Investigation of conditions for creation of hydrophobic coatings

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ABSTRACT

As part of the planned work, work was carried out to create hydrophobic fillers and waterproofing construction materials based on the obtained carbon nanomaterials with superhydrophobic properties, such as water-repellent and self-cleaning surfaces, anti-corrosion paints. To achieve this goal, a hydrophobic silica powder, obtained by burning silicon waste, and a hydrophobic carbon black, which is formed during combustion of the propane-butane gas mixture, was applied to the surface of the metal and drywall and the surface properties of the materials were investigated. Work was done on imparting waterproofing properties to putty using superhydrophobic carbon black as a filler. Studies have shown that the addition of soot increases the hydrophobic properties of the putty to a certain limit, the maximum wetting angle (above 150 °) was recorded at a concentration of soot equal to 8%.

Keywords: hydrophobic coating, silicone waste, hydrophobic powder.

1. Introduction

Currently, there is a wide range of modern hydrophobic coatings that provide reliable protection against the impact of aggressive environmental components and reduce absorption of water by the surface of materials. But their main disadvantage is the high production cost. In addition, over time, water flushes out hydrophobic compounds and, therefore, with a certain interval, they need to be restored. If you take into account the expensive cost of these materials, the economic part of this issue plays an important role.

Therefore, today there is a need for hydrophobic composite materials, the production of which would be profitable making their application effective [1].

2. Experimental part

With this aim in view, a method was developed for synthesizing nanodispersed superhydrophobic powder formed in the process of incineration of silicone waste materials was developed [2].

The waste silicone products were placed in a metal container and then ignited, the resulting material was milled to the required grinding. As a result, a polydisperse powder of gray color was obtained (Fig. 1).

Elemental analysis of the obtained powder showed a high content of silicon, as well as the presence of oxygen and carbon.

The contact angle of wetting the surface of the powder exceeded 150 degrees, i.e. wetting practically does not occur. The optical images presented in Fig. 2 show the presence of particles of different sizes from 10-12 μm to 100-200 μm. The particles are stacked in rounded aggregates.

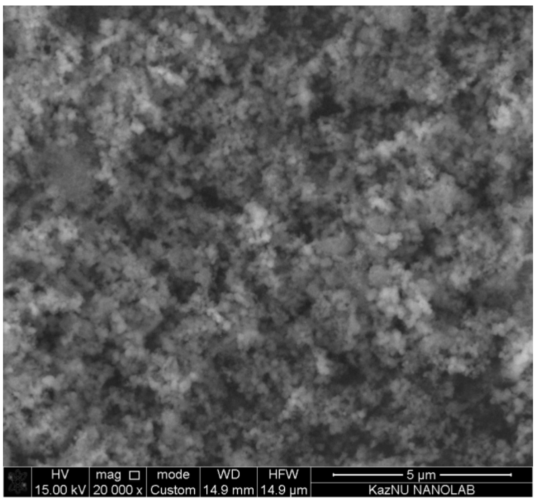

Fig. 1. Electron microscopic image of a powder obtained from silicone waste.

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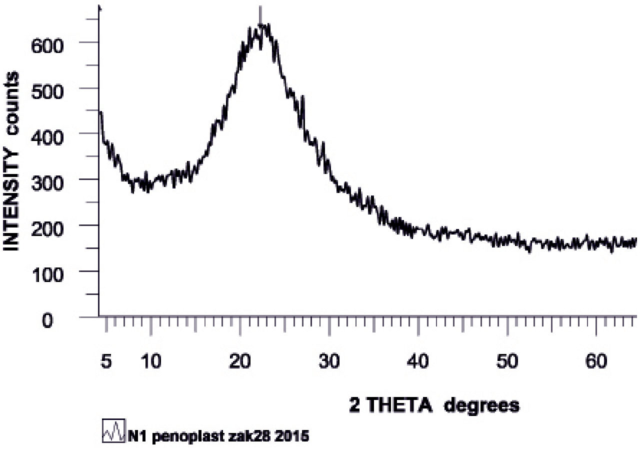


Fig. 2. X-ray diffraction pattern of the powder obtained from silicone waste.

Figure 2 shows its X-ray diffraction pattern which shows the absence of crystalline phases and the presence of only an amorphous phase.

The resulting hydrophobic powder was used to create anti-icing coatings.The problem of using superhydrophobic coatings for anti-icing purposes in aviation is relevant, since about 7% of aviation accidents are associated with icing of an aircraft [3]. For example, for aircraft and helicopters, accumulation of ice leads to a change in the shape of the aircraft, its air flow around it and the corresponding aerodynamic forces and moments.

The main negative effects of icing are associated with an increase in aerodynamic resistance, a decrease in the stall angle and lifting force. In addition, icing of the measuring and control equipment leads to violation of its normal operation and controllability of the aircraft. In recent decades, significant efforts by engineers and researchers have been aimed at both a more detailed understanding of the physico-chemical phenomena that determine the processes of icing, and creation of more effective systems for preventing icing and fighting its effects. The results of studies already conducted have shown the need to solve two problems.

This, firstly, prevents or slows down the transition of supercooled water droplets falling on the structural elements into a solid state, followed by their removal from the surface under the action of air currents. Secondly, it reduces the adhesion of already formed ice deposits to the surface of structural elements and equipment, which contributes to the removal of ice under the influence of aerodynamic forces.

3. Results and discussion

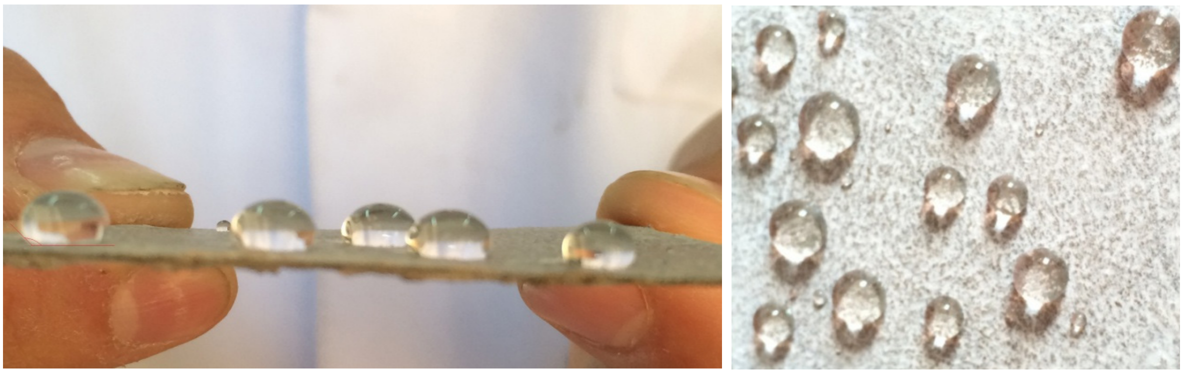
In the proposed study, based on the obtained nanodispersed powder and polyphenyl sulfide used as a binder, an anti-icing composite was developed and created. The process of applying it to the surface of duralumin consisted of several stages. Initially, the metal surface was applied with a brush of TritonX-100 and then a powder of polyphenyl sulfide was sprayed over the surface. The sample was then heated to 320 °C for several minutes. After cooling, a silicone gel was applied to the sample surface with a brush.

Then, a nanosized silicon oxide powder obtained from silicone waste was sprayed onto it. The coated sample was kept at a temperature of 335 °C for an hour. The final result is formation of an anti-icing coating. The resulting surface has a hydrophobic property, the wetting contact angle is 160 °. The expected service life of the de-icing coating obtained is 5 years.

Figure 3 shows a picture of the behavior of water droplets on a synthetic coating that was applied to a metal surface.

The obtained composite material has a high adhesion not only to metals, but also to wood, cardboard and glass. The tests were carried out to blow the coating applied onto the surface of the duralumin plate at a temperature of -5 °C. The results of the research showed that about 20% of the entire surface

Fig. 3. Behavior of water droplets on a synthetic de-icing coating applied to a metal surface.



(a) (b)

Fig. 4. Anti-icing coating on the surface of the slate: (a) – front view; (b) – top view.

is covered with an ice crust, and a small force effort leads to separation of the ice crust from the surface.

Also, laboratory studies were conducted to create an anti-icing coating on roofing slate. To create an anti-icing coating on the slate, silicon dioxide, synthesized according to the above method from silicone waste and carbon black, obtained from the combustion of hydrocarbons, the content of which was 20%, was used. Such soot, formed under certain conditions (temperature, pressure, fuel/oxidizer ratio), has superhydrophobic properties [4].

A thin layer of TritonX-100 gel was applied on to the slate surface. After drying, polyphenylene sulfide (PPS) was sprayed onto the surface and the sample was heated at 320 °C for 1 hour. After cooling, a thin layer of Triton X-100 gel was again applied to the surface. After drying, a thin layer of silicone was applied to the surface.

A mixture of silicon dioxide powder and carbon black was sprayed onto the silicone surface. The sample was heated at a temperature of 380 °C for several hours. As a result of these operations, a gray anti-icing coating was formed.

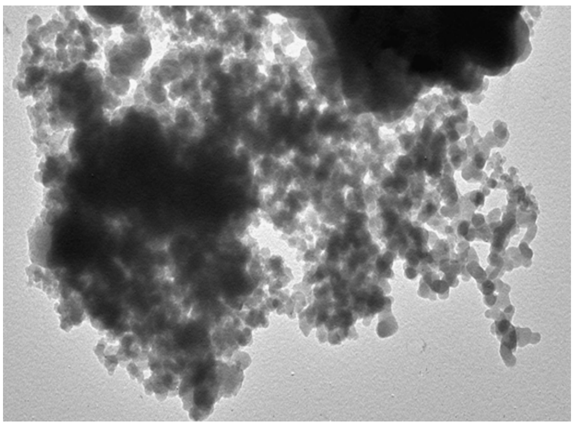
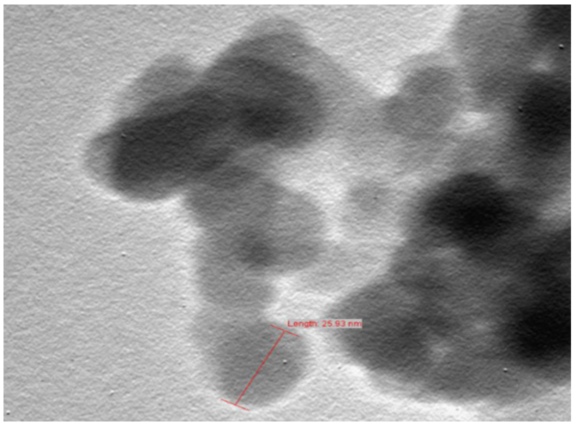
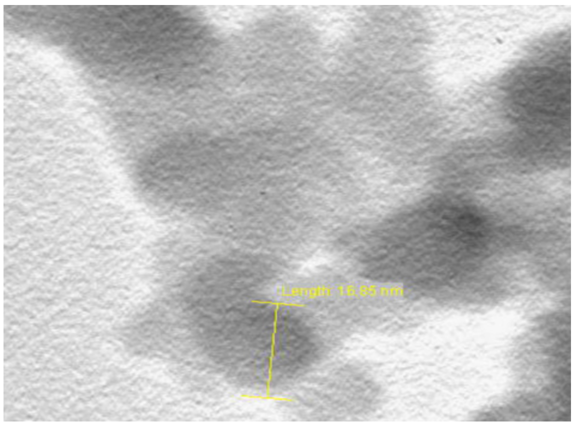


Fig. 5. Photograph (TEM image on a scale of 1 x 60 000) of samples of the glass surface treated by gas-thermal spraying.

Figure 4 shows photographs of the de-icing surface on the slate with droplets of water. The contact angle of wetting is more than 150 °. In the next series of experiments, the possibility of applying hydrophobic powder to glass by the method of gas-thermal spraying was investigated. As is known, the method of gas-thermal spraying is the process of heating, dispersing,



(a)



(b)

Fig. 6. Photographs (images of translucent electron microscopy: (a) – magnification in scale 1x200 000, (b) –1x150 000 increase in scale).

and transferring condensed particles of a sputtered material by a gas or plasma flow on a substrate to form the necessary layer [5]. For this, the hydrophobic powder was milled (mechanically activated), then it was mixed with ethyl alcohol in a ratio of 1:2 until complete dissolution, then the mixture was sprayed into a gas flame. Sprayed droplets in a gas stream reached the glass surface.

After evenly spraying the mixture on the glass surface, the sample was left to dry completely. The treated glass surface after application of water droplets on it showed superhydrophobic properties.

The contact angle of wetting the surface was more than 150°, the water droplets did not spread over the glass and kept their shape for a long time. In addition, some areas of the superhydrophobic surface were transparent, which demonstrates the great advantages of the gas spraying method used. When beating against the rough surface of the glass, the smallest particles that have a high temperature equal to the temperature of the flame get deformed and, penetrating into the pores and irregularities of the surface, form a coating impervious to drops of water. The obtained samples were examined by the method of transmission microscopy (TEM). Figures 5 and 6 show TEM images at various scales.

With a large scale increase, it is seen that on the glass surface there are mainly rounded silicon particles with the sizes of about 16 ± 25 nm. Dark places in the pictures speak of superimposition of several or more silicon particles, in these places supposedly glass is opaque.

The glass retains its transparency, if individual nanoparticles with the sizes from 6 to 16 nanometers were deposited on the surface. Thus, further work on creation of a hydrophobic glass should go in the direction of obtaining a nanosized monolayer on the glass. For this purpose, the most promising is the use of the method of gas-thermal spraying.

In the course of further research, a hydrophobic powder was used to create a loose hydrophobic material based on river sand. The created bulk material is characterized by good water-repellent properties and durability. Previously, the data on the conditions for obtaining hydrophobic sand using superhydrophobic soot obtained by burning hydrocarbons were presented in [6]. In the course of further research, soot was replaced with a

Fig. 7. Water droplets on the surface of hydrophobic sand.

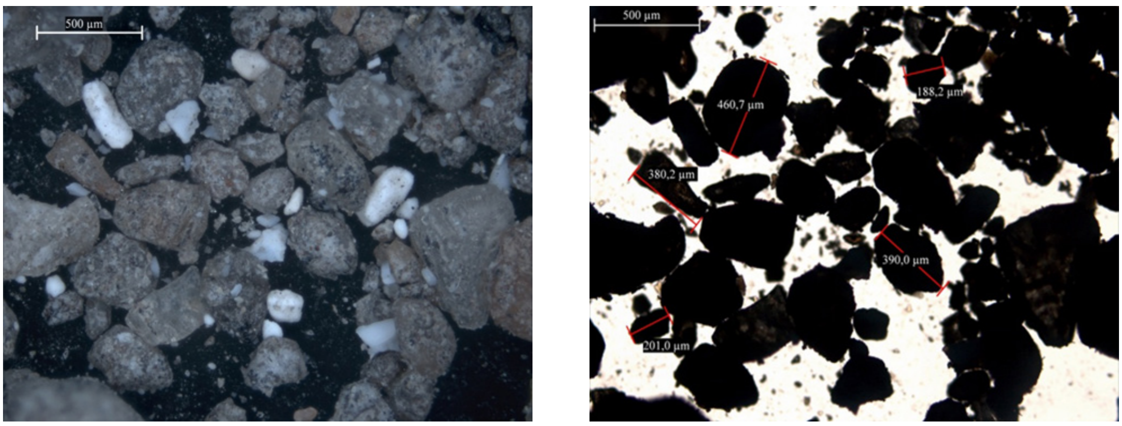


Fig. 8. Optical microscopic image of the surface of grains of sand.

hydrophobic powder. This made the process of obtaining a bulk hydrophobic material based on river sand more economical.

Figure 7 shows a photograph of the behavior of water droplets on the surface of the hydrophobic sand obtained. The angle of wetting of water droplets was more than 150 °. When immersed in water, it does not sink, but floats on the surface of the water.The obtained sand was investigated by optical microscopy, optical images are shown in Fig. 8. The studies have shown that a hydrophobic powder does not envelop the surface of grains of sand, but only uniformly mixes with them.

The size of the obtained grains was about 200-400 μm. Along with the experiments discussed above, attempts have been made to apply a hydrophobic powder to the surface of the enamel paint. Optical images of the samples of the obtained hydrophobic surface on the enamel coating demonstrate the presence of particles of approximately the same size of about 2.5-5 μm, the particles have predominantly rounded shapes. The wetting angle is more than 150 degrees. It can be assumed that the upper layer has a structured surface of elevations and depressions formed by particles, which in our case have an average diameter of about 200-300 nanometers.

Conclusion

The results showed that the obtained hydrophobic sand remains completely dry for a long time without losing its hydrophobic properties. The obtained hydrophobic surfaces can find application in those areas of technology where it is necessary to impart the properties of self-cleaning to the surface, as well as in domestic applications, for example for treating glasses and car bodies. Thus, using recycled wastes of organosilicon compounds, relatively cheap hydrophobic coatings can be created.

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Гидрофобты жабындылар алудың шарттарын зерттеу

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Аңдатпа

Жоспарланған жұмыстардың шеңберінде аса гидрофобты қасиетке ие көміртекті наноматериалдар негізінде алынған су жұқтырмайтын және өздігінен тазаланатын беттер, коррозияға қарсы сырлар секілді, гидрофобты толтырғыштар мен гидроизоляциялық конструкциялық материалдарды алу жөнінде жұмыстар жүргізілді. Қойылған мақсатқа жету үшін силикон қалдықтарын жағу кезінде алынған кремний диоксидінің гидрофобты ұнтағы мен пропан-бутан газ қоспасының жануы кезінде түзілетін гидрофобты көміртекті күйе металл, гипсокартон бетіне жағылып, материалдардың беттік қасиеттері зерттелінді. Шпаклевкаға гидроизоляциялық қасиеттер беру мақсатында толтырғыш ретінде аса гидрофобты көміртекті күйені қолдана отырып зерттеу жұмыстары жүргізілді. Зерттеу нәтижелері бойынша күйені қосу кезінде шпаклевканың гидрофобты қасиеттері белгілі бір шекке дейін, масималды жұғу бұрышы (150 ° жоғары) концентрациясы 8% күйені қосқан кезде артатыны анықталды.

Түйін сөздер: гидрофобты жабындылар, силикон қалдықтары, гидрофобты ұнтақ.

Исследование условий создания гидрофобных покрытий

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Аннотация

В рамках запланированных работ были проведены работы по созданию гидрофобных наполнителей и гидроизоляционных конструкционных материалов на основе полученных углеродных наноматериалов обладающих супергидрофобным свойством, такие как, водоотталкивающие и самоочищающиеся поверхности, антикоррозийные краски. Для достижения поставленной цели гидрофобный порошок диоксида кремния, полученный при сжигании силиконовых отходов, и гидрофобная углеродная сажа, которая образуется при горении пропан-бутановой газовой смеси, наносился на поверхность металла, гипсокартона и была исследована поверхностные свойства материалов. Были проведены работы по приданию гидроизоляционных свойств шпаклевке с использованием в качестве наполнителя супергидрофобной углеродной сажи. Исследования показали, что добавление сажи повышает гидрофобные свойства шпаклевки до определенного предела, максимальный угол смачивания (выше 150 ^{o}) был зафиксирован при концентрации сажи, равной 8%.

Ключевые слова: гидрофобное покрытие, силиконовые отходы, гидрофобный порошок.