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Green Nanotechnology

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Abstract

This article described some nanomaterials and nanoproducts based nontoxic materials according on existing principles of green chemistry and green engineering.

This article describes some laboratory experiments and results of additives to polymers in order to improve their properties.

This article describes some laboratory experiments and results of adding natural substances in the form of nanopowders to polymers in order to improve their properties.

Keywords: Green nanotechnology, nanomaterials, nanopowders, epoxy binders

Green nanotechnology has two goals: producing nanomaterials and products without harming the environment or human health and producing nanoproducts that provide solutions to environmental problems. It uses existing principles of green chemistry and green engineering to make nanomaterials and nanoproducts without toxic ingredients, at low temperatures using less energy and renewable inputs wherever possible, and using life cycle thinking in all design and engineering stages.

Green nanotechnology aims to develop clean technologies to minimize potential environmental and human health risks associated with the manufacture and use of nanotechnology products and to encourage the replacement of existing products with new nanomaterials that are more environmentally friendly. There are two key aspects to green nanotechnology. The first involves nanoproducts that provide solutions to environmental challenges. These green nanoproducts are used to prevent harm from known pollutants and are incorporated into environmental technologies to remediate hazardous waste sites, clean up polluted streams, and desalinate water, among other applications. The second aspect of green nanotechnology involves producing nanomaterials and products containing nanomaterials with a view toward minimizing harm to human health or the environment - Green nanotechnology involves the following:

- Use of less energy during manufacture
- Ability to recycle after use
- Use of ecofriendly materials

The most important component of nanotechnology is nanomaterials, that is, materials with the ordered structure of their nanofragments having sizes from 1 to 100 nm. The production and process aspects of green nanotechnology involve both making nanomaterials in a more environmentally benign fashion and using nanomaterials to make current chemical processes more environmentally acceptable. A 2023 estimate by the Nano Business Alliance identified nanomaterials as the largest single category of nanotech startups. There are two basic ways to create Nano objects (3):

- Reduce the size of macroscopic objects (dispersing, disintegrating, or grinding to the cluster level using a ball mill or using the mechanochemical synthesis)
- Create nanostructures from atom and molecule (crystallization) clustering, nanostructuring, nucleation, condensation, coagulation, polymerization, etc.

The first ways illustrated producing nanopowders of organic products using an original hyper-resonant dispersant is proposed. The results of nano-dispersion for four agricultural products are given. Obtaining nanopowders of organic products: polymers and agricultural products is one of the most important tasks of modern nanotechnology. A review of methods for dispersing organic polymers and products was presented in (US Patent, 2013). Using the principles of abrasive-vortex dispersion, a technology has been developed that provides organic particles with a size of 900-1300 nanometers.

Subsequent additional grinding by the piezoelectric method made it possible to increase the dispersion of organic nanopowders by 10-15%. Similar results were obtained by Japanese researchers (WO Patent, 2013). Therefore, to grind plastic substances such as organic matter, it is necessary to apply a completely different principle of influence on the substance being crushed.

To grind plastic organic substances, it is necessary to apply a completely different principle of influence on the substance being ground, for example, using the principles of hyper-resonance, described earlier in the work on the wave theory of polymer strength (WO Patent, 2013).

Nano-powders of 4 types of organic products were obtained using an original hyper-resonant dispersant; tests of which confirmed the possibility of obtaining powders with a dimension of less than 500 nm - see Table 1.

Substance	First common size	Second common size	Energy consumption per 1 kg of substance
Grape seeds	244.3 nm \ 93.1 %	11.25 nm \ 6.9 %	7 kW / kg
Reishi mushroom	197.5 nm \ 70.06 %	143.3 nm \ 29.7 %	8 kW / kg
Amaranth	288.9 nm \ 100%	0.000	5 kW / kg
Oats	482.8 nm \ 97.36 %	467.6 nm \ 2.64 %	8 kW / kg

Table 1: Nano-powders of 4 types of organic products

As can be seen from Table 1, the possibility of obtaining organic nanopowders was demonstrated for the first time using the example of 4 types of products with sizes less than 500 nm, and in most cases less than 300 nm. Grape seed nanopowder is used mainly in medicine, as a remedy for varicose veins and has a powerful antihistamine and antiparasitic effect. Reishi mushroom nanopowder contains microelements (especially high levels of germanium), organic acids, polysaccharides, coumarins, vitamins, and phytoncides. The most important compounds of the fungus are triterpenes, polysaccharides, ganodermic acids and germanium.

It is these compounds that determine the medicinal properties of the mushroom as a means of strengthening the immune system and suppressing the development of tumors of various origins, increasing blood oxygen saturation. It also helps normalize blood pressure, lower cholesterol levels, and prevents the formation of blood clots.

Academician N.V. Vavilov predicted that amaranth would be the main grain crop of the 21st century. Amaranth nano-powder is an easily digestible, perfectly balanced protein and proteins, which makes it widely used in the diet of athletes to increase muscle mass. The plant fiber included in its composition improves intestinal function, promotes weight loss and cleansing of the intestines. Amaranth nano-powder is included in baby and medical nutrition. Nano-oat powder consumers have the highest HFI (healthy nutritional index) and lower body weights, waist circumferences, and body mass indexes. The use of such oat powder, due to the presence of dietary fiber and polyphenols - avenatramide, prevents the incidence of colon cancer.

This nanopowder is especially widely used in cosmetics as it performs many functions: it is an anti-inflammatory component, an astringent, an emollient, and a protective element that promotes skin regeneration after damage (restores the protective barrier of the epidermis); also provides the skin with significant hydration, has antioxidant properties - inhibits the development of oxidative stress induced by ultraviolet radiation. Currently, research has begun on nano-dispersion of engineering thermoplastics, in particular fluoroplastics.

The second ways illustrated epoxy-rubbers nanocomposites. Epoxy oligomers were cured with amine hardeners: polyethylene polyamines, diethylenetriamine, xylenediamine and diaminodiphenylhexafluoropropane. Oligomeric (molecular weight no more than 25,000) rubbers of various structures were used as modifying additives: carboxylate butadiene nitrile, divinyl isoprene (ПДИ-3- with terminal epoxy-urethane groups, ПДИ-В - with terminal vinyloxy groups), fluorine rubber СКФ-26-0НМ, non-isocyate polyacetalurethane rubber Acetur. In addition to carboxylate serial rubbers with a statistical arrangement of carboxyl groups, butadiene nitrile oligomers with terminal carboxyl groups СК-30-КТР of various molecular weights were also used. The work used fluorine-aliphatic surfactants with terminal mono-amine, amide, carboxyl and hydroxyl groups with a molecular weight of 250 - 2500. The following methods were used to obtain data on the phase structure of the sample under study using an electron microscope:

- ultra-thin sections with a thickness of ~ 400 A ˙ were obtained from the sample of the binder after its complete hardening, after which the preparation was examined using an electron microscope with a resolution of at least 8 A ˙ in high contrast mode with an accelerating charge of 75-100 kv. We used an LKB ultramicrotome (Sweden) and a JEM-100B microscope (Japan).
- a sample of the binder after its complete curing was cooled to the temperature of liquid nitrogen and a brittle fracture was obtained, the surface of which was subjected to ion sputtering to obtain a conductive layer with a thickness of 150 A ˙ and then examined using a scanning electron microscope with a resolution of at least 150 A ˙ at an accelerating voltage 20-25 kv. We used the TV-Z ion sputtering installation (Japan) and the JSM-Z5 microscope (Japan).

The absolute specific phase interface was determined from micrographs by the random secant method, and the relative specific phase interface was determined by the point method in combination with the secant method adopted in stereology (6).

Establishing the optimal structure of binders is the most important task, since it makes it possible to obtain binders and polymer solutions with a complex of the most favorable properties. We conducted studies of the influence of the content of 4 different rubbers and the properties of 4 different epoxy binders. We investigated epoxy rubber binders used as the basis of materials for anti-corrosion protection. Moreover, both diene rubbers with a statistical arrangement of reactive groups (СКН-26-1А) and with terminal reactive groups (ПДИ-3 and ПДИ-В) and non-isocyanate polyurethane rubber (Acetur) were covered.

Analysis of experimental data (a typical pattern is shown in Fig. 1) shows that the optimum physical and mechanical indicators of the properties of binders observed in the region of maximum values of the absolute specific phase interface. S observed in the region of maximum values of the absolute specific phase interface.

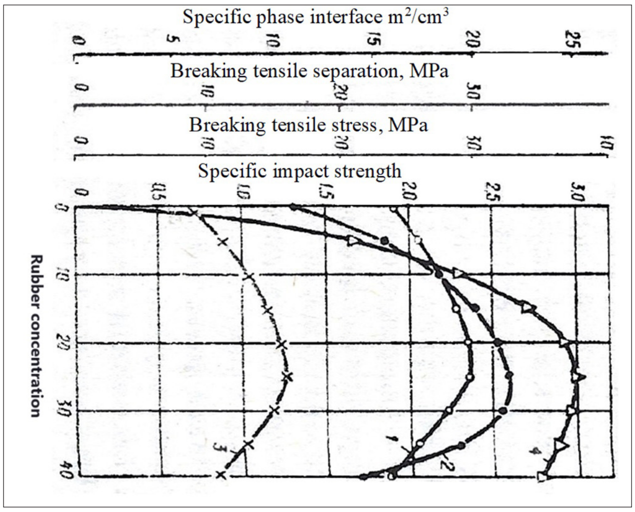

Figure1: Properties of a heterogeneous epoxy-rubber binder depending on the rubber concentration

1. specific impact strength;
2. breaking tensile stress;
3. the same, right separation;
4. specific phase interface.

The concentration dependences of the absolute specific phase interface are extreme and are described by equations of the same type.

$$S=aC-bC^2+cC^3-dC^4$$

For the four systems studied, they are expressed accordingly:

$S_1 = 3.2C_1 - 0.16C_1^2 + 0.0037C_1^3 - 0.000034C_1^4$

$S_2 = 1.54C_2 - 0.095C_2^2 + 0.0026C_2^3 - 0.00027C_2^4$

$S_3 = 2.93C_3 - 0.315C_3^2 + 0.0143C_3^3 - 0.00023C_3^4$

$S_1 = 0.43C_4 - 0.042C_4^2 + 0.0017C_4^3 - 0.00003C_4^4$

In increase in specific impact strength is achieved, respectively, with an increase in the intergrid distance (M_c) of the epoxy polymer, a decrease in the Mc of the rubber and an increase in its content. The specific surface area of the phases in the epoxy rubber binder increases with a decrease in the Mc of the polymer and rubber and the concentration of rubber from the values of these parameters at the zero level. When approaching the composition x to the extreme by determining both the step of values (X_1, X_2, X_3) and their vector, binding properties with higher property indicators are obtained (Table 2), and the optimum property indicators are established not only when the structure of the epoxy polymer and rubber is optimal, but also at optimal. microconglomerate structure. The integral indicator of this structure is the specific surface area of the phases. Indeed, as can be seen from table. 2, the extrema of the properties (y_1=87.3, y_2=7.4, y_3=2.0) are achieved at the maximum specific interface between the phases (y_4=11.9).

Structure parameter values			Value of property parameters			
X_1	X_2	X_2	$У_1$	$У_2$	$У_3$	$У_4$
460	2715	12	84.8	7.3	2.0	11.8
483.5	2615	9.4	87.3	7.3	2.0	11.9
507	2515	6.8	87.5	7.0	2.1	11.7

Table 2: Influence of structure parameters on properties

Analysis of experimental data shows that the introduction of flour-surface active matters allows rubber phase to be dispersed in the epoxy polymer matrix; at their concentration of 0.4-0.7%, a significant increase in the interface between phases in the binder is achieved, especially when moving from hydrocarbon rubbers to fluorocarbon rubber. An increase in the specific phase interface leads, as expected, to an increase in tensile stress and specific impact toughness.

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