smart
NANOTECHNOLOGIES

INDUSTRIAL
CATALOG

smartnanotechnologies.com

TABLE OF CONTENTS

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NANOTECHNOLOGIES

01 About us

We have been with you since 2013, actively working in the field of combating microorganisms, bacteria and viruses. Thanks to our experience, commitment and extensive specialized knowledge, over the years we have developed a number of innovative materials and products dedicated to solving specific problems. We operate in the industrial sector, specializing in antibacterial additives for plastics, but also in the production of colloidal solutions of nanoparticles. We offer various types of coatings: with antibacterial properties, hydrophobic and hydrophilic characteristic. Smart also has an Agro department that cares for the welfare of small and large animals.

- The highest quality products with silver nanoparticles
- Innovative solutions in the field of nanotechnology
- Support for many industrial sectors
- Comprehensive customer service and consulting
- Certified solutions that meet international standards

02 Our brands

SMART CleanAir

SNT-Ag Service

GLADOC

AGuscio

POLYDEF
LINIA BIOBÓJCZYCH DODATKÓW DO POLIMERÓW

SILVEREPOXY

Private Label

03 Private labels and personalized solutions

Private Label

Private label products are gaining popularity because customers have appreciated their high quality at an attractive price compared to products offered under well-known trademarks. This comes down to the trend of moving away from well-known and expensive brands towards purchasing products of similar quality to those with a recognizable logo and packaging. This business model is used by companies that have an idea for introducing a new solution, but also by those who want to enter the market with a competitive offer.

This is due to the fact that manufacturing chemical products requires large investments in your own production lines which generates higher costs than commissioning the development and production to professionals. In addition, the positive perception of goods manufactured under your own brand translates into an advantage over the assortment of well-known companies and allows for a freer search for your sales market. Additionally, expanding the line with new products builds the trust of an increasingly large group of recipients.

Why us?

We meet the expectations of our customers and offer the possibility of preparing products dedicated to the needs and requirements of the customer. We have many years of experience in creating products with silver and copper particles which are used in many industries. Our knowledge and modern technical facilities and laboratory will allow us to implement each stage of the project - from idea to production. We have our own production lines, laboratory and a team of specialists who will cope with any challenge. This means that we have all the competences to create modern and safe products that will appeal to even the most demanding users.

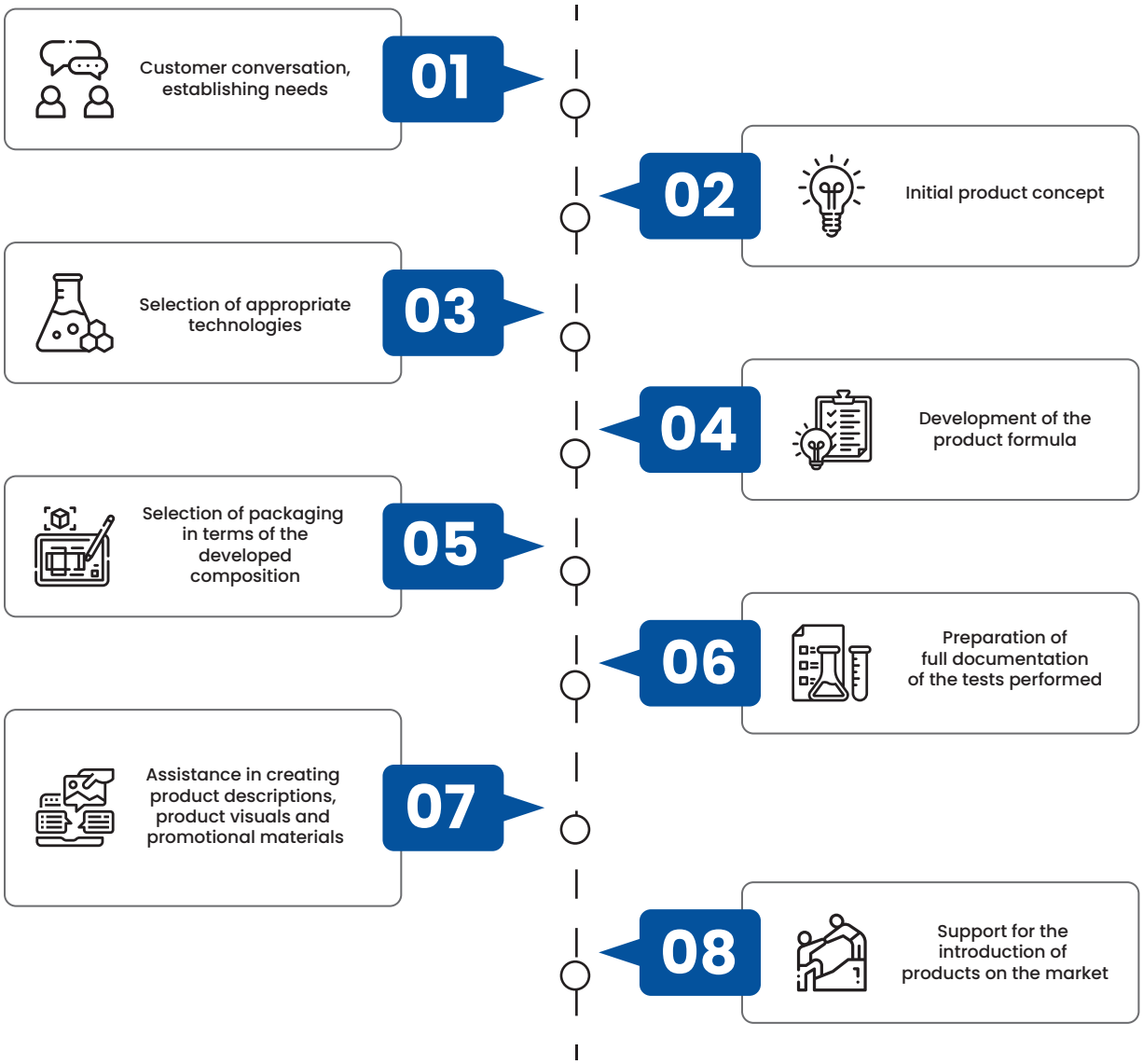
Dedicated projects

In Smart Nanotechnologies we implement projects ***"from idea to product".***

Modern technological facilities and a multi-disciplinary research team allows us to meet the needs of the market and implement advanced application projects while maintaining the highest quality standards. We provide services in the development of methodologies and implementation of research and development works, as well as technical consulting. We have extensive research facilities that allowing for comprehensive characterization of the produced nanostructures. An innovative approach in the process of creating new technologies is our everyday life.

We invite everyone who wants to enrich their offer with innovative nanotechnological solutions to cooperate. Our extensive know-how will provide you with the optimal selection of product manufacturing technologies and transform them into market success!

We invite you to cooperate!



If you have any additional questions regarding starting cooperation, the functioning of our company or our possibilities, please contact us.

Antibiotic resistance

04 Antibiotic resistance

What is antibiotic resistance?

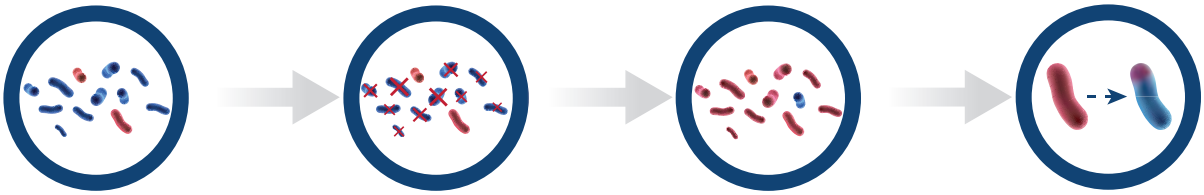
Antimicrobial resistance (AMR) threatens the effective prevention and treatment of an increasing number of infections caused by bacteria, parasites, viruses, and fungi. Antibiotic resistance occurs when microorganisms change over time and stop responding to medications, making it harder to treat infections and increasing the risk of spreading disease, serious illness and death. As a result, they become ineffective and infections persist in the body increasing the risk of passing the disease to others. Antibiotics, antivirals, antifungals and antiparasitics are medications used to prevent and treat infections in humans, animals, and plants. Microorganisms that have developed resistance to antimicrobials are sometimes called “superbugs”.

How do bacteria become resistant?

Antibiotic resistance is nowadays one of the biggest threats to public health today. Diseases that used to end in death are now minor ailments that require simple treatment regimens. The increasing resistance of microorganisms to antibiotics results in the exhaustion of therapeutic options, a greater risk of bacteria spreading and a longer duration of infection. This, in turn, translates directly into higher treatment costs and higher mortality.

Antibiotic resistance occurs when microbes change in response to the use of antibacterial drugs, allowing them to survive the effects of pharmaceuticals intended to kill them. If antibiotics lose their effectiveness against these bacteria, we lose the ability to treat infections and control threats to public health. Antibiotic resistance does not mean that the body becomes insensitive to antibiotics. Instead, the bacteria in the body have become insensitive to antibiotics - they have developed resistance to them.

How does antibiotic resistance develop?



1

There are many microorganisms, some of which are resistant to antibiotics.

2

When antibiotics kill the bacteria that cause disease, they also kill the good bacteria that protect the body from infection.

3

Antibiotic-resistant bacteria are growing and taking over.

4

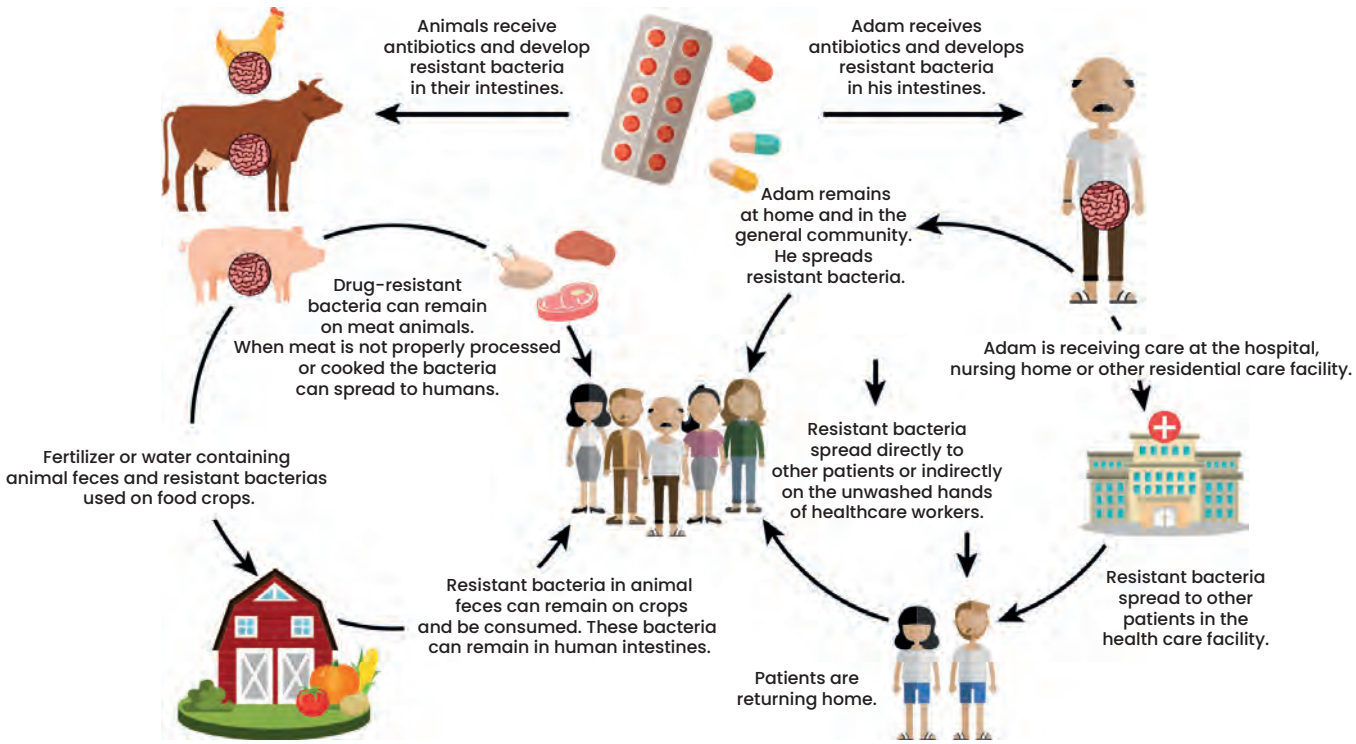
Some bacteria pass on their antibiotic resistance to other bacteria, causing more problems.

Why is antibiotic resistance so important?

Antibiotic resistance is one of the greatest threats to public health. Each year in the United States more than 2.8 million people are infected with antibiotic-resistant microorganisms, killing more than 35,000 people directly. Many more die from complications of infections caused by antibiotic-resistant strains.

A growing number of infections—such as pneumonia, tuberculosis, gonorrhea and salmonellosis—are becoming increasingly difficult to treat as the antibiotics used to treat them lose their effectiveness.

Antibiotic resistance leads to longer hospital stays, higher treatment costs and increased mortality. Antibiotic resistance can affect anyone, at any age, in any country.



Inappropriate use of antibiotics contributes to the development of antibiotic resistance.

Silver and copper

05 Silver and copper

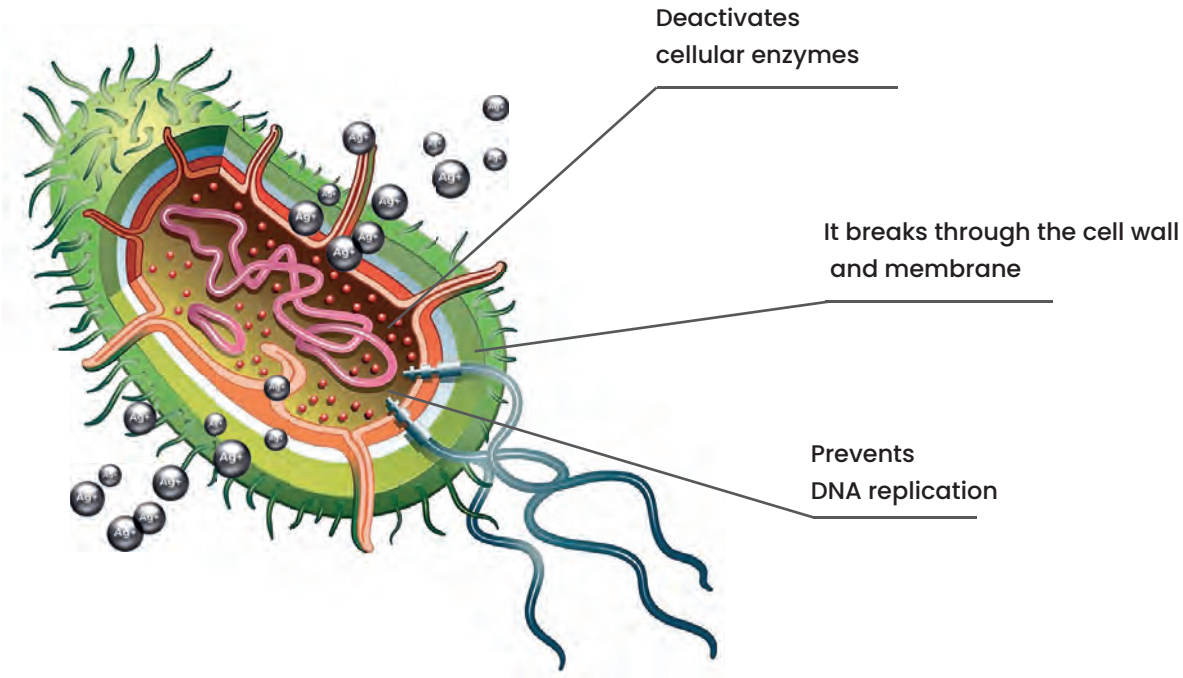
Why silver and copper?

Silver and copper are elements valued for their catalytic properties, thermal and electrical conductivity, but above all for their killing effect on pathogens - bacteria, viruses and fungi. The high antimicrobial activity of these elements has been used since ancient times, but at that time the mechanisms responsible for their high effectiveness were unknown. Today, the principles of action and their multitude explain not only the effectiveness, but also the inability of pathogenic cells to develop resistance to these metals. This last feature is particularly important in the current era of growing antibiotic resistance of many bacterial strains.

The development of technology has made it possible to use silver particles on a nanometric scale. Such significant fragmentation of this material affects its distribution, thus enabling very high antimicrobial effectiveness to be achieved even at very low concentrations. All these features mean that silver is currently considered as one of the most attractive alternatives to many drugs and biocidal agents.

Until now, the most commonly used biocidal agents were biocides which are compounds characterized by limited durability of action and a negative impact on the environment. Recently, much attention has been paid to alternative solutions using silver particles, whose antibacterial activity has been known for centuries and used in medicine and cosmetology. It is worth emphasizing that silver has a strong biocidal effect even at very low concentrations. The advantage of solutions containing this element is the difficulty in developing resistance of pathogenic strains to the active substance. Additionally, its activity does not change over time, so this guarantees a lasting effect, unlike the frequently used organic biocides that degrade over time. As it results from a review of the literature, silver nanoparticles have bactericidal activity against about 650 types of bacteria.

How does silver affect bacteria?



» It acts as a catalyst, causing the oxidation of many chemical compounds essential for the life of bacteria and as a result their deactivation. The bacterium loses its ability to breathe, its genetic material is destroyed.

» When it comes into contact with the cell wall of the microorganism, it blocks the flow of energy and its respiratory channels.

» By denaturing proteins it destroys their structures which causes the loss of biological activity which is an irreversible and deadly process.

» By combining with chemical compounds that create DNA chains, it destroys their bonds. The microorganism loses the ability to replicate (reproduce), so the next generations are not created and information about threats is not transmitted.

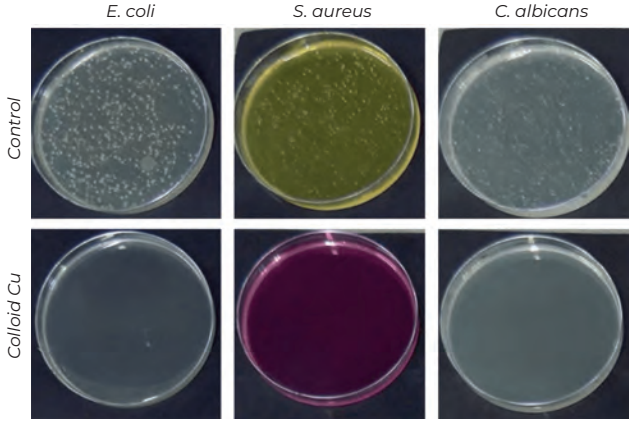
Colloids

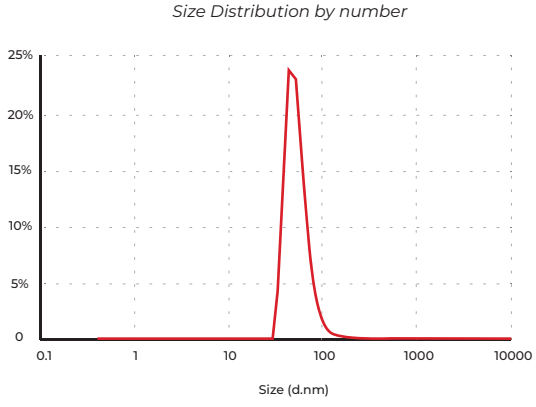
06 Copper colloid

Aqueous colloid containing 50 ppm of nanometric copper complexes. The preparation has strong fungicidal and bactericidal effects. It can be used as an additive to liquid products, including household chemicals and cosmetics. This allows you to increase the attractiveness of the product by providing additional microbiological action.

Colloidal copper:

- has antimicrobial effectiveness above 90%,
- contains components safe for health,
- is an odorless, aqueous liquid,
- is intended as an additive to cleaning agents from the area of household chemicals, cosmetics, as well as plant protection products,
- provides appropriate microbiological activity with the suggested content of colloid in the finished product in the range of 5 to 15%.





07 Silver colloids

Our colloids based on silver nanoparticles are an effective solution for improving microbiological safety. The products can be applied directly to the protected surface or be one of the components of finished products.

As a manufacturer, we offer a wide range of products including various bases such as water, isopropyl alcohol and propylene glycol, thanks to which the products are characterized by high compatibility with a wide group of articles.

Colloidal silver
50 ppm

Colloidal silver
1000 ppm

Colloidal silver 10,000 ppm
in isopropyl alcohol

Colloidal silver 10,000 ppm
in propylene glycol

Application

Intended for use as an additive in disinfectants and protective agents with immediate and prolonged effect. It can also be used, among others, as: an ingredient in animal care preparations, products for protecting plants against the development of mold and fungi, an additive to polyacrylic resins, water-based paints and others.

Why silver colloids?

Nanosilver is valued in the medical, pharmaceutical and cosmetic industries as well as by the household chemicals market and agriculture. Colloidal silver brings numerous benefits in terms of microbiological safety and hygiene. High antimicrobial effectiveness affects very high efficiency, while ensuring a much higher level of hygiene compared to traditional solutions.

Silver colloids provide:

- high effectiveness,
- health safety,
- environmental friendliness,
- a wide range of applications in various industries.

Product Line POLYDEF

08 Few words about POLYDEF technology

What is POLYDEF?

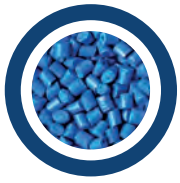
Polydef technology is a specially developed solution based on silver and copper nanoparticles which allows for obtaining antibacterial and antifungal properties. The presence of nanosilver in the protected polymer provides a biocidal effect by inhibiting the metabolic pathways of microorganisms, contributing to the elimination of sources of unpleasant odors and extending the life of the material. Matrix enriched with POLYDEF line additives also have a food contact certificate and meet RoHS requirements. The component provides long-term microbiological protection and increases the safety and attractiveness of the product.

Where can technology be used?

Polymers with biocidal properties can be used in places particularly exposed to microorganisms, such as ventilation pipes, RTV/AGD elements, hospital waiting rooms and sanitary facilities. The use of silver nanoparticles provides long-term microbiological protection while maintaining the safety of finished plastic products for their users. Our ambition is to implement products and solutions that have a potential to create new standards (e.g. in medicine, veterinary medicine, construction, transport, industrial technologies and many others) by giving everyday products existing on the market (such as paints, tiles, grouts, textiles, products made of wood, steel, polymers, etc.) new functional features such as protection against the development of microorganisms.

Powder additives

Recommended dosage at the level of 0.1-0.3% by weight.



Masterbatches

Recommended dosage at the level of 2-6% by weight.

Granulates for filament production

The product is ready to use.

09 POLYDEF Masterbatches

Our product range includes masterbatches dedicated to specific plastics.

General information

Masterbatch is added to the finished product during its production. The granulate provides antimicrobial properties and does not affect the basic colour or surface finish of the product. Active substances do not degrade/wash out. The additive is designed to demonstrate constant activity throughout the product's life cycle.

Recommended dosage

To obtain a bactericidal effect, a dosage of 2-6% by weight of the finished polymer composite is recommended, while to obtain a fungicidal effect, a dosage of 6% by weight is recommended. Validation of the antibacterial article is recommended before introducing the product to the market.

Product	Compatible matrix	MFR / MVR*	Food Contact	RoHs	Application
POLYDEF Cu+ LDPE	LDPE, MDPE, HDPE, PP	20 g/10 min	YES	YES	pool liners
POLYDEF Ag+ LLPDE	LDPE, MDPE, HDPE, PP	20.0 g/10 min	YES	YES	pipes, packaging, packaging foils, bags
POLYDEF Ag+ LDPE	LDPE, MDPE, HDPE, PP	31.55 g/10 min	YES	YES	kitchen equipment, home furnishings, toys, packaging
POLYDEF Ag+ HDPE	HDPE, PP	0.59 g/10 min	YES	YES	ventilation pipes, canisters, packaging
POLYDEF Ag+ PP	PP	43.97 g/10 min	YES	YES	toys, cleaning equipment, brooms, brushes, buckets
POLYDEF Ag+ ABS	ABS, SAN	6.53 g/10 min	YES	YES	light switches, vacuum cleaner parts (e.g. pipes)
POLYDEF Ag+ PC	PC	4.59 g/10 min	YES	YES	kitchen equipment, medical equipment, office equipment, humidifiers
POLYDEF Ag+ EVA	EVA	21.79 g/10 min	YES	YES	crocs shoes, soles, foam puzzles
POLYDEF Ag+ TPE-U	TPE	-	YES	YES	phone case
POLYDEF Ag+ PVC	PVC	-	YES	YES	seals, cable sheaths, bottles
POLYDEF Ag+ PS	GPPS, HIPS	3.0* g/10 min	YES	YES	toy components, electrical device housings, food packaging
POLYDEF Ag+ PA6	PA	120.0* cm^3/10 min	YES	YES	multi-layer foils, door handles, grips, stadium seats, carpets, brushes

It is possible to prepare polymer granules according to the customer's special order.

10 Powder additives – POLYDEF Ag and POLYDEF Ag+

Silver is an element valued for its catalytic properties, thermal and electrical conductivity, but above all for its killing effect on pathogens - bacteria, viruses and fungi. The high antimicrobial activity of this element has been used since ancient times. At that time, the mechanisms responsible for the high antimicrobial effectiveness of silver were unknown. Today, the principles of action and their multitude explain not only the effectiveness but also the inability of pathogenic cells to develop resistance to silver. This last feature is particularly important in the current era of growing antibiotic resistance of many bacterial strains.

POLYDEF Ag and **POLYDEF Ag+** are specilized solutions based on silver nanoparticles, which allow for obtaining antibacterial and antifungal properties. The presence of nanosilver in the protected polymer provides a biocidal effect through multi-level disruption of the normal functioning of the bacterial cell, which consequently leads to the death of microorganisms, contributing to the elimination of sources of unpleasant odours and extending the life of the material. The additive is environmentally friendly, does not change the physical properties of polymers and does not cause degradation of the protected material. The component provides long-term microbiological protection and increases the safety and attractiveness of the product. In addition, the nanoadditive is characterized by higher stability at high temperatures and high humidity compared to traditionally used biocidal agents.

POLYDEF Ag

POLYDEF Ag

Basic information

State of matter: powder with a fraction of < 500 um

Colour: yellow-brown

Silver particle shape: spherical

Silver content: 10%

Silver particle size: < 100 nm

Biocidal properties: yes

Recommended dosage: 0.1 – 0.3% by weight

Carrier: silicon oxide

POLYDEF Ag+

POLYDEF Ag+

Basic information

State of matter: powder with a fraction of < 500 um

Colour: grey

Silver particle shape: spherical

Silver content: 10%

Silver particle size: < 100 nm

Biocidal properties: yes

Recommended dosage: 0.1 – 0.3% by weight

Carrier: zinc oxide

Recommended dosage by weight according to biocidal permit no. 9491/23: 0.1 - 0.3%

11 Powder additives – POLYDEF Cu and POLYDEF Cu+

Copper is characterized by very good antifungal and antibacterial properties. For this reason it is used, among others, in the production of ship hulls to protect them from algae and crustacean growth and in the production of door handles and hospital equipment to reduce the risk of pathogen transmission. Thanks to modern technology it has become possible to use copper nanoparticles in the fight against bacteria and fungi, which allows for a significant reduction in the costs of surface protection. The biocidal effect of copper is based on a wide range of separate mechanisms which translates into high effectiveness of the additive in the long term.

POLYDEF Cu and **POLYDEF Cu+** are advanced biocidal additives based on copper nanoparticles that allow for obtaining antibacterial and antifungal properties in the finished material. The presence of copper in the protected polymer provides a biocidal effect by disrupting the normal functioning of the cell, which consequently leads to the death of microorganisms. This contributes to the elimination of sources of unpleasant odors and extends the life of the material. In addition, zinc oxide used in the POLYDEF Cu+ additive has a synergistic biocidal effect which enhances antimicrobial properties. The component provides long-term microbiological protection and increases the safety and attractiveness of the product. The additive is not only environmentally friendly, but also does not change the physical properties of polymers and does not cause degradation of the protected material. The nano-additive stands out from traditionally used biocidal agents with higher stability at high temperatures and high humidity.

POLYDEF Cu

POLYDEF Cu

Basic information

State of matter: powder with a fraction of < 500 um

Colour: grey

Shape of copper particles: spherical

Copper content: 10%

Size of copper particles: < 100 nm

Biocidal properties: yes

Recommended dosage: 0.1 - 0.3% by weight

Carrier: silicon oxide

POLYDEF Cu+

POLYDEF Cu+

Basic information

State of matter: powder with a fraction of < 500 um

Colour: grey

Shape of copper particles: spherical

Copper content: 10%

Size of copper particles: < 100 nm

Biocidal properties: yes

Recommended dosage: 0.1 – 0.3% by weight

Carrier: zinc oxide

12 Proven effectiveness and safety

Microbiological tests

Test standard	Test microorganisms
PN-EN ISO 22196 Plastics: Measuring the Antibacterial Activity of Plastics and Other Nonporous Surfaces	*Legionella pneumophila, Salmonella enterica* *Escherichia coli, Staphylococcus aureus*
PN-EN ISO 846 (method A)	*Aspergillus niger, Paecilomycesvarioti* *Penicilliumpinophilum, Trichodermavirens* *Chaetomiumglobosum*
PN-EN ISO 846 (method B) Assessment of the effects of microorganisms on plastics	*Aspergillus niger, Penicilium pinophilum* *Paecilomyces variotii, Trichoderma virens* *Chaetomium globosum*
PN-EN ISO 846 (method C) Assessment of the effects of microorganisms on plastics	*Pseudomonas aeruginosa*
ASTM G21-15 Determination of resistance of synthetic polymeric materials to fungi	*Aspergillus brasiliensis, Penicilium funiculosum* *Chaetomoium globosum, Trichoderma virens* *Aureobasidium pullulans*
PN-EN ISO 16421:2015-01 Impact of materials on water intended for human consumption -- Increased growth of microorganisms.	

Migration Studies

Test standard	Confirmation of compliance
PN-EN ISO 1186 Testing of the overall and specific migration of formaldehyde, bisphenol A, elements and primary aromatic amines from plastic products intended for contact with food, in accordance with the requirements of the PN-EN 1186 series of standards: "Materials and articles intended for contact with food. Plastics",	*Compatible*
PN-EN ISO 13130 Testing of the overall and specific migration of formaldehyde, bisphenol A, elements and primary aromatic amines from plastic products intended for contact with food, in accordance with the requirements of the PN-EN 13130 standard from the series: "Materials and articles intended for contact with food products. Substances in plastics subject to restrictions",	*Compatible*

13

Case study

MEDICAL FOOTWEAR

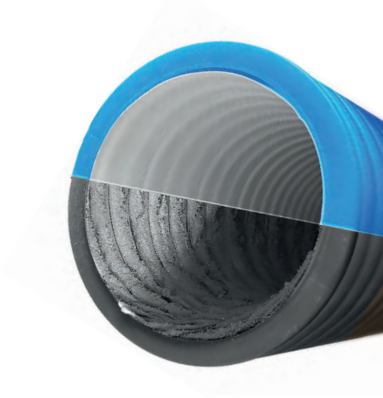
Problem: Prolonged wearing of medical footwear during shifts lasting 8 or 12 hours creates moist and warm conditions conducive the growth of pathogens, leading to foot dermatoses.

Reason: The interior of medical footwear, worn by medical personnel during long shifts, is an ideal environment for the growth of microorganisms due to high humidity and temperature caused by inadequate ventilation and the limited ability of the materials to wick away moisture.

Threat: Pathogens such as *Actinomyces, Dermatophilus congolensis, Kytococcus sedentarius* and fungi, including *Candida albicans*, are capable of causing a variety of skin infections of the feet, including pitted keratolysis and athlete's foot. Symptoms of such infections can include maceration of the epidermis, burning, itching, skin peeling and changes in the appearance and texture of the nails.

Solution: An effective way to prevent the development and transmission of pathogens in medical footwear is to use antibacterial and antifungal additives from the POLYDEF line in the production process of footwear materials. Additives containing silver nanoparticles (e.g. Polydef Ag+) are highly effective in inhibiting the growth of both gram-positive and gram-negative bacteria, as well as various species of fungi. Studies confirm that materials impregnated with silver nanoparticles are able to significantly reduce the number of microorganisms inside footwear, thereby reducing the risk of developing foot skin infections. The use of such technologies in the production of medical footwear contributes to improving the hygiene of medical personnel and increasing protection against skin infections.

VENTILATION SYSTEMS



Problem: The growth of bacteria and fungi on the surfaces of ventilation and air conditioning ducts poses a significant threat to public health and the efficiency of HVAC systems. These microorganisms, growing in humid and warm conditions can lead to the formation of biofilms, which in turn increase airflow resistance and can be a source of unpleasant odors. In addition, fungal spores and bacteria can be transferred through ventilation systems to the indoor environment which is associated with the risk of infections, allergies and air quality problems.

Reason: The growth of bacteria and fungi in ventilation and air conditioning systems is often associated with the condensation of water vapor and its liquefaction. This condensation creates a moist environment that is ideal for the growth of microorganisms. Studies have shown that relative humidity above 70% significantly contributes to the growth of mold and bacteria.

Threat: Infected ventilation and air conditioning systems can be a source of serious health hazards, including diseases caused by pathogens such as *Legionella* and threats caused by molds. Epidemiological data indicate that outbreaks of legionellosis are most often associated with inadequate maintenance of water systems in buildings. In turn, mycotoxins, toxic substances produced by molds, can lead to a range of health problems - from skin and mucous membrane irritations, through allergic reactions, to serious poisoning.

Solution: The solution to the problems with pathogens multiplying in ventilation ducts is the Polydef technology which uses silver and copper nanoparticles to give materials antibacterial and antifungal properties. The presence of silver nanoparticles provides a biocidal effect, inhibiting the metabolic pathways of microorganisms, which helps eliminate sources of unpleasant odors and extends the life of the material. This technology is environmentally friendly, does not change the physical properties of polymers and does not cause their degradation, providing long-term microbiological protection. Regular disinfection and cleaning are not able to provide lasting effects which is why our 24/7 solution is so extraordinary.

ORTHOPEDIC MATS

Problem: Transmission of pathogens on the surfaces of orthopedic mats used in hospitals and rehabilitation centers poses a serious threat to patients, especially those with weakened immune systems. The large number of patients and the difficulty in keeping the mats perfectly clean contribute to the spread of germs.

Reason: Orthopedic mats are subject to frequent use which increases the risk of pathogen transmission. It becomes problematic to thoroughly clean the unevenness and pores on the mat surface which can be hidden habitats for bacteria, including *Mycobacterium leprae, Staphylococcus aureus, Actinomyces israelii* or *Corynebacterium minutissimum*. Standard disinfection methods are not always effective against all types of microorganisms, especially in the hard-to-reach nooks and crannies.

Threat: These pathogens can cause a variety of diseases, from leprosy, pyoderma, actinomycosis, to erythrasma. The effects of infection vary depending on the type of pathogen and can lead to serious, long-term health problems and, in extreme cases, even death.

Solution: The use of antibacterial additives from the POLYDEF line containing silver nanoparticles in the production of orthopedic mats can significantly reduce the risk of pathogen transmission. Silver nanoparticles, known for their strong antibacterial and antifungal properties, can be effectively incorporated into the mass of polymer materials (such as PP, HDPE, LDPE, and PVC) from which mats are produced. Studies confirm that materials containing silver nanoparticles are highly effective in reducing the population of both gram-positive and gram-negative bacteria on treated surfaces, which contributes to a significant reduction in the risk of infections.

SHOPPING CARTS

Problem: Carts and baskets in retail stores are an essential part of every shopping experience. Thousands of peoples touch their handles and other elements every day, leaving microorganisms on them. The elements are often sticky with dirt and various bacteria, viruses and fungi that develop on the surface. Customers often encounter carts and baskets covered with food remains, receipts or vegetable leaves. Cleanliness constantly leaves much to be desired. Lack of regular cleaning and disinfection poses a direct threat to our health.

Reason: The main cause is direct contact of shopping cart elements with people's hands, which contributes to the transfer of harmful microorganisms. The sanitary inspection finds not only dangerous microorganisms on shopping carts but also eggs of zoonotic parasites and even very dangerous *staphylococcus*. Scientists from the University of Arizona tested shopping carts in the USA for bacterial contamination. It turned out that pathogenic bacteria found in feces were found on 72% of them, many different strains dangerous to humans were found in 50% of samples and extremely dangerous *E. coli* bacteria were found on 36%.

Threat: All microorganisms found on shopping carts can cause various diseases such as: diarrhea, nausea, boils, suppuration, joint swelling, including diseases requiring long-term treatment and hospitalization. Particularly susceptible are the elderly and children, whom we so willingly transport in shopping carts and at the same time they touch the carts with their hands and then put them into their mouths along with the bacteria.

Solution: The solution to the problem of pathogen development and transfer on usable surfaces, in addition to regular cleaning and disinfection, is their permanent protection using POLYDEF line antibacterial additives applied to the mass of the material from which the polymer elements most often in contact with the skin of the hands are made. The most widely used polymers are PP, HDPE, LDPE and PVC. The use of additives containing silver nanoparticles (Polydef Ag+ PP, Polydef Ag+ HDPE or Polydef Ag+ PVC-U) will prevent bacteria and other pathogenic microorganisms from developing on usable surfaces, additionally reducing them.

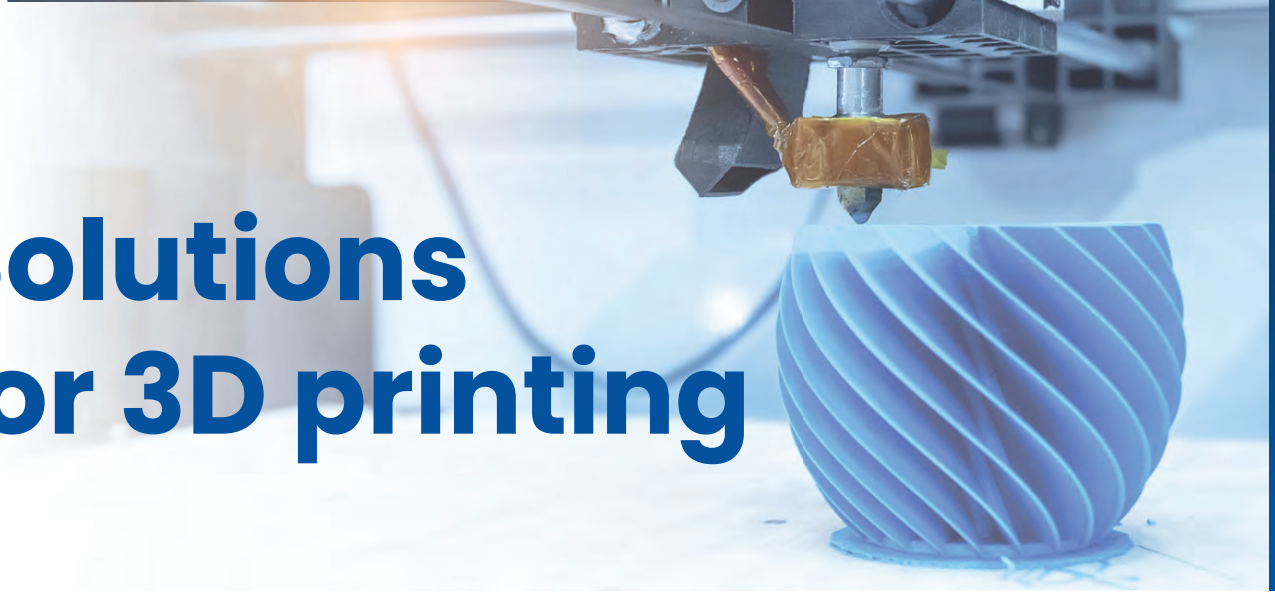
TOY BLOCKS

Problem: Toys, especially those made of plastic, are prone to harboring bacteria and other pathogens. Children often put them in their mouths, which leads to the transmission of microorganisms. Additionally, toys left on the floor or in sandboxes become a breeding ground for pathogens carried by animals.

Reason: The main cause is direct contact of toys with an environment full of potential sources of infection, as well as frequent exchange of toys between children. Since most pathogens, both bacteria and viruses, are transmitted by droplets - it is impossible to avoid the migration of germs between children. Group play or using the same toys - this is a perfect opportunity for pathogens to spread.

Threat: The presence of pathogens on toys can lead to various diseases in children, such as scarlet fever, whooping cough or tuberculosis. Bacteria such as *Streptococcus pyogenes* or *Mycobacterium tuberculosis* are particularly dangerous. Symptoms of infection are very versilate from starting with fever, vomiting to runny noses, cough and rashes.

Solution: Regular disinfection and cleaning cannot provide lasting effects, which is why our solution which work 24/7 is so extarordinary. Polydef is an innovative biocidal additive applied to the polymer mass which uses silver nanoparticles to combat bacteria and other microorganisms on the surface of plastics. It is effective in reducing pathogens and safe in contact with children. Its use in toy production can significantly reduce the risk of disease transmission due to the lack of growth of pathogenic organisms on the toy surface.



Solutions for 3D printing

14 3D printing

FDM technology

Fused Deposition Modeling, commonly called "3D printing from plastic", is currently the most widespread 3D printing method in the world. Its popularity means that for the vast majority of people who have limited contact with additive technologies it is tantamount to three-dimensional printing in general. Like all 3D printing technologies, FDM was made as a way to create prototypes faster and cheaper. Over time, users of 3D printers of this type began to expand the possibilities of their use also producing final products or their components with their help.

Biocidal filaments for 3D printing

It is an additive containing silver nanoparticles for the production of filaments used for three-dimensional printing in FDM technology. The product can be offered in the form of a powder additive containing nanosilver which the manufacturer will dose on the line to create a "string" or in the form of ready-made polymer granulate. Nanoparticles can be used in a wide range of polymers used in three-dimensional printing: PLA, PET-G, CPE, ABS, ASA, PA.

What materials are used in the FDM method?

The most popular types of materials used in this additive method are ABS (acrylonitrile-butadiene-styrene copolymer) and PLA (polylactide). Other popular materials include PA (polyamide), PETG (polyethylene terephthalate with glycol admixture) or TPU (thermoplastic polyurethane elastomer).

The fact that FDM technology uses exactly the same plastics as those used, for example in injection molding, makes it ideal for creating functional prototypes with the same or very similar physical and chemical properties as the final products, on the other hand it can be used for creating final products or prefabricated parts in lower quantities, which would be unprofitable in the case of injection molding. In other words, FDM is the only existing additive technology that allows printing objects from thermoplastics used in injection molding. This makes it an ideal complement to any company operating in the plastics sector as a support for the R&D department or a tool complementing production processes.

POLYDEF Ag+ 3D PETG

PETG is one of the easiest materials to 3D print, it is inexpensive and suitable for beginners. Its relatively high tensile strength and temperature resistance make it suitable for the production of mechanical parts.

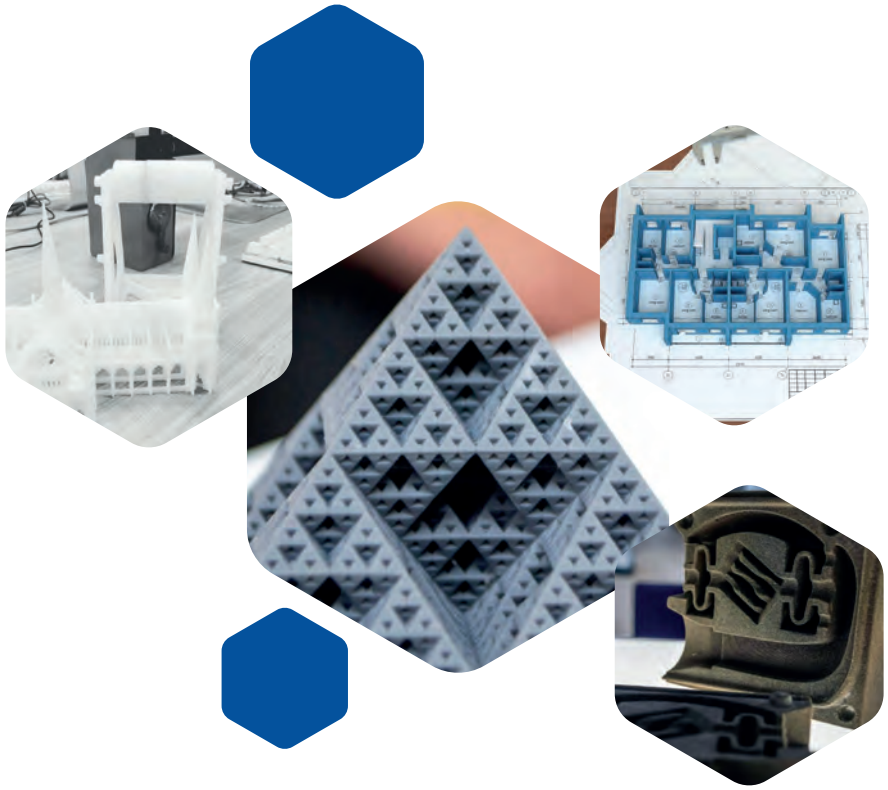
PETG is most often used for various mechanical elements, handles, clamps and waterproof parts (thanks to the excellent adhesion of the layers). The surfaces of PETG prints are glossy and the prints adhere very well to the table without curling and warping (its thermal expansion is very low), therefore it works well when printing large models. The tensile strength and flexibility it offers prevent parts from cracking. Due to its temperature resistance it is suitable for use indoors and, in many cases, outdoors (at temperatures below 80°C).

Advantages	Disadvantages
» easy printing	» susceptible to stringing
» good layer adhesion	» poor bridges and overhangs
» strength and durability	» not very detailed prints
» low shrinkage	» adheres very strongly to the print surface
» good temperature resistance	» soluble only in hazardous chemicals
» resistance to water and moisture	» supports can be difficult to remove

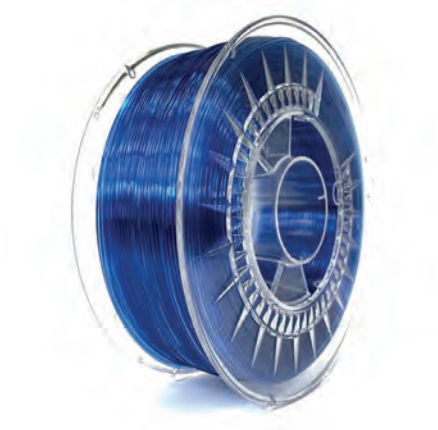
POLYDEF Ag+ 3D PLA

One of the easiest to print is PLA – inexpensive and suitable for beginners. It is usually used for printing detailed models, figurines and rapid prototyping that do not require high mechanical, chemical or temperature resistance. It does not require a heated bed and can be printed with low nozzle temperatures (its melting point is about 175 ° C). PLA can be used to print both small, detailed models and those that fill almost the entire work area. Unlike some other materials. PLA is not susceptible to bending during printing. It is suitable for rapid prototyping and creating cheap conceptmodels, simple toys, jewelry, figurines, etc. It is not suitable for manufacturing mechanical and outdoor objects. It does not withstand higher temperatures (it softens and deforms at a temperature of approximately 60°C), it degrades in UV light and has quite low mechanical strength - it breaks and splinters upon impact.

Advantages	Disadvantages
» low price	» brittleness and hardness
» easy to print, good for beginners	» low UV and temperature resistance
» high detail and slight warping	» difficulty in print processing
» suitable for large models	



POLYDEF Ag+ 3D CPE HT



CPE has properties similar to PETG, it is odorless and has very low warpage. CPE has good chemical resistance, layer adhesion and adhesion to the table. Thanks to its properties similar to PETG and ABS and good layer adhesion, it is suitable for prototyping mechanical parts. CPE is distinguished by its chemical, mechanical, temperature resistance (prints withstand up to 75°C) and dimensional stability. Its tensile strength is similar to ABS. It can be used for printing thin-walled models due to its transparency. CPE is suitable for aesthetic and functional prototypes, mechanical parts, etc.

Advantages	Disadvantages
» good mechanical strength	» requires high printing temperature
» good layer adhesion	» strong adhesion to the printing surface
» good temperature and chemical resistance	» susceptibility to stringing similar to PETG
	» hygroscopicity

Additives for epoxy resins

Today's progress in construction also focuses on the development of materials with higher sanitary and cleanliness standards. This translates into the requirement to take hygiene into account in the very structure of the building. In the food industry, especially in production rooms or places where food products are processed, maintaining the highest level of hygiene is crucial. The finishing materials used in such facilities, including floors, affect the level of microbiological safety of both the products manufactured in the facility and the employees. In order to function well they should be easy to clean, durable and strong. Such materials should be carefully selected so that their properties in terms of mechanical, thermal and chemical resistance corresponding to the conditions of use.

Powder additives from the POLYDEF line containing silver nanoparticles are perfect as a component for epoxy resins used in thin-layer and self-leveling floors. Thanks to this, it is also possible to achieve increased microbiological cleanliness in hospitals. The additive is recommended for use in the production of epoxy resin flooring components thanks to which the antimicrobial activity remains unchanged throughout the time of use.

Additives for polyurethanes

Polyurethane foam is highly prone to bacteria, mold, yeast and algae due to its porous structure and ability to retain high levels of moisture. Some polyurethane foams use “greener” ingredients that become a good source of food for microorganisms.

Antibacterial additives help to limit the growth of bacteria, mold and fungi in and on the polyurethane foam. Inhibiting the proliferation of microorganisms in PUR materials reduces microbial-related odors, maintains aesthetic appeal and minimizes degradation. Ultimately this leads to longer product life, economic savings and fewer materials going to landfills because treated products do not need to be replaced as often.

Mattresses made from polyurethane foams with the addition of silver nanoparticles are a revolutionary solution for use in the broad field of patient care. With its antibacterial, virucidal and fungicidal properties nanosilver provides long-term microbiological purity. Mattresses of this type support wound healing and also have an anti-bedsore effect. They do not require expensive disinfection procedures, therefore allow savings on maintaining cleanliness and limit the use of aggressive chemicals in the patient's immediate environment. Thanks to this, the risk of allergic symptoms also decreases. At the same time it will limit the number of microorganism development centers, increasing safety and reducing the likelihood of hospital infections caused by microorganisms.

Active Silver Protection

15 Trademark and Certification

The Polydef additives line is an innovative, fully proprietary solution based on silver nanoparticles, thanks to which the finished product gains antibacterial and antifungal properties. Thanks to this we create a new quality and a new trend on the market. Use products that give surfaces self-cleaning properties, preventing the development of pathogenic pathogens and introduce new standards in many areas of life - medicine, veterinary medicine, construction, industrial technologies and more!

Products containing the Polydef additive become unique and gain the Active Silver Protection certificate which is synonymous with the highest quality and a determinant of safety. This is a trademark that will distinguish your offer from the competition and make your solutions the first choice of consumers. Step out in front of the line and mark your products with the ASP symbol - this is your key to success!

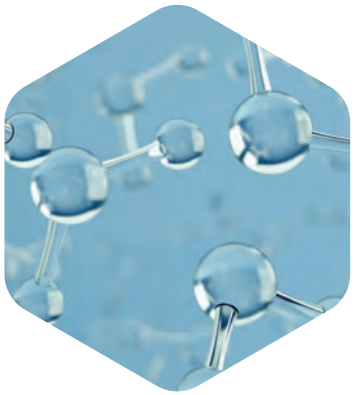
- Technical support during implementation of technology
- Support in sales training
- Microbiological testing
- Connecting Topics Among Business Partners
- Products of the highest quality
- Increased standard of microbiological purity
- Production in accordance with due procedures
- Products tested according to the standard PN-EN ISO 22196

16 Active Silver Protection certificate

What are the requirements to obtain certification with the Active Silver Protection by POLYDEF mark?

The condition for obtaining the Active Silver Protection by POLYDEF certificate is to conduct tests on the content of the POLYDEF additive and to analyze the antimicrobial activity of the product before it is introduced to the market. It is required to achieve at least a 90% reduction in the number of bacteria determined in accordance with the PN-EN ISO 22196 standard.

What advantages do you gain from having a certificate?



- highlighting the quality of selected products in which the POLYDEF biocidal additive was used,
- distinguishing products with an increased standard of safety and microbiological purity,
- minimizing and combating the availability of pseudo-biocidal products that do not meet the standards for reducing microbiological activity,
- marking products with an emblem that aims to increase consumer awareness of the quality of the products purchased.

What tests are necessary for a product to be considered for certification?

The process is as follows:

- testing samples submitted by manufacturers seeking certification,
- conducting technological tests and selecting production concentrations,
- testing samples before they are put on sale and confirming antimicrobial properties.

After a decision is made to meet all the conditions, a certificate and the right to use the mark is issued for 1 calendar year.

ACTIVE SILVER PROTECTION BY POLYDEF

is support and a guarantee of quality at every stage of cooperation

SMART CleanAir

17 Legionella bacteria

Building related disease complex

Building-related illness is a disease of people working or living in air-conditioned buildings. These people complain about fatigue, shortness of breath, headaches and dizziness caused by the presence of biological factors in the air. They can cause allergic diseases and respiratory infections, as well as irritability, decreased ability to concentrate, memory disorders, irritation of the mucous membranes of the eyes and upper respiratory tract, skin changes and inflammation of the respiratory tract.

18 Legal regulations in the fight against Legionella

The Regulation of the Minister of Health on the quality of drinking water of 7 December 2017 specifies the maximum permissible concentration of bacteria in water. For most buildings, it is 100 cfu per 100 ml. For hospitals where weakened patients are located, the standards are more restrictive and amount to 50 cfu per 1000 ml. Water tests in these facilities must be performed at least twice a year. In other buildings, the regulations require annual tests.

Legionella

Legionnaires' disease, often called legionellosis, is an acute pneumonia with a severe course caused by *Legionella* bacteria.

Legionella is one of the bacteria commonly found in freshwater reservoirs, especially standing water, where the temperature temporarily rises above 20 °C.

It occurs in natural and artificial freshwater reservoirs and water installations, such as air conditioning units, cooling towers, steam condensers, whirlpools, spas, fountains, garden sprinklers, respiratory therapy equipment.

Infection most often occurs in susceptible individuals as a result of inhaling water aerosols. In Europe, the species responsible for 96% (in 2011-2015) and 82% (2016) of confirmed cases of infections recorded in humans is *Legionella pneumophila*. The peak incidence of the disease occurs in the summer months which is closely related to weather conditions, i.e. increased humidity and air temperature as well as increased tourism and recreation.

What diseases can it cause?

Legionellosis, also known as Legionnaires' disease, is an acute pneumonia. The first symptoms appear after an incubation period of about 7 days. Typical symptoms include severe headaches and muscle pain combined with a fever of about 40 degrees. There is a strong cough with expectoration of sputum, often stained with blood. Shortness of breath and severe chest pain are common. Legionnaires' disease is often accompanied by diarrhea and vomiting. The bacteria can spread to other internal organs, attacking the liver, spleen, lymph nodes or brain, among others. Initially, the symptoms of Legionellosis are often confused with the flu. Pontiac fever is characterized by symptoms similar to a cold. Characteristic symptoms include headache, muscle pain, fever and a general feeling of being down. It does not require specialist treatment, it goes away on its own after 1-2 days.

It reproduces and lives in biofilm which is found in water installations

It feels best at a temperature of 20-50°C

It is not contagious through contact with a sick person

It can be dangerous to humans causing pneumonia and Pontiac fever

It dies thanks to silver and copper ions

19 SMART CleanAir

Air conditioning cleaning and disinfection with active silver nanoparticles from SMART CleanAir

Start a revolution in maintaining air freshness for your customers with unique SMART CleanAir products with active silver nanoparticles. Our innovative formula uses the power of nanotechnology. Effectively removes bacteria, viruses and fungi.

Give your customers a guarantee of clean and healthy air. Choose SMART CleanAir with active silver nanoparticles to experience innovative effectiveness in maintaining air conditioning hygiene. Order our products - choose an easy and effective solution! Choose professional air conditioning cleaning and disinfection products that will save you time and money. SMART CleanAir offers economical packaging, thanks to which you can effectively manage your supplies of cleaning and disinfecting agents.

Our products with active silver nanoparticles are a guarantee of effective combating of bacteria, viruses and allergens, which translates into a healthier working environment for your customers. It is also a guarantee of safety for you. All products are carefully tested for safety and active silver nanoparticles are adapted for professional use. We ensure full compliance with industry standards which is confirmed by the PZH Certificate.

INTERNAL UNITS

Smart CleanAir air conditioner and refrigeration equipment cleaner is a modern product with a formula based on active forms of silver for professional use. The silver contained in the product provides long-term protection against the development of pathogenic microorganisms, reduces the number of microorganisms, including *Legionella*, and eliminates unpleasant odors. After using the product, a high level of hygiene and cleanliness of HVAC systems is maintained. Effectively removes dirt, dust and deposits. The product does not cause corrosion, can be used on surfaces made of plastic, metal, ceramics, glass, aluminum and painted elements. The product is safe to use, does not contain phosphates. The product is ready to use.

- ATEST PZH — **Product with PZH certificate**
- **Ready for use**
- **Safe for surfaces**
- **A product with a wide range of applications**
- **Safe for users**

Permit no. 8952/22 for marketing a biocidal product.

Smart CleanAir+ is a modern, biocidal preparation for disinfecting surfaces of air conditioners and refrigeration devices with strong bactericidal and fungicidal properties. It is recommended to use the product for disinfecting surface elements of HVAC systems in private buildings, in the medical, food, industrial, institutional sectors and public utility facilities including schools, hospitals, airports, train stations, offices, hotels and beauty salons. After using the preparation, a high level of hygiene and cleanliness of HVAC systems is maintained. The effectiveness of the preparation has been confirmed against bacteria: *Pseudomonas aeruginosa, Escherichia coli, Staphylococcus aureus, Enterococcus hirae, Legionella pneumophila,* fungi: *Candida albicans, Aspergillus brasiliensis* according to the PN-EN 13697:2015 standard.

- Product with PZH certificate
- Biocidal Registration
- Safe for surfaces
- Disinfects, defungiates, cleanses and refreshes
- Safe for users

Smart CleanAir Concentrate is a modern, concentrated preparation for cleaning air conditioners and refrigeration devices with a formula based on active forms of silver. For professional use. The silver contained in the product provides long-term protection against the development of pathogenic microorganisms, reduces the number of microorganisms including *Legionella* and eliminates unpleasant odors.

- Product with PZH certificate
- Safe for users
- Safe for surfaces
- Economical 1 l = 10 l of finished product
- Highly concentrated formula

OUTDOOR UNITS

Smart CleanAir Active is a modern, concentrated preparation designed for washing and cleaning dirty external air conditioning, which thanks to the use of strongly washing, active foam, effectively removes the most stubborn dirt. Effectively removes dirt, dust, deposits, oil contamination and fats. The silver contained in the preparation ensures long-term reduction of microorganisms. The formula is based on surfactants. After using the preparation, a high level of hygiene and cleanliness of HVAC systems is maintained. It is safe for painted surfaces, plastics, metals, ceramics and aluminum. It does not contain corrosive acids or alkalis, does not cause corrosion.

- Product with PZH certificate
- Active, powerful washing foam
- Safe for surfaces
- Economical 1 l = 5 l of finished product
- Highly concentrated formula

INTERNAL AND EXTERNAL UNITS

Smart CleanAir Wash is a safe and effective preparation intended for cleaning the surfaces of air conditioning device elements, which thanks to its strong cleaning formula, effectively removes all dirt (dirt, dust, deposits, greasy contamination, biological residues). Formula based on surfactants. The product is recommended for cleaning surfaces before the actual disinfection stage. It is safe for painted surfaces, plastics, metals, ceramics and aluminum. Does not contain corrosive acids or alkalis. Does not cause corrosion. Does not cause discoloration, does not stain. For professional use.

- For all kind of surfaces
- Effectively and quickly removes dirt
- Convenient to use
- It does not leave discoloration
- Does not cause corrosion

INTERNAL UNITS

SMART CleanAir Foam is an active foam for cleaning HVAC system units that effectively removes dirt, dust, deposits, oil contamination and grease. Thanks to its modern formula, the foam adheres and penetrates dirt, condenses without the need for mechanical cleaning and leaves no sticky marks. The silver content provides long-lasting protection against microorganisms, reduces microorganisms and eliminates unpleasant odors. The product does not cause corrosion and is safe for various surfaces.

The product is available in 3 fragrance versions:
Neutral, Citrus, Aloe.

- Acid-free, alkaline-free formula
- Long-term protection
- Safe for metals, plastics plastics and rubber
- Removes unpleasant odors

Smart CleanAir Home is a modern preparation for cleaning filters and elements of air conditioners, air coolers, air purifiers and humidifiers or other cooling devices. Contains active forms of silver which have antibacterial, antifungal and antiviral effects, providing long-term protection against the development of pathogenic microorganisms, reduces the number of microorganisms and eliminates unpleasant odors. The use of the preparation improves the quality and hygiene of the air in the room and provides proper protection between services. The product does not cause corrosion, can be used on surfaces made of plastic, metal, ceramics, glass, aluminum and on painted surfaces.

- Convenient application
- Safe for user
- No tools required
- Removes unpleasant odors

AUTO

Smart CleanAir Auto allows you to clean air conditioning and ventilation systems in all types and models of cars. It can be used for any type of air conditioning: manual, automatic, and single and multi-zone. It is easy to use, so you can clean it yourself without having to disassemble it. The product removes unpleasant odors, including mold or tobacco smoke.

The product is available in 3 fragrance versions:

Neutral, Mandarin, Green Tea with Prickly Pear.

- Three fragrances to choose from
- Safe for user
- No tools required
- Removes unpleasant odors

SCENT

SMART CleanAir Aroma with active silver for use in air purifiers and humidifiers as an additive to water and air conditioning cleaning products. Silver present in the preparation ensures the elimination of pathogens found in the water in the tank and additionally protects against their development and thus improves the quality of air leaving the device.

The product is available in 4 fragrance versions:

Aloe, Lavender, Zesty Tea and Cherry.

- Four fragrances to choose from
- Safe for user
- Product with a wide range of application
- Fresh, pleasant fragrance

Silver Epoxy

Functional coating for galvanized and stainless steel with biocidal and hydrophobic properties. Thanks to the content of nanosilver the coating is characterized by high efficiency, durability and protection of the protected surface against the growth of microorganisms. In addition it significantly increases the resistance of the surface to standard detergents and thus reduces its susceptibility to corrosion, which translates into lower operating costs of protected steel elements.

- Reduction of operating costs of protected steel surfaces
- High durability of the coating and low migration of nanosilver (< 0.1 ppm)
- Simple, conventional surface coating technology
- Hydrophobic properties
- Protection of the covered surface against the growth of microorganisms
- Surface resistance to standard detergents
- Much lower susceptibility to corrosion
- Bacteriocidal and fungicidal properties

Recommended application parameters

- Distance of the gun from the "painted" surface: optimally 20 cm (range 15 - 25 cm). For smaller elements select parameters by changing the nozzle diameter and working pressure.
- Working pressure for the gun: approx. 7 bar.
- Nozzle diameter: 1.5 mm.
- Dynamic viscosity values are 400-600 mPas.
- Before applying the layer the steel should be degreased with alcohol or solvent and then dried. After drying, check whether there are no dirt marks on the surface.
- We apply 1 layer of coating.
- The pot life of the mixture at 20° C is 25 min.
- 1 kg of ready-made mixture of Silver Epoxy A and B components is enough to cover 30-50 m^2 of surface (depending on the thickness of the coating).
- The coating should be cured at 60 - 80° C for 30 - 60 s.

ventilation ducts

heat exchangers

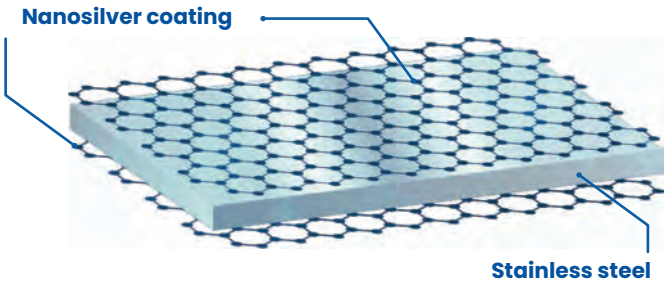
industrial hoods

drip trays

condensers

AG-Service

We offer a service of covering stainless steel elements with a nanosilver coating which provides antibacterial, antifungal and antiviral properties, thus increasing the biological safety of the covered elements. The coating is characterized by high microbiological activity (reduction > 99%). The technology used ensures the efficiency and repeatability of surface coating and guarantees safety of use.



Wide range of applications

The coating perfectly protects all steel elements with a high level of exposure to colonization, e.g.: flow systems of coffee machines and water dispensers, sanitary drains, door handles, elements of hospital bed frames and many others.

Biocidal action

Wide range of applications

Safe use

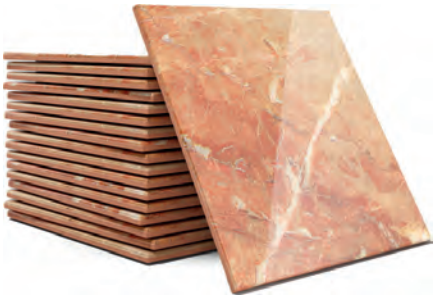
Cost efficiency

Preventive action

It is possible to adjust the concentration of nanosilver according to the customer's needs.
Our coatings are also characterized by high cost efficiency.

AGuscio

One of our products is the AGuscio technology which combines the production and adaptation technology of a bioactive additive to ceramic coverings (tiles, stoneware, sanitary equipment, etc.). The use of the developed coating allows the production of ceramic tiles and devices with new, previously unseen features and the construction industry gains a new standard of safety and protection against the development of pathogenic pathogens. The innovative technology of applying nanosilver to ceramics, developed and tested by Smart Nanotechnologies, allows manufacturers to create any collections of self-disinfecting ceramic products, e.g. tiles and stoneware. Such products can permanently protect the user against bacteria. Thus we have established a new global standard of safety, comfort and hygiene of life.



Biocidal ceramic tiles

- the developed solution ensures over 90% reduction of bacteria according to ISO 22196,
- the developed component demonstrates antibacterial effectiveness on all types of ceramic tiles,
- the nano-additive is permanently bonded to the protected surface and demonstrates high thermal stability,
- application is carried out using existing lines, standardly used devices in the production of ceramic elements,
- the component does not affect the appearance of the final product,
- low cost of securing a running meter.

Virucidal effectiveness

As a result of the undertaken studies, the virucidal properties of ceramic tiles against *adenovirus type 36* were assessed using the method described in ISO 21702:2019: "Measurement of antiviral activity on plastics and other non-porous surfaces"

The exposure time was 24 hours.

After this time, a virus reduction of ≥ 4 log10 was observed (virucidal efficacy of 99.99%).

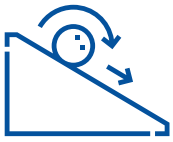
GLADOC

GLADOC is a specially developed component for windscreen washer fluids created based on nanotechnology which results in new functional properties, using traditional solutions. Regular use of fluids with the addition of GLADOC leads to the sealing of scratches, as a result of which the transparency of the glass and its functional properties are improved.

Windscreen washer fluids containing the GLADOC additive have strong hydrophilic properties, which means they easily penetrate deep into the surface which facilitates quick and effective removal of dirt and insects. Elimination of minor windscreen damage has a positive effect on visibility while driving and driving comfort, and consequently on the safety of the driver and passengers.

Improving the efficiency of the windshield washer fluid

Easier removal of grease and insects

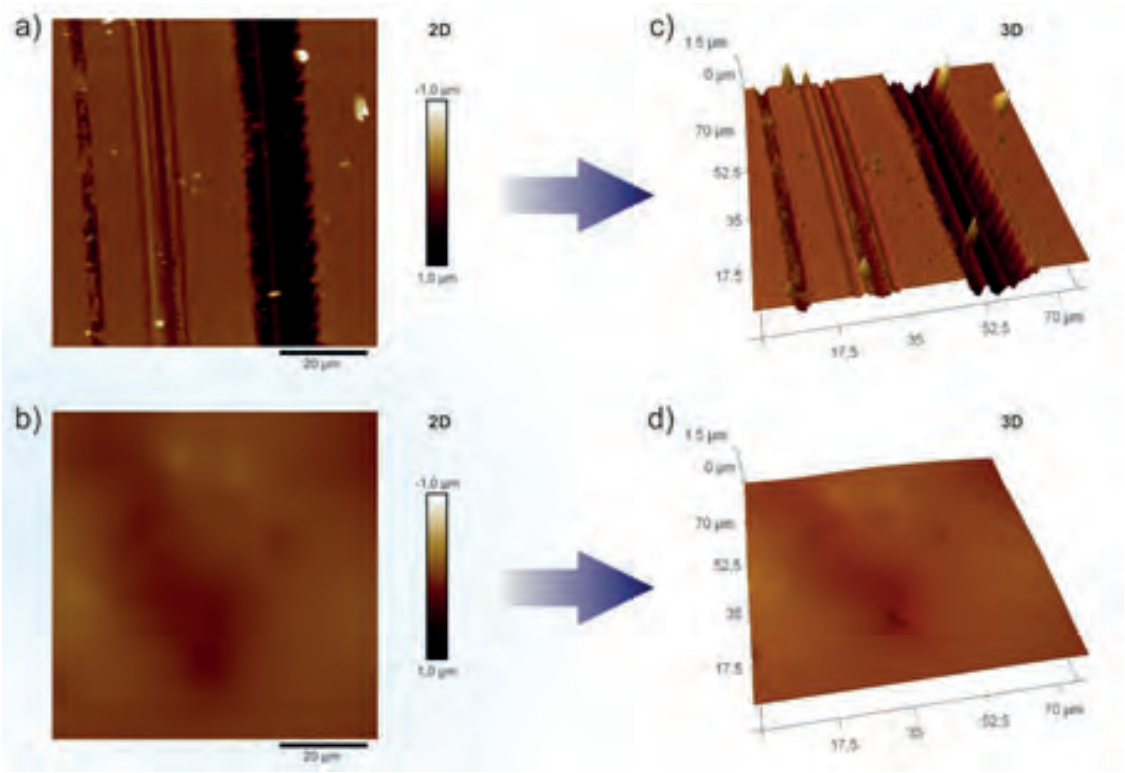


Reduction of surface friction

GLADOC eliminates shallow scratches and significantly reduces the size of deep scratches.

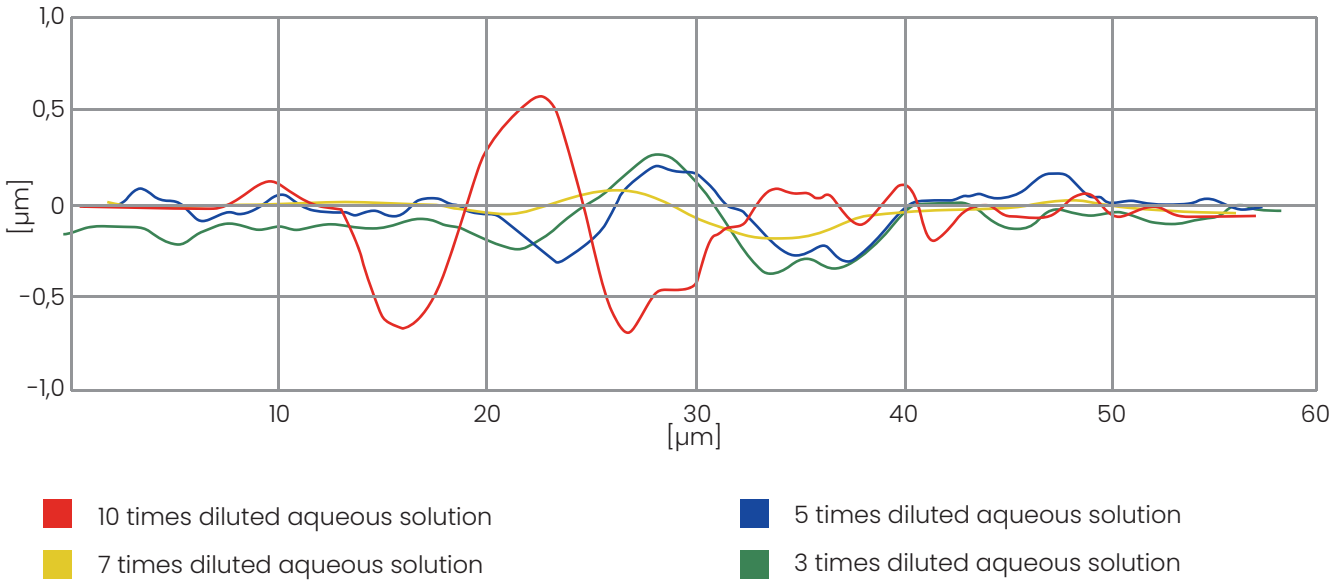
Research conducted in independent scientific units confirms the effectiveness of the preparation.

GLADOC does not negatively affect metal and rubber elements. It doen't change the color, transparency, smell or viscosity of the windshield washer fluid.

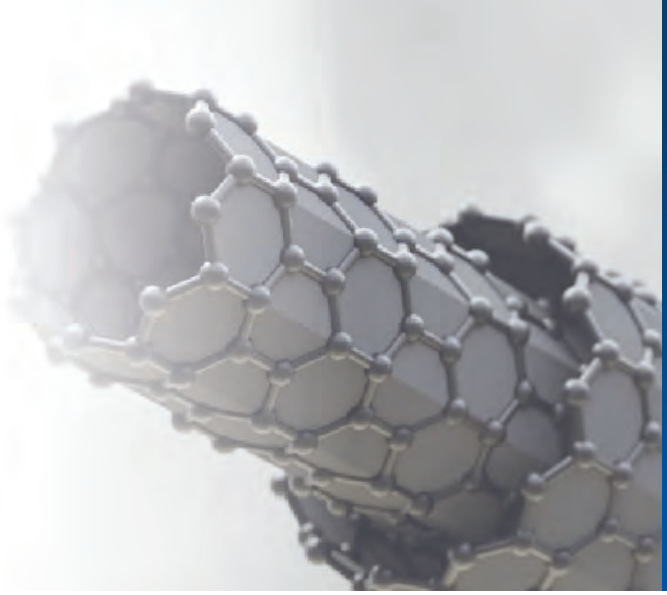


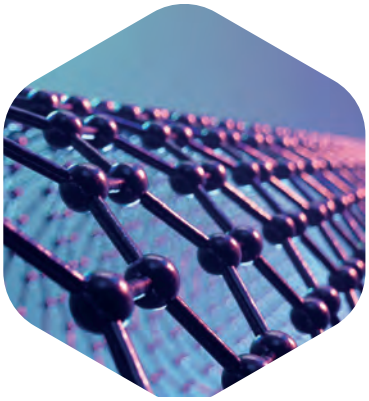
Two-dimensional (a,b) and three-dimensional (c,d) atomic force microscope (AFM) imaging of the scratched glass surface after three applications of GLADOC (b,d).

Summary of average scratch depths after application of GLADOC solution:



Carbon nanotubes





Carbon nanotubes, along with graphite, diamond, and fullerenes, are an allotropic form of carbon. Carbon nanotubes are made of rolled graphene (a single-atom layer of graphite) and the thinnest have a diameter of one nanometer, although their length can be millions of times greater. Carbon nanotubes are attractive for a wide range of applications due to their size, tensile strength, thermal and electrical conductivity, exceptionally large specific surface area and chemical inertness. These properties make them investigated as promising materials for applications in nanotechnology, electronics, optics and modern materials.

Example applications include high-strength polymer composites, electrode materials for high-capacity batteries, efficient field emitters for microscopy and lithography, X-ray tubes, hydrogen storage devices, discharge tubes, vacuum microwave amplifiers, nanoelectronic systems and conductive fillers. Carbon nanotubes can also be used in electron guns, FED displays, biosensors, fuel cells, transistors and stealth technology. They can also be used as fibers and as polymer/carbon nanotube composites for electronic textiles. Very small amounts of carbon nanotubes in plastic allow the formation of a percolating network which makes the obtained material conductive, without the filler causing degradation of the initial properties of the matrix. They are also an excellent lubricant and additive to greases and oils. Research is ongoing on the use of carbon nanotubes for hydrogen storage and such hydrogen nanotubes could be used as fuel cells to power energy-efficient and environmentally friendly vehicles. A few years ago, the production of carbon nanotubes was very complicated and expensive, but now efficient, stable and relatively inexpensive production methods have been developed, an example of which is the CVD (Chemical Vapour Deposition) method.

Idea 3W

The 3W Idea: water-hydrogen-coal (in Polish: woda-wodór-węgiel) was created on the initiative of the National Economy Bank. The aim of the project is to support the world of science and business in the development of modern technologies used in industry, energy and medicine. Three resources - water, hydrogen and coal - properly used will change the Polish economy into a more innovative and competitive one. 3W is a long-term project that is to activate society, business, the world of science and state administration. 3W is actions forthe sustainable development of the economy and society.

The 3W Idea is a unique concept on a global scale which combines the competences and needs of the world of science, business and administration in order to build a better, modern, sustainable future based on technologies from the area of water, hydrogen and elemental carbon.

3 resources, one planet, shared responsibility

Today - not only as Poland but the whole world - we are facing enormous civilizational challenges, because climate change is progressing faster than we initially assumed. Societies in developed countries already expect that we will not develop at the expense of future generations and the environment and the coming years and decades will be crucial in this matter. The 3W idea is a vision of the future in which - as an entire society - we responsibly manage the resources at our disposal and in which we can maintain and improve the quality of our lives while using less energy and fewer non-renewable resources.

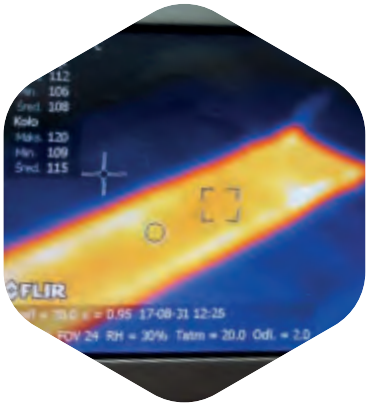
In 3W we focus on three resources that will have a huge impact on our future: water, hydrogen and coal. Carbon has been indicated as the material of the future, because thanks to its extraordinary properties it allows scientists to design lighter and more durable engineering materials. Graphene, fullerenes, nanotubes and activated carbon are used, among others, in construction, medicine and pharmacology, as well as in the space industry.

WATER HYDROGEN CARBON

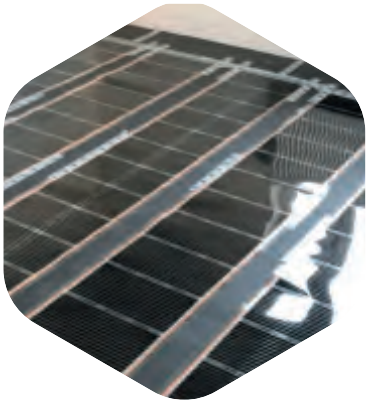
CASE STUDY

The use of carbon nanotubes in heating mats

Even heating of the apartment can be problematic. Conventional heating systems are based on convection, i.e. air circulation in the room. First, the air heated by the radiator rises to the ceiling and then, as it cools, flows down the opposite wall. This causes temperature differences in the room of up to several degrees. For this reason, it is coldest near the floor, which causes the feeling of freezing feet. The solution to this problem is to use underfloor heating systems for heating. One of them is heating mats. Until now, old-type mats were used, based on rigid kanthal resistance wires which were often characterized by failures. Modern materials developed by our company allow the use of a new type of mat with carbon nanotubes which ensure failure-free operation and save electricity necessary to heat them.



By using appropriately surface-modified multi-walled carbon nanotubes, we have replaced traditional solutions that use electrical paths or wires with resistive properties to the flow of current with a nanocomposite heating material.



Application

in the military for simulation purposes, heated tents, heated mats, telemedicine, automotive.

Even temperature distribution over the entire heated surface

Quick response time in achieving the expected temperature

Safe supply voltages (up to 12 V)

Possibility of adjusting the shape and plasticity of the material

Wide range of possible temperatures: up to 120 °C

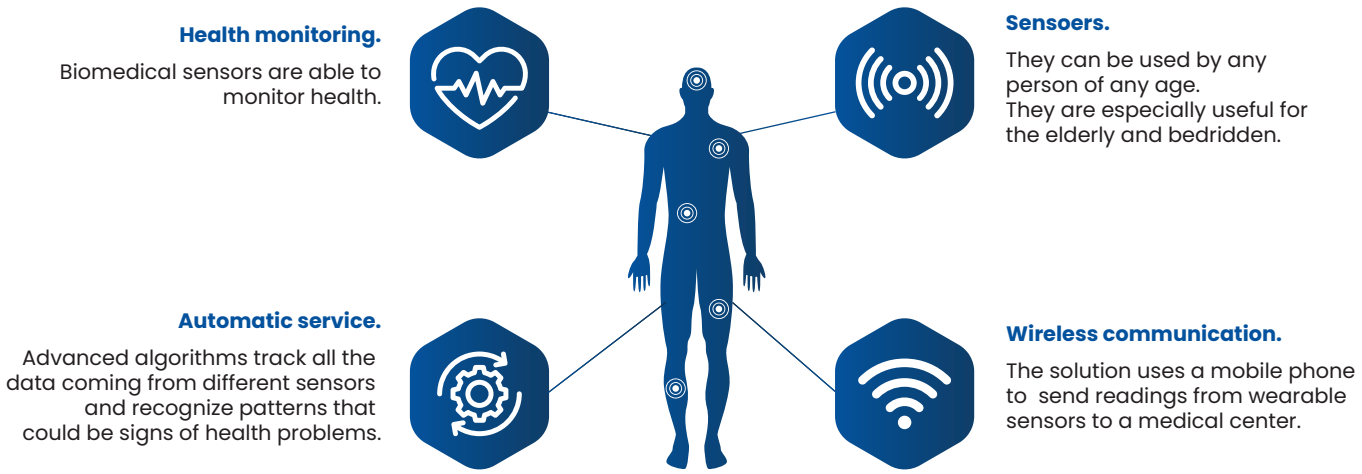
CASE STUDY

Application of carbon nanotubes in health monitoring electrodes

Nowadays, an aging society struggling with a fast and stressful lifestyle suffers from many diseases of civilization. The number of people requiring constant supervision and monitoring of their health is continuously growing. This motivates the use of the latest technologies to provide sophisticated and at the same time convenient medical services supporting the elderly and chronically ill. In this context, measuring biopotentials is very useful because it provides feedback on the state of the cardiovascular system and other physiological processes that are key to life. In the above measurements, appropriate electrodes are one of the most important aspects. The effects occurring at the contact surface of the material with the skin are complex and can be observed as a resultant of coexisting phenomena. This problem can be effectively compensated by using wet silver chloride electrodes, but in some applications, e.g. solutions integrated with textiles, this is still an area of research and development in the context of advanced materials.

In the project, we prepared a set of material samples and then analyzed their properties and structure. Our research team has extensive experience in this field and we have chosen polymer nanocomposites with carbon nanotubes as a promising solution. The addition of a multi-walled carbon nanotube ensures the electrical conductivity of the composite. According to the requirements of the specific application, the material must be characterized by appropriate flexibility and elasticity. To ensure such properties, a rubber matrix in the form of a mixture of siloxane polymers was used. This can be an alternative to standard gel pads and innovative metal dry electrodes. In addition to the excellent mechanical properties of the composite, the main goal is to obtain a reliable ECG signal. We plan to conduct a series of material tests with the main emphasis on electrical properties. First, we will evaluate the conductivity and accompanying effects in most material samples. For this type of test, impedance spectroscopy seems to be the most suitable method. The next step after examining the material properties is to recognize and quantitatively measure the effect on the electrode surface of the sample in contact with a phantom electrolyte simulating the skin. For this purpose, we plan to prepare a system that will simulate the skin electrode interface and enable tests and precise measurements.

Using Wearable Sensors to Provide Telemedicine Services



CASE STUDY

Application of Carbon Nanotubes in Composites Shielding Electromagnetic Radiation

The phenomenon of electromagnetic radiation shielding is used in military low-detection technologies which include a number of solutions used in the construction of aircraft, ships or missiles to make them more difficult for the enemy to detect. Currently, low-detection technology includes the design and selection of appropriate materials that allow for limiting the possibility of measuring physical fields enabling recognition, hence effective solutions are based on materials and structures that reduce the optical, acoustic, thermal, infrared and radar signature of the target. Today's state of the art allows for achieving "invisibility" using shapes that ensure the reflection of the incident electromagnetic wave everywhere except the source of radiation, construction materials that poorly reflect or absorb electromagnetic waves, coatings and paints that suppress electromagnetic waves or appropriate tactics of action, primarily night flights, at altitudes that prevent the enemy from using short-range anti-aircraft means, using electronic warfare means. In the context of the described application, great expectations are associated with carbon nanotubes. The effect of improving functional properties is the result of strong interfacial reactions between carbon nanotubes and the polymer while maintaining a high degree of dispersion.

The addition of functionalized carbon nanotubes made it possible to obtain an electrically conductive material in which the nanotubes create a network for the charge flowing through the material. The shielding effect is observed when the number of carbon nanotubes exceeds the percolation threshold. This solution allows electron transfer from the surface of carbon nanotubes to the polymer matrix, thus improving radiation absorption. The increase in conductivity increases the shielding efficiency of the material and the conductivity itself increases with the increase in the frequency of electromagnetic radiation which results in the shielding efficiency increasing with the increase in frequency.

The developed material also achieved a significant improvement in tensile strength and Young's modulus improvement. The increase in tensile strength of polymer composites with nanocomposites results from the transfer of loads present in the material to the reinforcing phase. The fact that the material is characterized by high shielding efficiency of electromagnetic waves and that the use of carbon nanotubes improves mechanical properties means that the material can be used as a core - a construction material, as well as a coating that can be applied to another material. The tests carried out have shown that a 3 mm thick material guarantees absorption of over 90% of incident energy.

Create an innovative future with us

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