Igor ČATIĆ, Gordana BARIĆ, Maja RUJNIĆ-SOKELE
Faculty of Mechanical Engineering and Naval Architecture
University of Zagreb, Croatia

Polymers and non-polymers – a new systematisation of substances and materials*

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Summary

For a very long time materials have traditionally been classified in two main groups: metals and non-metals. Now we need a new paradigm in substances and materials (macromolecular compounds) and product classification. One demand for this new paradigm is based on the definition of polymers and their quantity. The second reason is the increased availability of composed and hybrid materials and products. The third one is the possibility of better understanding the nature, interconnection or comparability of substances and materials, which are basically made from the same basic group. The new classification, according to the proposed criterions, divides materials into polymers and non-polymers. Both groups can be inorganic or organic ones. Today the materials are mostly man-made, so the use of the word natural materials e. g. for cotton is unjustified

KEY WORDS:
materials
new systematisation
non-polymers
polymers
substances

KLJUČNE RIJEČI
materijali
nepolimeri
nova sistematizacija
polimeri
tvari

Polimeri i nepolimeri – nova sistematizacija tvari i materijala

Sažetak

Dugo vremena materijale se dijelilo na metale i nemetale. Danas je potrebna nova razredba tvari i materijala (makromolekulnih spojeva) te proizvoda. Jedan od kriterija temelji se na definiciji polimera i njihovoj proširenosti. Drugi kriterij je proširenje uporabe kompozitnih i hibridnih materijala i tvorevina. Treći razlog uvođenja nove razredbe je bolje razumijevanje prirode, međupovezanosti ili usporedivosti tvari i materijala načinjenih iz istih temeljnih skupina. Prema novoj razredbi materijali se dijele na polimere i nepolimere. Obje skupine sadržavaju organske i anorganske tvari i materijale. Današnji materijali pretežno su rezultat ljudskog rada i načinjeni su od prirodnina poput fosilnih goriva ili uzgojina. Stoga je u takvim slučajevima uporaba riječi prirodan (npr. za pamuk) pogrešna.

Introduction

In our previous texts we discussed the globalisation of tools.[1,2] One of the ideas that originated from these papers is the discussion about the meaning of the term polymers.[2] We must take into account the fact that we can differentiate in technology between substances, materials and products made from substances, like thermoset switches, rubber tyres, concrete panels or ceramic insulators.

This text has multiple purposes. After the analysis we came to the conclusion that the word polymers covers a wide range of substances and materials, from proteins to polyethylenes or glass-reinforced plastics. For instance, bags made of paper, fabric, and polyethylene, are all organic polymeric bags.[3]

Journals, magazines and newspapers are full of words beginning with bio: biofuel, bioplastics, biocosmetics and so on. Is all beginning with the syllable "bio" an universal solution for our problems with climate changes, famine in the world, and food as a weapon?[4] The most important purpose of this text is to improve the education at all levels in the concept of materials, and not just in plastics, metal, or wood. One of the aims is to stimulate the better systematisation and classification of materials than the one proposed here.

Observation

For more than 40 years, one part of our research can be described as synthesiological one. This means that we are trying to find some laws or interconnections between knowledge from very different sources.[5,6]

Our study of the influence of rubber and plastics on globalisation was based on the theory of systems in general technology.[7] We have come to the conclusion that human beings were using at first natural and then man-made stone tools, mostly for separation of the natural polymers: wood, bones and skin, respectively between 3.4 and 2.6 million years ago.[1,2]

This gave us the idea to propose the new systematisation of materials, from quarks to composed and hybrid materials and products.

Basic ideas for the new systematisation

Introduction into basic ideas

The proposal for the new systematisation of substances and materials is based on some ideas which we have used in the systematisation of macromolecular compounds. The first one originates from the Greek philosopher Aristotle: without exception, each level of matter is preceded by the creation of its shape.[8]

This means that primary shaping precedes the creation of each level of matter above the quarks and gluons. The second important idea is based on experience. The observation, discovery precedes the invention.[3]

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TABLE 1 – From quarks and gluons to composed and hybrid materials, and composed and hybrid products

<table>
<tr><td>P</td><td colspan="3">Composed and hybrid materials and products</td><td>L7</td></tr>
<tr><td>P</td><td colspan="3">Production of composed and hybrid materials and products</td><td></td></tr>
<tr><td>P</td><td>Inorganic substances and materials</td><td colspan="2">Organic substances and materials</td><td>L6</td></tr>
<tr><td>T</td><td>Controlled inorganic reactions</td><td>Controlled organic synthesis</td><td>Controlled biosynthesis</td><td></td></tr>
<tr><td>T</td><td colspan="3">Artificial technology</td><td></td></tr>
<tr><td>P</td><td>Natural inorganic macromolecular (non-living natural products – minerals)</td><td colspan="2">Natural organic macromolecular compounds (living natural products – living organisms)</td><td>L1</td></tr>
<tr><td>T</td><td>Geological processes of non-living</td><td colspan="2">Biosynthesis (synthesis of living)</td><td></td></tr>
<tr><td>P</td><td colspan="3">Macromolecular compounds (substances)</td><td>L0</td></tr>
<tr><td></td><td colspan="3">...</td><td></td></tr>
<tr><td>P</td><td colspan="3">Matter (quarks, 10^{-20} m)</td><td>L-x</td></tr>
<tr><td>T</td><td colspan="3">Natural technology</td><td></td></tr>
<tr><td>T</td><td colspan="3">General technology</td><td>Levels</td></tr>
<tr><td colspan="5">T – Technology, technique, process; P – Product</td></tr>
</table>

Finally, for our explanation the syntagma of general technology is of importance as the common name for natural technology and artificial technology.[9]

Nature has resulted from the action in natural technology. The questions are – when did artificial technology start, with what tools and what did they process? The last question originated from Alger's definition of polymers.[10] Table 1 shows the results of natural and artificial technology.

From quarks and gluons to composed and hybrid materials and products

The general technology starts with a natural one. The natural material technology starts with quarks and connected with gluons in one moment development resulted in macromolecular compounds (substance, level L0). The macromolecular compounds have been shaped (formed) by geological non-living processes into natural inorganic materials – minerals (L1). The results of biosynthesis are natural organic macromolecular compounds – living organisms (L1).

The artificial technology started when human beings invented the procedure of manufacturing stone choppers and flakes (inorganic polymer products) in Lomekwi 3, West Turkana, Kenya, about 3.3 million years ago. Cutting animal bone (organic polymer). This was the starting point of human material culture.[11] One of the earliest artefacts ever discovered is a drinking vessel made of sun-dried clay.[12] We understood sun-dried clay as the first artificial material which is dated to pre-historic times. The drinking vessel made of sun-dried clay is connected with Aristotle's sentence: *There is a relationship between the form and the matter; the form being always the first, generally and in any particular case.* This led to a very important conclusion: creation of form, primary shaping but also primary structuring, precedes the creation of any level of matter. For example, the making of thermoset, rubber, and ceramic materials precedes primary shaping. This is the reason why we can not see these materials; they always have the necessary form (e. g. a thermoset boat, rubber baffle, ceramic vase or concrete pillar).

By controlled inorganic reactions, we get inorganic substances and products. By controlled organic synthesis and biosynthesis we get organic substances and materials. In some cases, we are making products which demands first to be primary shaped and then by chemical reactions the necessary material is made (e. g. ceramic, rubber and thermoset parts or combination of substances and materials, like rubber compound-metal).

The production of composed products is relatively new, the earliest man-made products were formed bricks for building construction several thousand years old, made from straw and mud[13]. Now we have composed materials like glass reinforced polyamide. Hybrid materials are new, e. g. organic-inorganic polymers like poly(organosiloxane). Hybrid products can be combinations made from two non-living materials (e. g. plastic/rubber moulding) or a combination of living and non-living (e. g. cyborgs).

What is the meaning of the word polymer?

At one moment during the history of nature, macromolecular compounds were constituted. These macromolecular compounds can be inorganic and organic ones.[14**]

A common name for natural and synthetic substances and materials with a basic ingredient system of macromolecules, macromolecular compounds with repeating units, is polymers.[16-19]

The name polymers is an umbrella term for natural and synthetic substances and materials with the basic component being a system of macromolecules, i. e. macromolecular compounds with *repeating units*.[10] Based on this definition it is possible to differentiate four basic groups of macromolecular compounds: the inorganic macromolecular compounds (inorganic polymers and inorganic non-polymers) and organic macromolecular compounds (organic polymers and organic non-polymers).[2] According to this criterion, there are inorganic and organic polymers as well as inorganic and organic substances and materials, which are not polymers.

If we carefully read the references, we can conclude that there are numerous inorganic and organic substances and materials which fulfil the basic criterion of polymers that they are macromolecular compounds with repeating units.

The fact that we have only two groups of substances and materials – polymers and non-polymers, led us to the idea to propose a new systematisation of substances and materials.

Proposal for systematisation of substances and materials

From the point of view of material technology[20] all starts with primary shaping by joining of quarks and gluons (Table 1).

The following steps in natural technology, up to colloids and nanoparticles as well as macromolecular compounds, are beyond our interest. Our intention is to describe some details in the development of natural technology and artificial technology, starting from macromolecular compounds.[9]

** K. Adamić in[15] stresses the fact that the terms inorganic (non-organic) and organic are not sufficiently precise. For example, water is an inorganic compound. The contents of living beings can include up to 90 % water, but we assume that they are organic.

Natural technology

The two first basic groups of natural technologies are (Table 2): geological processes of the non-living materials and biosynthesis (synthesis of the living). First, we will follow the inorganic side of natural technologies.

From geological non-living processes and biosynthesis to non-living organic natural products

We assume that the first shaped product in nature was the inorganic polymer, mineral zircon (Zr[SiO4]) and that it is 4.3 to 4.4 billion years old (L2).[21] Other examples of natural inorganic polymers or natural geopolymers are clay, mica, zeolite and gypsum.

Natural non-polymer inorganic macromolecular compounds can be native metals, like gold and mercury, or metal ores (L2).

The basic organic polymers, biopolymers with very complicated and complex forms and structures, are proteins, nucleic acids, and polysaccharides. They are at least 4 billion years old.[22]

Non-polymer organic macromolecular compounds include lipids (L2).[23]

From proteins, nucleic acids, and polysaccharides at one moment in history appeared the living organisms, first microorganisms and macroorganisms (L3), followed by plants and animals (L4). The death and decomposition of living organisms resulted in the non-living organic natural products: crude oil, natural gas, coal, bitumen (L5). This means that fossil fuels are natural raw materials, pure products from nature.

From human beings to artificial technology

Through evolution of animals, at one moment in history our predecessor, the human being, stood upright and began to walk on two feet, 6 or 7 million years ago.

What were the human beings doing in the span from 6 or 7 million years BC to 3.3 million years BC? This was the beginning of the use of natural tools: hand, stone, etc. In this period, the human beings observed that they could use sharp stones to separate some natural products or work on them. Which ones? The answer is: natural inorganic and organic materials. They worked on natural organic materials – wood, bones and skin, as well as on inorganic materials like stone.

The answer to the question when did the artificial, man-made technology begin, has two phases. Humans first observed that with a naturally sharp item (e. g. sharp-edged stone) it is possible to treat materials like bones (a natural polymer of animal origin) and we predicted that the separation of natural materials was older than 3.3 million years.[2] This has been proved in a recent report that presented the evidence of natural stone-tool-assisted consumption of animal tissues 3.4 million years ago at Dikika, Ethiopia.[24,25] Human beings invented the procedure of manufacturing stone choppers and flakes (products) in Lomekwi 3, West Turkana, Kenya, about 3.3 million years ago. This was the starting point of human material culture.[11]

Artificial technology

History of artificial technology

We now know well that the separation of natural polymers is very old as well as the invention and manufacturing of the first tool. In[1] we have described two polymeric artefacts. The oldest wooden artefact is wooden spear II, 2.3 m long, from Schöningen, Germany, 400,000 years old.[26, 27] A very old artefact made of animal polymer, from a femur of a cave bear's youngling might represent the flute. The flute made by a Neanderthal man, found in Divje babe I, Slovenia, is around 55,000 years old. [12, 28, 29] The natural organic polymer in the femur is ossein, collagen from bones. Much later, during the Paleolithic period, one of the very widespread biopolymeric materials was ivory. Ivory is a common name for some animal natural polymers like: elephant tusks from mammoths or Siberian ivory, teeth from sea-cows, walruses, narwhals, hippopotamuses, bones from horses, and shells. Until now, the first artefacts made using stone tools were from mammoth ivory and were found in the cave of Vogelherd, Germany.[30]

In this text, our intention is to discuss four main points in developing artificial materials, from ceramic to synthetic plastics (Table 3).

TABLE 2 – From inorganic and organic macromolecular compounds to non-living organic natural products; A – inorganic non-polymers, B – inorganic polymers, C – organic polymers, D – organic non-polymers[4]

P			Non-living organic natural product (e. g. natural gas)			L5
P			Phytopolymers (e. g. wood)	Animal polymers (e. g. bones, skins)		L4
			Living organic natural products			
P			Biopolymeric organisms (microorganisms and macroorganisms)			L3
P	**Natural:** • Native metals: gold, mercury • Metal ores	**Natural**: • Clay • Gypsum • Mica (glimmer) • Zeolites • Zircon	**Natural:** • Proteins • Nucleic acids • Polysaccharides		Natural	
P	Other natural inorganic macromolecular compounds (non-polymers)	Natural gepolymers (natural inorganic polymers)	Natural organic polymers		Other natural organic macromolecular compounds (e. g. lipids)	L2
	A	B	C		D	
P	Natural inorganic macromolecular compounds (non-living natural products – minerals)		Natural organic macromolecular compounds (living natural products – living organisms)			L1
T	Geological processes of non-living		Biosynthesis (synthesis of living)			
P	Macromolecular compounds (substance)					L0

T – Technology, technique, process; P – Products

TABLE 3 – Activities and results in artificial technology

P	**Metal** • Steels, alloys, Cu-alloys, etc.	**Thermoplastics** • E. g. polysilazanes **Elastomers** • Polysiloxanes **Ceramics** • Alumina	**Thermosets** • PF, UP, PU, etc.	**Thermoplastics** • PE, PVC, PS, PA, etc.	**Elastomers** • Vulcanised rubber (from synthetic rubber) • Thermoplastic rubber	**Thermosets** • PF, UP, PU, etc.	**Thermoplastics** • PE, PVC, PS, PA, bio-fibre from milk (protein-based), etc.	**Elastomers** • Natural rubber (latex) • Planted rubber		
			Fossil-based			Bio-based				
P	Inorganic nonpolymeric substances and materials	Inorganic synthetic polymers (non-living)	Organic synthetic polymers (from non-living)			Chemically modified biopolymers from natural and cultivated products (from living)			E. g. oils	
P	Inorganic substances and materials		Organic substances and materials							L6
T	Controlled inorganic reactions		Controlled organic synthesis			Controlled biosynthesis				
T	Artificial technology									

Ceramic products

One of the earliest artefacts ever discovered is a drinking vessel made of sun-dried clay. We will analyse through the eyes of engineers connected with the production of plastic and rubber parts the following sentences. *Clays exhibit plasticity when mixed with water in certain proportions. When dry, clay becomes firm and when fired in a kiln, permanent physical and chemical reactions occur. These reactions, among other changes, cause the clay to be converted into a ceramic material.*[31]

Our reading is the following. Mineral, inorganic polymer, clay is compounded with water in certain proportion. Then is this compound primary shaped in desired form of earthenware, stoneware and porcelain, followed by drying and furnace firing. Unless the shaped compound is fired, this material possesses no application properties. This is the case of reactive primary shaping, so often in the production of plastics (always for thermosets and in some cases for thermoplastics) and rubber parts. A very important conclusion from this analysis is, as mentioned before, that we can not see thermosets, rubber or ceramic materials. We see only the products made of these materials. This means that the application properties are very strongly dependent on the geometry of the part.

There follows the question: Since when have the products starting from inorganic polymer, clay, been produced? One of the world's oldest ceramic artefacts is the Venus of Dolni Vestonice, from the Czech Republic, 26,000 years old.[32] There are some indications that the oldest ceramic part can be several thousand years older, but without verified sources.

One very important remark is that owing to their excellent application properties, the products made of inorganic polymeric materials are very durable.

Metals

The metals (inorganic non-polymers) from ores are relatively new. In the history of metals, gold was discovered by human beings. In the Stone Age man learned to fashion gold into jewellery and ornaments, learning that it could be formed into sheets and wires easily. However, its malleability, which allows it to be formed into very thin sheets (0.000005 inches), ensured that it had no utilitarian value and early uses were only decorative. After gold, copper and copper alloys have been discovered and developed about 6,000 BC.[33]

Rubber products

Hosler, who reconstructs the history of making rubber parts, found evidence that the Mayan people in ancient Mesoamerica made rubber and used it as far back as 1,600 BC.[34]. In their new research Hosler and Tarkanian indicate that not only did these pre-Columbian people know how to process the sap of the local rubber trees along with juice from a vine to make rubber, but they also perfected a system of chemical processing that could fine-tune the properties of rubber depending on its intended use. For the soles of their sandals, they made a strong, wear-resistant version. For the rubber balls used in the games that were the central part of their religious ceremonies, they processed it for maximum bounciness. And for rubber bands and adhesives used for ornamental wear and for attaching blades to shafts, they produced rubber optimised for resilience and strength. [35]

Chemically modified organic polymers from natural and cultivated products (from the living)

Our intention is just to mention the beginnings in each group of materials. In the group of chemically modified organic polymers, casein-based plastics are probably the first ones. Schobinger (1500 – 1585) described the production of artificial horn, which means the casein plastics. But, Schobinger wrote that the production of artificial horn is older than him.[36]

Now we are witnesses of the renaissance of bioplastics.[37]

Synthetic plastics and rubber

Synthetic plastics and rubber can be made by different polymerisations from natural sources: crude oil, natural gas or coal or from planted products: corn or potato, etc. (Table 3).

The first synthetic plastic was phenol formaldehyde (L. Baekeland, 1907) and the first synthetic rubber was methyl isoprene (F. Hofmann, 1909).[38]

Inorganic and organic plastics and rubber

When we are talking about plastics and rubber, we pay attention practically only to organic products. But inorganic plastics and rubbers are more and more significant in the industry and in education. So the forecasts for these groups of polymers deserve more and more attention (e. g. silicone parts).

Composed and hybrid materials and products

Precisely here we are talking about man-made composed and hybrid materials and products.***

The term composed materials and composed products include composite materials (e. g. reinforced thermoplastics) and composite products (e. g. carbon fibres reinforced epoxy products). Other groups of composed materials are hybrid materials shown in table 1.

*** Wood is a natural composite material with cellulose as natural polymer.

TABLE 4 – Composed materials and composed products

P	• Organic product of synthesis and inorganic polymers (e. g. thermoplastic material and glass fibres)	• Organic product of synthesis (e. g. polyethylene fibres and thermo- plastic matrix) • Organic product of synthesis and cultivated products (e. g. thermo- set matrix and jute) • Organic product of synthesis and inorganic polymers (e. g. thermo- set matrix and glass fibres) • Organic product of synthesis and metals (e. g. metallic reinforce- ment agent and plastic matrix) • Organic multilayer fibres (e. g. bullet proof vests)	• Plastic/rubber/ ceramic products • Hybrid textiles (e. g. carbon/ aramid, aramid/ glass)	Cyborgs: • Animal • Human	• Inorganic-organic polymers (e. g. polymer-zeolite hybrid) • Organic-inorganic polymers (e. g. poly(organosiloxanes)) • Organic xxx + organic basic polymer (xxx and proteins) • Organic polymer + organic non-polymer (e. g. poly(lactic-coglycolic acid) and lipide)	
P	Composite materials	Composite products	Hybrid products (non-living)	Hybrid Hybrid products (living and non-living)	Hybrid materials	
P			Hybrid products (living and/or non-living materials)		Hybrid materials	
P	Composite materials and products (non-living)		Hybrid materials and products			
P	Composed materials and composed products					L7

Composed materials are more and more frequent in practice: composites and hybrids in any possible combination. This field demands more work on systematisation. A first approximation is given in table 4, but this will not be described in details. Very important hybrid products are cyborgs, combinations of living (born human being) and non-living parts made from polymers or metals.

Social criterion for the categorisation of plastics

The main subject of interest of the authors of this paper is the field of plastics and rubber. So we will prove this new systematisation for this field.

There are different divisions of plastics and rubber. The two most frequent ones are the division based on the fundamental processes of polymerisation and on the behaviour of polymeric materials at elevated temperatures.

Bioplastics is not a new term, but they participate only with about 0.5 % in overall production of plastics.[37] However, a number of leading global companies impose bioplastics as an absolute hit, and a universal solution for all the world's problems, particularly for climate change.

This favouring of bioplastics was especially evident during the two K fairs in Düsseldorf, Germany (2007 and 2010). The way of presenting the advantages of bioplastics and propaganda that followed, prompted the authors to respond.[39, 40] In fact, they came to the conclusion that such propaganda that favours bioplastics as a form of plastics derived from renewable biomass sources, such as vegetable oil, corn starch, pea starch, or microbiota, can cause unforeseeable consequences for fossil plastics image and plastics in general.

The authors had in mind the ambiguity of converting food into plastics and especially into biofuel.[41] This led the authors to add a new criterion for the classification of plastics to the existing criteria, according to the origin of the input into the process.[42]. The original criterion for this type of the division is a consequence of culturological analysis of using planted products for the production of bioplastics and biofuel.[43] This is a so-called social criterion of evaluating the technical solution, and some examples and the explanation for this criterion are presented next.

Substances and materials on the basis of plants and animals have been regularly called natural products.[44] This is only partly true. Today, they are rarely used in the production of living natural products that would justify the name of natural substances or material. Such an exception is forest timber, Hevea brasiliensis (rubber tree - material) from which we receive the sap-like extract known as latex (substance) which can be collected and is the primary source of natural rubber.[45] As a rule, the grown matter from the living is used, e. g. cellulose can be obtained from natural or planted wood. By modifying cellulose we make e. g. cellulose acetate (CA). It is similar with raw rubber; it is possible to distinguish between natural, grown, plantation, and synthetic rubber. This should be distinguished regardless of whether the properties of natural and cultivated rubber match or do not match. Starch, sugar, and castor oil are made from cultivated plants such as maize, sugarcane, and castor beans, Corn (grain and stems) is used to make plastic intermediates: lactic acid, homopolymers and copolymers of p-dioxin (PDO), methanol and ethylene glycol.[47] On the basis of sugar from sugar cane, polyethylene (PE) and poly(vinyl chloride) (PVC), for instance, can be made. Polyurethane (PU) and polyamide (PA) are products of castor oil.[47] Cotton is also grown on plantations. From the grown, the wool fleece is obtained from the domestic sheep shearing. Silk can also be a natural object, but it is most commonly farmed from silk worms. The main characteristic of natural organic polymers is the forming by reactions of biopolymerisation.

From this analysis we have come to the conclusion that according to the origin of the substances used as input into the process, the plastics can be bioplastics or fossil plastics (more in[48]). This is a new, additional criterion for the division of plastics. At the same time, this is the base for one of the conclusions from this paper. Bioplastics are also man-made organic polymers and thus just one group of plastics, and at the moment with a very low share in the total production of plastics. Concerning the environmental impact, the criterion for division of plastics can not be the origin of the input into the process, but only the footprints.

Bioplastics and fossil plastics – sources for bags

We decided to make an excerpt from table 1 to emphasise two points. The first one is the origin of inputs into the fabrication process of fossil plastics and bioplastics (Table 5). The second is to stress that all the bags in use now are organic ones (Table 5).

TABLE 5 – Fossil plastics and bioplastics – nature of bags (excerpt from table 1)

Bags **Plastics: PE** (carrier bages – fossil)	**Bags** **Plastics: PE** (carrier bags – bioplastics) **Cotton bags** (planted) **Paper bags** (carrier bags and bags from natural or planted wood)
Organics synthetic polymers (from non-living) **Fossil plastics**	**Chemically modified biopolymers from natural and cultivated products (from living)** **Bioplastics**

The dominant theory is that fossil fuels are formed from dead plants or animals. But this theory has never been proven. So, we decided to cite the researchers from the *Royal Institute of Technology* (KTH) in Stockholm.[47,49] They wrote: *We have managed to prove that fossils from animals and plants are not necessary for crude oil and natural gas to be generated. The findings are revolutionary since this means, on one hand, that it will be much easier to find these sources of energy and on the other hand, that they can be found all over the globe.*[47, 49]

We have to stress that according to Table 5, plastic bags made of fossil or biosources, cotton bags and paper carriers – and other bags from natural or planted wood are all organic ones and all are man-made. So the origin of input into fabrication of these bags is not important. Much more important are e. g. footprints.

Conclusion

In this paper we have combined all the possible knowledge to give a proposal for better systematisation of materials, which must be multidisciplinarily developed. This is more and more needed, because we have more and more combinations of four main groups given in table 1.

Table 6 summarises the whole description of this new systematisation of matter and materials.

TABLE 6 – Summary of the new systematisation of substances and materials

<table>
<tr><td>P</td><td colspan="2">• Organic product of synthesis and inorganic polymers (e. g. thermoplastic material and glass fibres)</td><td colspan="2">• Organic product of synthesis (e. g. polyethylene fibres and thermoplastic matrix)
• Organic product of synthesis and cultivated products (e. g. thermoset matrix and jute)
• Organic product of synthesis and inorganic polymers (e. g. thermoset matrix and glass fibres)
• Organic product of synthesis and metals (e. g. metallic reinforcement agent and plastic matrix)
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• Hybrid textiles (e. g. carbon/ aramid, aramid/ glass)</td><td>Cyborgs:
• Animal
• Human</td><td colspan="2">• Inorganic-organic polymers (e. g. polymerzeolite hybrid)
• Organic-inorganic polymers (e. g. poly(organosiloxanes)
• Organic xxx + organic basic polymer (xxx and proteins)
• Organic polymer + organic non-polymer (e. g. poly(lactic-coglycolic acid) and lipide)</td><td></td></tr>
<tr><td>P</td><td colspan="2">Composite materials</td><td colspan="2">Composite products</td><td colspan="2">Hybrid products (non-living)</td><td>Hybrid proHybrid products (living and non-living)</td><td colspan="2">Hybrid materials</td><td></td></tr>
<tr><td>P</td><td colspan="2"></td><td colspan="2"></td><td colspan="3">Hybrid products (living and/or non-living materials)</td><td colspan="2">Hybrid materials</td><td></td></tr>
<tr><td>P</td><td colspan="4">Composite materials and products (non-living)</td><td colspan="5">Hybrid materials and products</td><td></td></tr>
<tr><td>P</td><td colspan="9">Composed materials and composed products</td><td>L7</td></tr>
<tr><td>P</td><td>Metal
• Steels, alloys, Cu - alloys, etc.</td><td>Thermo-plastics
• E. g. poly-silazanes
Elastomers
• Polysiloxanes
Ceramics
• Alumina</td><td>Thermosets
• PF, UP, PU, etc.</td><td>Thermo-plastics
• PE, PVC, PS, PA, etc.</td><td>Elastomers
• Vulcanised rubber (from synthetic rubber)
• Thermoplas-tic rubber</td><td>Thermo-sets
• PF, UP, PU, etc.</td><td>Thermo-plastics
• PE, PVC, PS, PA, bio-fibre from milk (protein-based), etc.</td><td>Elastomers
• Natural rubber (latex)
• Planted rubber</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td colspan="3">Fossil-based</td><td colspan="3">Bio-based</td><td colspan="2"></td></tr>
<tr><td>P</td><td>Inorganic non-poly-meric sub-stances and materials</td><td>Inorganic synthetic polymers (non-living)</td><td colspan="3">Organic synthetic polymers (from non-living)</td><td colspan="3">ChemicChemically modified biopolymers from natural and cultivated products (from living)</td><td colspan="2">E. g. oils</td></tr>
</table>

P	Inorganic substances and materials	Organic substances and materials				L6
T	Controlled inorganic reactions	Controlled organic synthesis	Controlled biosynthesis			
T	Artificial technology					
P			Non-living organic natural product (e. g. natural gas)			L5
P			Phytopolymers (e. g. wood)	Animal polymers (e. g. bones, skins)		L4
			Living organic natural products			
P			Biopolymeric organisms (microorganisms and macroorganisms)			L3
P	**Natural:** • Native metals: gold, mercury • Metal ores	**Natural:** • Clay • Gypsum • Mica (glimmer) • Zeolites • Zircon	• Proteins • Nucleic acids • Polysaccharides		Natural	
P	Other natural inorganic macromolecular compounds (non-polymers)	Natural gepolymers (natural inorganic polymers)	Natural organic polymers		Other natural organic mac-romolecular compounds (e. g. lipids)	L2
	A	B	C		D	
P	Natural inorganic macromolecular compounds (non-living natural products – minerals)		Natural organic macromolecular compounds (living natural products – living organisms)			L1
T	Geological processes of non – living		Biosynthesis (synthesis of living)			
P	Macromolecular compounds (substance)					L0
P	Composed and hybrid materials and products					L7
P	Production of composed and hybrid materials and products					
P	Inorganic substances and materials	Organic substances and materials				L6
T	Cont- Controlled inorganic reactions	Con- Controlled organic synthesis	Controlled biosynthesis			
T	Artificial technology					
P	Natural inorganic macro-molecular (non-living natural products – minerals)	Natural organic macromolecular compounds (living natural products – living organisms)				L1
T	Geological processes of non-living	Biosynthesis (Synthesis of living)				
P	Macromolecular compounds (substances)					L0
	...					
P	Matter (Quarks, 10^{-20} m)					L-x
T	Natural technology					
T	General technology					Levels

We can not use the term polymers just for plastics and rubber. If we use the concept given in table 1, we can say that bags made of paper, cotton and polyethylene are polymeric bags. And then the criteria for the assessment are footprints and not the origin of materials.

The most important conclusion from this text is that we need the education in the materials and not in plastics or ceramics or metals, at all levels of education.

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On our own account:

Prof. D. Sc. Igor Catic has already been concerned with the central themes globalisation, systematisation, and classification for decades. Publications such as "System analysis and morphological classification of procedures and moulds for injection moulds", "Influence of rubber and plastics on globalisation", and "Globalisation of stone tools and beginnings of mechanical processing of polymers" may serve as typical examples. His paper "Polymers and non-polymers – a new systematisation of substances and materials" being presented here proposes a new classification of materials starting from quarks and aiming at an "interdisciplinary description of complex systems" in the end. Prof. Catic's subject matter may be hard to understand and not everyone will follow such an approach, but we, GV, decided to put the article up for discussion and we would really like to get to know your view on this subject.

CONTACT
Professor emeritus Igor Čatić
University of Zagreb
Faculty of Mechanical and Naval Architecture
Ivana Lučića 5, HR-10 000 Zagreb
E-mail: igor.catic@fsb.hr