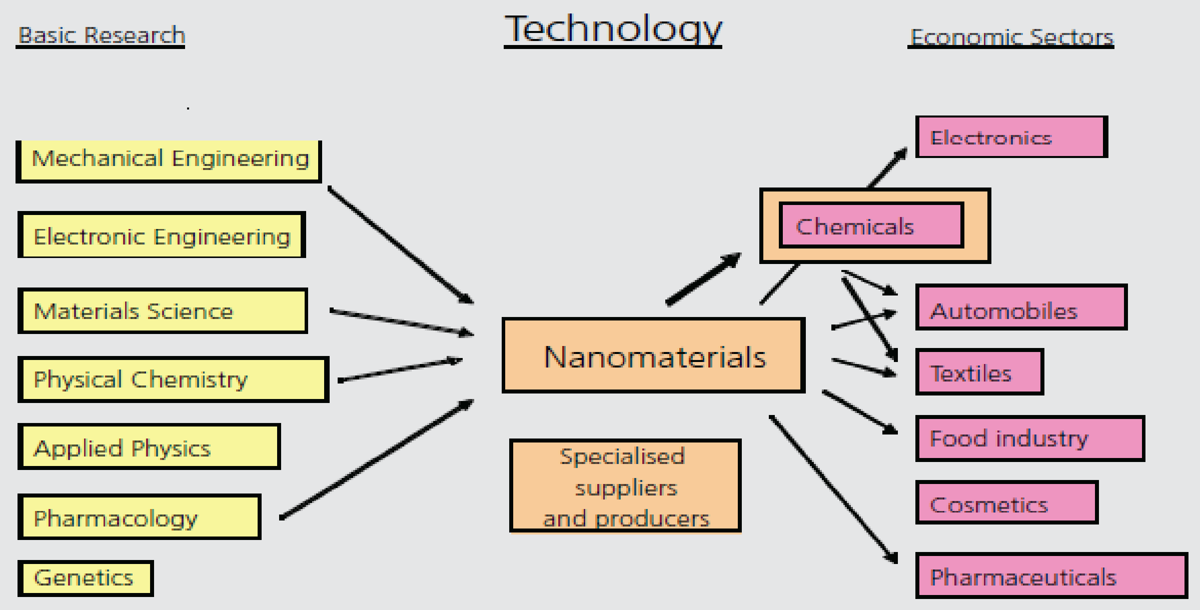
What information has been used?

- policies, concepts, recommendations and information of direct practical value for the environmentally sound management of nanowaste

Nanotechnologies and Nanomaterials

- new material properties
- rapid development
- promising new products
- growing market
- concern about possible risks for EHS

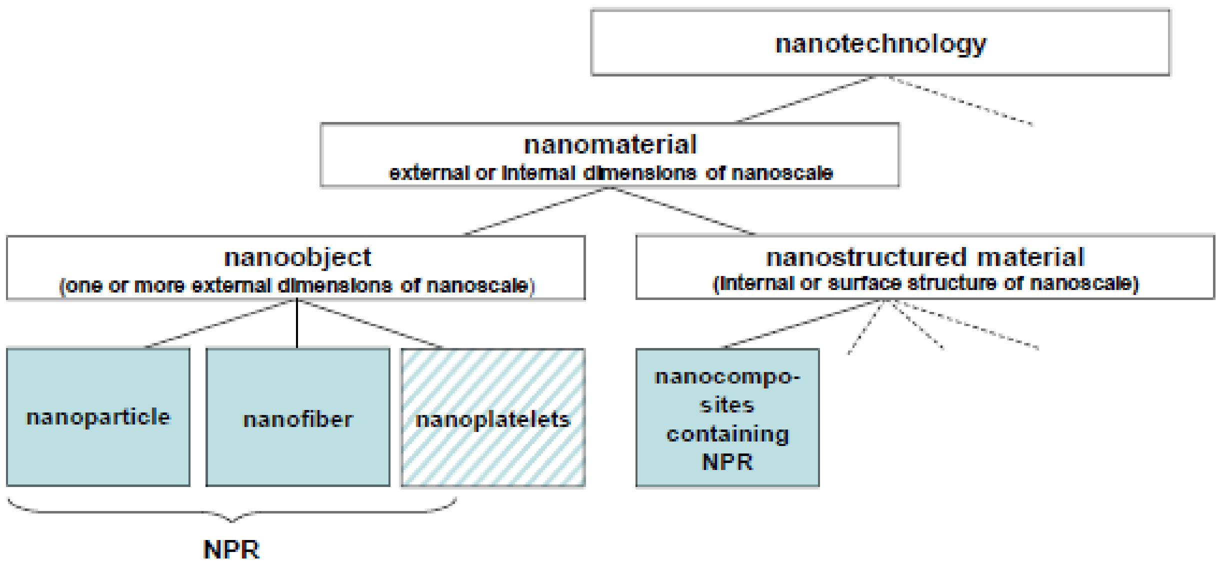
FIGURE 2-VI
Schematic representation of the diversity of scientific disciplines and economic sectors of the nanomaterials innovation system[37]



Source: Novel Materials in the Environment: The case of nanotechnology, UK Commission on Environmental Pollution 2008

Nanomaterial and Nanowaste

- Any product with nanomaterials will end up as a waste
- Not every nanomaterial is problematic
- Big challenge: **How do we know the difference?**
- Focus of concern: materials, products and waste with free or releasable nanoparticles and -rods NPR



Nanowaste from everyday products

- Potentially adverse effect, little information
- Diversity of materials and application, fast development
- Risk potential and exposure scenarios dependent on actual phase in the life-cycle:
  - Example Tennis Racket:
    Safe during use, what happens afterwards (shredder, incineration plant, landfill)?

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© www.tennis.fm

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Themes addressed in the documents that are referenced in the survey	„Rating“ (Frequency of the main themes)
Handling of nanowaste from research, production and professional processing of nanomaterial	✔ ✔ ✔ ✔
Waste management procedures (handling, information, storage, ..) for nanowaste from research, production and professional processing of nanomaterial	✔ ✔ ✔ ✔
Nanowaste specific risk assessment or risk estimation	✔ ✔ ✔
Legal framework, recognition as hazardous/non-hazardous	✔ ✔ ✔
Nanowaste specific strategies	✔ ✔ ✔
Types of nanowaste from consumer and industrial products	✔ ✔
Quantities and material flow of nanowaste	✔ ✔
Recommendations on recycling or disposal methods for nanowaste	✔

Lack of information and data

- Quantities
- Composition of products
- Nanospecific effects on EHS
- Fate/behavior of nanoproducts and nanomaterials in recycling or disposal facilities
- Exposure scenarios along the main paths of waste recovery and disposal
- Recommended and proven technologies for nanowaste recovery and disposal

Guiding Principles

Ship in the fog, © http://www.snodoglog.com/09Summer-Pg4.html

- General Principles of Environmentally Sound Management (ESM) of Waste
- Precautionary Principle
- Case by Case Approach

Findings – the Headlines

- **Risk awareness is rising – Knowledge still lacking!**
- **Countries and Organizations active – Consensus on greatest risk-potential emerging!**
- **Guidance for dealing with unknown risks is developing!**

(a) Awareness of potential risks posed by nanowaste; Lack of knowledge about appropriate disposal options

1) Increasing preoccupation with the potential risks in connection with engineered nanomaterials; open questions exist concerning the generation of nanowastes and their possible inherent risks.
2) There exists considerable lack of knowledge concerning the type and quantity of nanomaterials in products and the fate of these nanomaterials during use or disposal operations. There is a general lack of knowledge about safe disposal practices for nanowastes.
3) Virtually no regulations that specifically address nanowaste. Nanowaste is actually covered by the general waste regulations.

(b) Activities of individual countries and international organizations

(1) Work on environmental, health and safety aspects of nanomaterials is funded by many countries and organizations. However, studies with information on nanowaste, and guidance on nanowaste management are scarce.

(2) Environmentally sound management, recovery and/or disposal of nanowaste is one important aspect in order to ensure the successful development and use of products containing nanomaterials.

(3) waste with free or releasable nano-objects(NPR) may pose the greatest risk potential. Exposition of workers and consumers and the release of NPR into the environment should be minimized where there is uncertainty concerning possible risks or hazards.

(c) Existing guidance for dealing with unknown potential risks during nanowaste management

(1) The Precautionary Principle may serve as a guiding principle, pending the solutions by governments and industry to the actual problems raised by the generation of nanowaste, and within limits of existing laws.

(2) The most concrete and practical guidance is given about the ESM of nanowaste generated by research & development activities and during production and professional processing of nanomaterials.

(3) Recommendations for the recognition of nanowaste as hazardous or nonhazardous are given.

(4) In spite of the existing knowledge gaps, some indications on the appropriate disposal procedures and technologies are given that could be used for the safe and environmentally sound disposal of nanowaste.

Possible issues to be addressed by WPRPW

1. Addressing the lack of knowledge on nanowaste

2. Guidance for the application of existing guidelines or regulations to the problem of nanowaste

3. Preventive and precautionary action on an international basis

1. Addressing the lack of knowledge on nanowaste

- Search out existing data and make them available:
  - Types and quantities of nanomaterials in products
  - Waste streams from these products into main paths of waste treatment (recycling, incineration, landfill, sewage sludge)
- Meet the demand of stakeholders and public for knowledge and research on potential risk from nanowaste
  - OECD could act as a clearinghouse for information on nanowaste and nanowaste treatment
    - Development and sharing of a data-base
    - Accompanying meetings (identify problems, coordination, progress reports, de-blocking)
    - Support/cooperation: Governments, science, industry, ENV NGOs, OECD WPMN

2. Guidance for the application of existing guidelines or regulations to the problem of nanowaste

- Characterize nanowaste according to its properties and related potential hazardousness :
  - Examine existing practices/recommendations on recognition of nanowaste as hazardous/non-hazardous
  - Close cooperation with Member countries, BIAC, Basel Convention, CEC, EU.
  - Make use of existing data on chemical substances, e.g. REACH
- Ensure protection of workers in companies producing or processing nanomaterials with free NPR
  - Review existing national and industrial guidelines on workplace safety
  - Further development of guidance together with industry, governments, trade unions and ENV NGOs

3. Preventive and precautionary action on an international basis

- Use of the Precautionary Principle when dealing with unknown risks or risk potential of nanowaste
  - WPRPW could examine if the Precautionary Principle would be a possible way forward to reduce negative health and environmental impacts from nanowaste.
  - "Step-by-step" and "Case-by-case" approach for assessing possible risks and develop consensus on appropriate measures.
- Supplement OECD Guidelines on ESM of waste with advice and guidance addressing nanowaste
  - Starting point: existing strategies and recommendations on nanowaste management in R&D, production and processing of nanomaterials
  - Step-by-step extension to waste management facilities, incorporation in international ESM instruments for waste

Thank you for your attention!

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Relevance of Nanomaterials in Recycling of Wastes

Jutta Struwe
IFAT-Entsorga 2012 – OECD Workshop „Safe Management of Nanowaste“
Munich, 09.05.2012

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Focus of the Study

- Which kind of products or groups of products containing nanomaterials commonly undergo recycling processes in Germany?
- Which of those handle with high amounts of nanomaterials according to the quantity of recycling or the content of nanomaterial?
- What kind of potential risks belong to recycling processes according to included nanomaterials?
- Are there any laws and provisions for employee health and safety measures in recycling industries?
- Recommendations with focus on health and safety measures of employees in recycling industry and basic research

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01	Our Focus
02	Basics
03	Main Results
04	Recommendations

Cycle of Nanomaterials

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Nanomaterials	Middling Product	„Nano“-Product	Recycling
„native“ nanomaterial	middling products with characteristics of nanomaterials	products containing nanotechnology	recycling of products containing nanomaterials
Manufacturing	**Processing**	**Consumption**	**Waste**
e.g. CNTs, fullerenes, quantum dots	e.g. paint, covers, textiles, chips, textiles, chips, semiconductors	e.g. cars, cloth, planes, computers, electrical and electronic equipment	e.g. PET bottles, batteries, tires, cloth, paper, plastics

Source: Lux Research 2008; Struwe, J. et al: Relevanz von Nanomaterialien beim Recycling von Abfällen; Arbeitspapiere der Hans-Böckler-Stiftung, 2012

RISKS

exposition

release
- abrasion
- discharge
- evaporating

transport
- aerosol, smog, dust, fog)
- water

exposure
- inhalation
- dermal resorption
- oral reception

toxicity

characteristics
- cancer-causing
- effect levels
- behavior after exposure
- specific structure

prevention of risks

health and safety measure

Source: Struwe, J. et al: Relevanz von Nanomaterialien beim Recycling von Abfällen; Arbeitspapiere der Hans-Böckler-Stiftung, 2012

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Product groups in recycling processes containing nanomaterials

Source: Struwe, J. et al: Relevanz von Nanomaterialien beim Recycling von Abfällen; Arbeitspapiere der Hans-Böckler-Stiftung, 2012

Categories of Products in Recycling Processes

Category 1

- Different kinds of products with heterogenous composition are grouped in one waste category
- A variety of different nano-materials are being processed – partly unknown species and character
- Usually different recycling prozesses

Members:

- Wracked cars
- Electronic and electrical equipment
- Plastics

Category 2

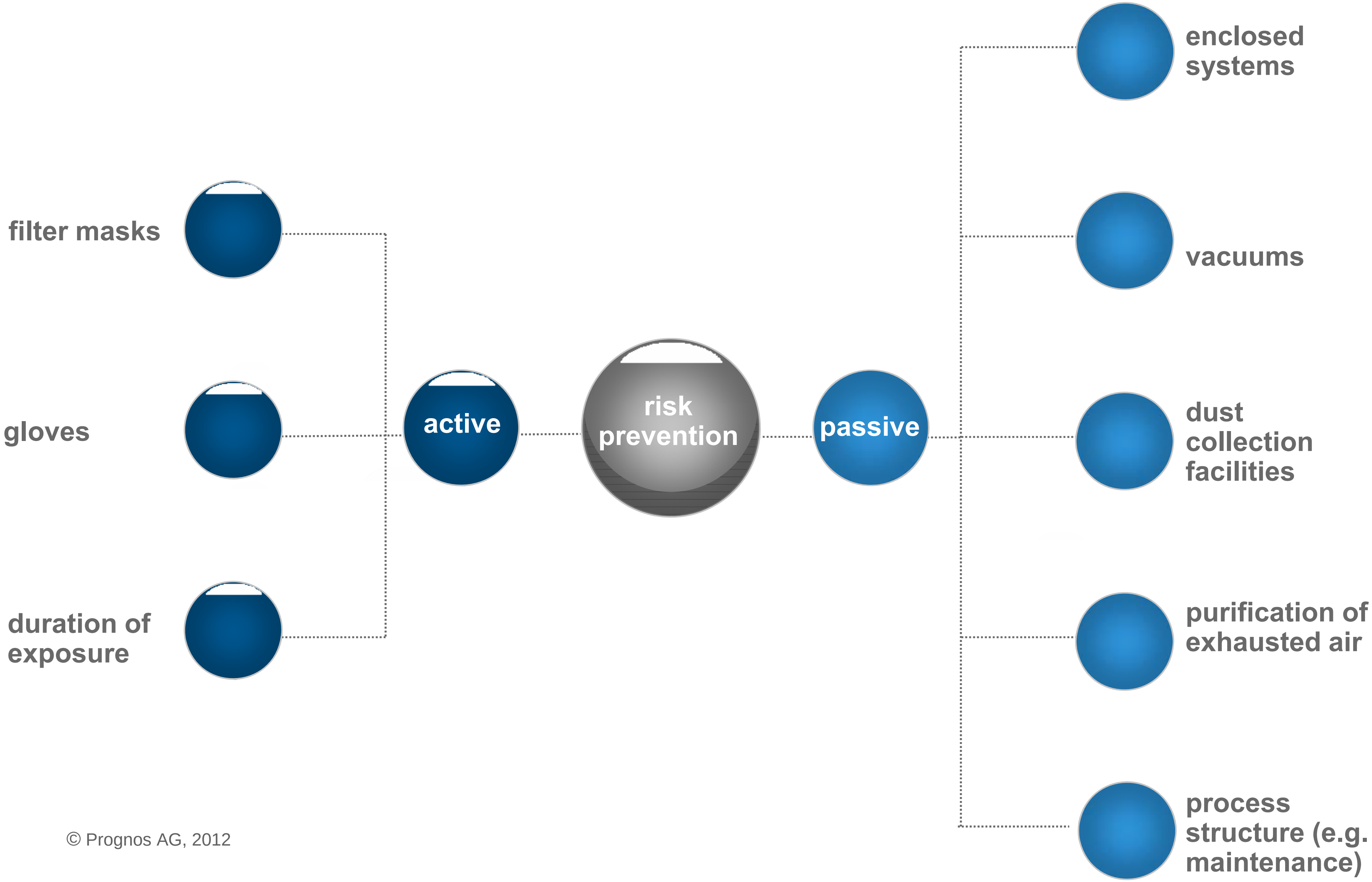
- Products contain single, generally known nanomaterials
- The product group is almost homogenous
- Usually only one recycling process

Members:

- PET-Bottles
- Tires
- Li-ion-batteries

Source: Struwe, J. et al: Relevanz von Nanomaterialien beim Recycling von Abfällen; Arbeitspapiere der Hans-Böckler-Stiftung, 2012

Precautionary health and safety measures the handling of nanomaterials



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- Awareness regarding health and safety measure in recycling industry (end of value chain) should be improved.

- Existing knowledge and guidelines for occupational health and safety measure according to the handling with nanomaterials should be transferred to recycling processes.

Further basic research is needed into:

- risk potentials caused by nanomaterials in products during recycling processes

- characteristics and behavior of nanomaterials in recycling processes

- diffusion of nanomaterials through recycling products

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