New materials as precursors for smart fibers, textiles, sheets and structures

Nové materiály jako suroviny pro vývoj inteligentních vláken, textilií, folií a inteligentních struktur

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Abstract
In the contribution the new materials as precursors for smart fibers textiles and smart complex structures are being discussed. The perception smart is being used in two meanings. The first one is in the sense new, modern and alike the second one in the sense clever, ingenious and intelligent. The perception smart can be used from one extreme to the other one. The meaning of smart materials is that these materials are being used in the future as precursors for smart structure of higher order or that they are being had the properties, these can be called intelligent. For instance they have a memory of some material properties as for example the form memory or the mechanical moduli are.
In the last time there are appearing some materials as glasses, ceramics, polymers which have such properties, which can be get after working to higher complex smart ones.

Key words
Smart materials, smart fibers, textiles, smart complex structures, rubber elastic polymers, electrolytpolymers, electroelasticpolymers, spider web fibers, nanofibers.

1. Introduction

In the 20th century there are discovered many physical properties and phenomena, which cannot be discovered previously. These quite new properties of matter going to the nanometers (molecular and atom dimensions) have been gotten quite new set of submicroscopical properties as the luminescence, transistors, Esaki, Shottky and laser diods are. From the new appearing phenomena the piezoelectricity, ferroelectricity, electrets, electromuninescence, mechanoluminescence and many others are. The aim of the 21th century is to apply all what has been discovered to the more complex structure named the smart ones, so that these new structures have been embodied such properties have been shown that what we are being called material intelligence. These materials are being shown the memory, hysteresis, reaction on the outer or inner stimulation and can be used as sensors as well as actuators. There are many physical properties which can be considered as precursors for smart materials [1],[2]. Some of the most important are being presented in this contribution.

2. Smart materials

The concept "Smart materials" has been firstly appeared in the year 1989 in Japan. The term "smart" is being used in two senses: 1. new, modern and 2. intelligent. The smart materials in the sense new , modern are being developed for the build of the intelligent materials and structures.
What does it mean exactly smart materials? There are the materials which are able to perceive and feel the stimuli from the environment as well as from their inner, to react on stimuli and adapt to them by integration of functionalities in their structures. The stimulus and response can be of electrical, chemical, thermal, magnetic, radiant and other nature.

The smart and/or intelligent materials have been divided into three groups: 1. active smart materials, 2.passive smart materials, 3. intelligent materials. As is being seen the smart materials are having different degree of intelligence but one can evaluate now only qualitative. Quantitative estimation of material intelligence is at present open problem.
Passive smart materials can only perceive and feel the stimuli of the environment as well as of the own inner and are being acted as sensors. Active smart materials have the properties of passive ones and additionally react to stimuli and have also the actuator. The intelligent materials are going further and can adapt the behavior to the circumstances.

3. Smart applicable phenomena

The smart materials are being based on the wide properties of the condense matter [1],[2]. Applicable are being the bulk as well as the surface properties. As examples it is possible to introduce mechanical moduli, strength, friction with their anisotropy, thermal and electrical conductivity, dielectric, feroelectric, piezoelectric, pyroelectric, electret properties,superconductivity and superfluidity. It is possible further to apply the different types of luminescence (electroluninescence, mechanoluminescence, termoluminescence, sonoluminescence and another [1], [2]. It is possible also to meet with applications of properties of liquid crystals, magnetic properties, optical properties and other.

4. Materials for smart structures

The carriers of properties are smart materials. Smart material properties are being sought and found between all types of materials as the metallic, glassy, polymeric, liquid crystalline and composite states are. The most important are the metals, glasses, polymers and composites. The glassy and polymeric state is structure conformable but polymers are more flexible and versatile than glass is [3] ,[4],[5],[6]. Therefore the next text is being restricted for their property richness only to polymers, which can be also modified to fibers.

5. Smart polymers

The polymers are being ranked to the most flexible and versatile condensed materials. Therefore between them it is possible to find the polystructural, polyfunctional , synergetic and intelligent precursors for the creation of intelligent structures. There are crystalline, semicrytalline as well as amorphous ones. Their structure can be relatively easy changed and thus prepared different smart properties. They can be prepared also as polymer liquid crystals [1],[2].They can be appeared also as the structure without symmetry center and thus having the piezo- and pyroelectric properties. The polymers are being also set electrical working and thus prepare polymeric electrets [7].
Smart polymer types and their applications
In this part of presentation the attention will be paid to a group of the most important smart polymers for their application.
Polypropylene
This is the most applicable polymer for technical and web textiles. The polypropylene is possible easy to be converted into electret one. It is sufficient to expose the polypropylene sheet to the glow discharge, its surface (Tamm) energetic level are being occupied with charge particles and polypropylene is being turned into the electret. The split sheets are converted into fibers and their web can be used for effective air filtration and ion separation.

Polyvinylchlorid(PVC), polyviniliden fluorid, polytrifluorclorethzlen and their copolymers

After some stretching operation these polymers are getting piezo- and pyroelectric [1], [2]. The corresponding pizoelectric coefficients

$d_{ijk}=\partial^2 G(E_i,T_{jk},T)/\partial E_i \partial T_{jk}$ and pyrolectric coefficients $p_i = \partial^2 G(E_i,T)/\partial E_i$ (1)

where G is Gibbs thermodynamical potential, E_i is the electric field intensity, T_{ij} is the stress tensor and T absolute temperature. Although the piezo- and/or pyroelectric coefficients are two hundred times for polymers smaller than for ceramics, the electromechanical coupling coefficient is in both cases comparable. Nearer information about the electret polymers in application is being found for instance in [8], [9].

Rubbers

Very important group of polymers are resin elastics, rubber. Their most important thermomechanical properties are very often applied. Their Poisson number is being reached the limit value ½ and there are very stretched out. For the stretched out force F it can be thermodynamically deduced the following formula

$$F = - T (\partial S/ \partial L)_T \quad (2)$$

S is entropy and L length of elongation.

From this relation it is evident that the force origin is in the entropy change and is conformational.

During the stretching the temperature is changing after the formula

$$\Delta T = - (T/C_L)(\int_{L_0}^{L} (\partial S/\partial dL)_T \, dL \quad (3)$$

Because the entropy is being during the drawing droped , the ΔT is being rised.

Polyelectrolytes

Polyelektrolytes are the particular polymers which are being dissolved in the polar solvent and can create kations and anions, they are being dissociated. That is being happened when mer units of the polymer chain are having groups of ionizable atoms. As an example it is being shown the anionpolyelectrolyte the polyacrylonitrilacid and kationelectrolyte polyvinyl-p- butylpyrinidinbromid. The repulsive forces are being rectified the polymer balls in solutions. They can be neutralized with the low molecular ion a their length is being changed. Polyelectrolytes are electrical conductive. Together with medium changes there are being occurred also the changes in configurations and conformations and macroscopic also the form changes. Chemical energy is being altered to the mechanical one. This phenomena are the basis of mechanochemistry.

Electric conductive polymers

The polymers are generally well known as good isolating materials. Therefore it has been gone to the great surprise when the discovery of the conducting polymers has been declaired. This very important discovery has been awarded with Nobel price for the year 2000 (A Heeger, a.G.Macdiarmid, H,Shirakawa, [9]). The candidates for electrical conductive polymers it is necessary to seek between the unsaturated hydrocarbons. One of such polyhydrocarbons is polyacetylene doped with chlorine (P- type) and sodium (N-type)(Fig.1). With such conductive polymers the semiconductive elements can be

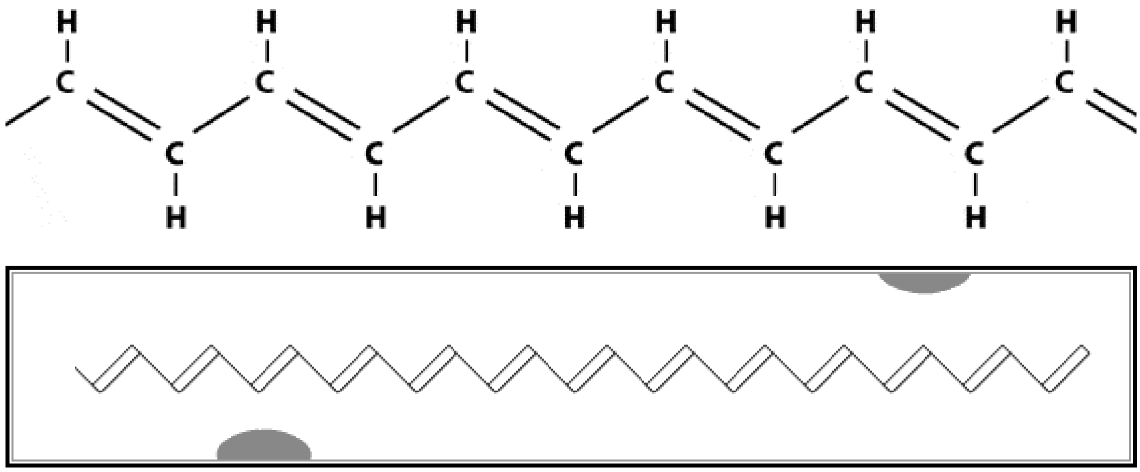

Fig.1 Polyacetylen doped with chlorine and natrium

carried out. These polymers are also electroluminescent and are being shown a series of the unusual semiconductive properties (see [1], [2]). These polymers are being well ranked between polyfunction smart materials for their universality and versality.
To the group of conductive polymers there are being belonging also superconductors. It has been shown that also some organic materials are being exhibited superconductivity. These problems are quite open.

Electroactive elastomery (EAE)
To the simulation of the activity of the animal beefs, the new types of materials has been sought. It is necessary for these materials to stretch their dimensions some hundreds percents. These materials have been called elctroactive elastomers (EAE). The chosen elastomers are the polyurethane, silicon-, acrylate- and nature rubber. The layer of these materials are being placed between condenser desks and high voltage has been connected to this condenser. After voltage application the EAE is being very much stretched. and conversely after deformation the voltage on the capacitor desk is being appeared. Because the stretching is very high the EAE can be used for the realization and simulation the animal beefs and because the voltage after deformation is also very great can EAE materials serve also as electricity generators.

Scintilation polymers
Some polymers activated with luminescent activators can embody the scintillation properties and can be used also as the detectors of charged particles as well as for the neutron. From the scintillation polymers the activated polymethylmetacrylate (PMMA) is being used.

Biopolymers
From all materials the most intelligent ones are the biomaterials. For the production of synthetic biopolymers the biotechnology is being applied.

6. Smart fibers
The fibers are the most applicable material form in the living organisms. The fiber properties are enhancing the same material in bulk. The fibers are having the high strength, great surface and great volume ratio of the surface structure to bulk structure. Surfaces are also entrance gateway to the material bulk through the diffusion. The fibers

have also very high flexibility strong inversely dependent to the 4^{th} fiber radius power [.
Because the fibers are handled to the 1D, 2D and 3D structures using the textile technology, is the fiber and its 1D,2D and 3D structure application wide-spread in material science, especially for technical textiles and textile composites.
The very important applications of all smart polymers are in progress and object of contemporary research for fabrications smart structures and systems [4].
As the smart fibers is allowed to be the fibers prepared from the special polymer types as the conductive, semiconductive, superconductive, optoelectronic, luminescent, polyelectrolyte, electroactivated elastomers. From the semiconductive and conductive, optoeletronic fibers are being used for lighting, making, the fiber lasers and optoelectronic nets. These polyfunction fibers are being used for the production of flexible light color area elements, for optoelectronic network and in future of smart textiles and fiber optical computer.
The scintilation polymer fibers will be used for cosmonaut clothing as the radiation detectors together with other smart material parts.
The piezoelectric and pyroelectric fibers are being used for the aerial operation and transport saveness check.
In the fiber technology there are being appeared quite new technologies as the spider and nanofibers are.
The spider fibers technology is derived from biotechnology and polymer technology. The spider fiber have very high mechanical properties.
The nanofibers are being produced using the melt blown technology [10] and the high electrostatic fields [11], [12], [13].

7. Smart textiles

From the smart fibers the smart textiles are being produced length (1D), area (2D) and volume (3D) textiles. From the nanofibers the filtration web fabrics are being put out, from the conductive fibers the area lighting elements are being produced, the Joule-heated textiles, from optoelectronic fibers the fiber lasers and optical network can be build. Itcan be say that the future is being belonged to smart textiles.

8. Smart clothing

The interest about smart clothing has been appeared in the at the end of 1990s, which was the cooperation between Levi´s and Philips. The small electronic apparatuses as microphones, earphone and mobile phone and the MP3 players have been put into the coats. This addition and integration electronic devices- clothing has not be synergetic. The further development is to add to the textile also the conductive fibers and other technical ones. It has been appeared the textiles as sensors. To implement the data processing devises directly in textiles have not be yet realized. The actuator function of textiles can be carried out after invention data processing textiles.
For the communication of clothing with the wider environment, the wireless connection is being needed that is meaning to realize in clothing the antenna what it is possible.

9. Estimation , closure and future

In the short review the problematic of the smart materials especially the polymers have been reported. The smart materials are being based on the known and new phenomena in the condense matter. The polymers have been shown as the most universal and versatile materials the most suitable for textile research and industry and for making new textile products arising from smart polymers.

This endeavors have to be based on the interdisciplinarity between technological domains as the biotechnology, optoelectronics, polymer chemistry, material science and computer science are.
The smart materials, fibers and textiles are fast developed which is making the textile branches again actual a preparing a new boom for them.
At the end the question is still putting. Where to look forward the subject matter for the smart materials, fibers, textiles and applications? The answer is not so difficult: Between the Nobel price discoveries in natural sciences [9] , in technical sciences and in the nature. To these efforts can also help a new discipline biomimetics.
In the future it will be appeared new fibers derived from carbon polyins and polycumulens a quite new 1D,2D and 3D structures derived from fullerenes [1] (chap.20.p.461], [2] (chap.20).

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