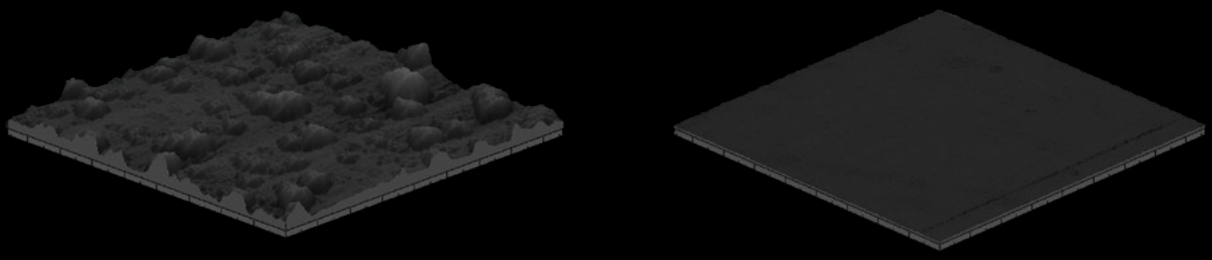
Antibacterial Coatings



PLATIT® π - Series

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New antibacterial coating with long-term bactericidal properties for components

Bacteria and their Consequences

Bacteria were one of the first species to appear on earth and are present in most of its habitant. There are approximately 5 × 1030 bacteria on Earth outnumbering all plants and animals. Bacteria can reside in soil, water, acidic hot springs, radioactive waste, and the deep biosphere of the earth's crust. In a gram of soil there are around 40 million bacterial cells and in a milliliter of fresh water approximately a million bacterial cells in versatile range of shapes from rods and spirals to spheres. Bacteria can be classified in different ways but almost all of them could be divided into two major groups based on their response to the Gram-staining procedure, namely gram negative and gram positive.

Many species of bacteria are pathogenic and cause infectious diseases, such as cholera, syphilis, bubonic plague (as gram negative examples) and anthrax, leprosy (as gram positive examples). The most common fatal bacterial diseases are respiratory ones. Just in one case and mostly in sub-Saharan Africa, Tuberculosis bacteria kills about 2 million people annually. Antibiotics are used to treat bacterial infections and are also used in farming, making antibiotic resistance and that is a growing problem.

Only in USA and only in healthcare segment, approximately 100,000 deaths due to infected patients merely from hospital facility and equipment, so called Healthcare-associated infections (HAI), have been reported annually [1].

In an academic investigation over course of 3 years, surfaces of 6 frequently touched objects in a health care facility have been replaced by bulk copper and its alloys acting as antibacterial surfaces and bacterial burdens monitored continuously. A significant bacterial burden reduction, from approximately 50 up to 98 %, could be observed in all cases.

PLATIT's Certified Solution

Despite of achieved successes, practically these approaches cannot be implemented in the real world, due to economical as well as technical issues. On the other hand, antibacterial PVD coatings can play a major role in providing bactericidal surfaces and decreasing hand-transmitted diseases as well as fatalities thereof while keeping the component's bulk properties intact and surface properties improved. PLATIT's antibacterial coating demonstrates the highest level of bactericidal properties according to ISO 22196:2011-08 and has been tested in 2 durability tests to resemble the long-term antibacterial effect in real world conditions. Along with the superior bactericidal features it also shows a high hardness, elastic modulus as well as a good adhesion to substrate (Table 1).

The PLATIT's developed antibacterial coating tested under ISO 22196:2011-08 standard exhibits a profound bactericidal performance for both gram negative, i.e., Escherichia Coli and gram positive, i.e. Staphylococcus Aureus. According to DIN EN ISO 20743:2013, Appendix F, highest efficacy level of antibacterial properties is achieved when reduction value A [lg cfu] is higher or equal to 3.

Table 1. Mechanical properties of developed antibacterial coating:

Specifications	
Color	Gold
Deposition technology	Cathodic arc
Nano-hardness [GPa]	25–27
Elastic modulus [GPa]	460
Coating thickness [µm]	1–2
Adhesion [Rockwell]	HF1
Coating temperature [°C]	200–450

ISO certified tests (performed at Hohenstein Laboratories – Germany):

Table 2. The PLATIT's developed TiAgN antibacterial coating tested under ISO 22196:2011-08 standard:

	Staphylococcus Aureus ATTC 6538P		Escherichia Coli ATCC 8739	
	Reduction value A in 24 h lg cfu	Reduction value A in 24 h %	Reduction value A in 24 h lg cfu	Reduction value A in 24 h %
TiAgN coating	≥ 3.2	≥ 99.94 %	4.15	99.992 %

Staphylococcus Aureus concentration of inoculum*: 4.77 × 105 cfu/ml**
Escherichia Coli concentration of inoculum: 6.45 × 105 cfu/ml
The value of gram growth is calculated over 24 h on the sample in comparison to the reference material and according to the formula:
S = [lg(B / A) - lg(C / A)]= [lg(B / C)]

S: specific antimicrobial activity
A: average number of active bacteria (cfu), eluted from the reference material immediately after inoculation
B & C: average number of active bacteria (cfu), eluted from the reference material and sample (respectively) after 24 h incubation
* An inoculum is the population of bacteria that is introduced in the fermentation medium or any other suitable medium
** Colony forming unit per milliliter

Certified long-term behavior

Apart from medical implants where bactericidal properties are vital primarily in the first two post-surgical weeks, for most of other coated components antibacterial properties should last leastways over a period of many weeks or months after multiple usages, cleanings, and touches. Two approaches have been adopted to resemble and reproduce the real usage conditions for the developed antibacterial coating.

1. 50 autoclave cycles (performed at RMS Foundation – Switzerland)

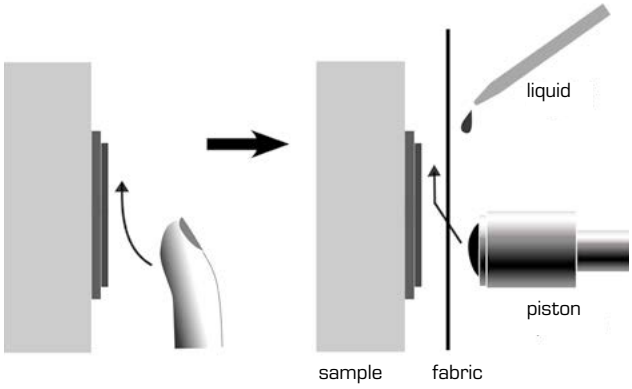
In this case antibacterial coated parts have undergone 50 autoclave cycles at RMS (Robert Mathys Stiftung) in Switzerland. The aim is to resemble antibacterial coated medical instruments and components in working conditions and investigate if the bactericidal efficacy will be sustained or adversely affected. Therefore, autoclaved parts have been subsequently tested for their antibacterial properties at Hohenstein Laboratories under ISO 22196:2011-08 standard again.

Each autoclave cycle: 1× vacuum (20 kPa) / steam burst (160 kPa), Sterilization (15 min at 120 ± 2°C), drying (5 min)

2. 50,000 touches (tribo-touch testing with 50,000 strokes at KIMW Lüdenscheid – Germany)

In public space and facilities there are numerous frequently touched objects, e.g. door handles, elevator buttons, stair railings, vending machines and so on. These are considered as a fast track for hand-transmitted bacteria and infections. To resemble these conditions, the developed antibacterial coating has undergone 50,000 strokes in tribo-touch test at KIMW Lüdenscheid institute in Germany and subsequently tested for their bactericidal properties under ISO 22196:2011-08. Test schematic can be seen in figure 1.

Figure 1. Schematic depiction of the test by Co. Tribotron resembling a frequently touched surface:

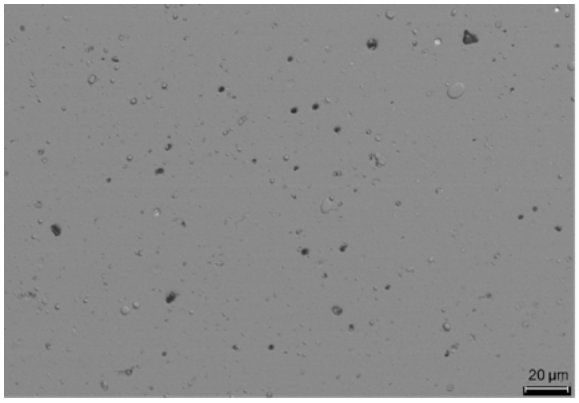


Testing distance: 5 mm, No. of cycles: 50,000 strokes, testing frequency 2 Hz, test media: artificial hand perspiration acc. to 8.13 of the standard, media feed: 0,5 ml / 400 cycles, testing force: 6 N, test plunger: Ø10 mm.

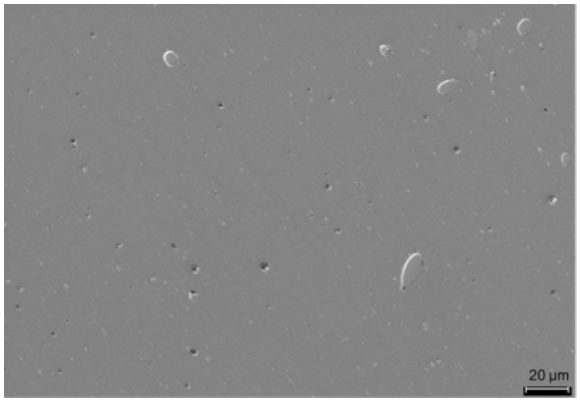
PLATIT's antibacterial coating has a high hardness of ≥ 25 GPa and has experienced almost no change of the surface rather than a very slight surface polishing (figure 2). Therefore, it can be concluded that the developed coating could withstand factors higher number of touches over months of usage in public surfaces on frequently touched components with almost no mechanical properties deterioration.

Figure 2. Scanning electron microscopy (SEM) images of the antibacterial coatings before (a) and after (b) 50,000 strokes, i.e. touches, in the tribo-touch test:

a)

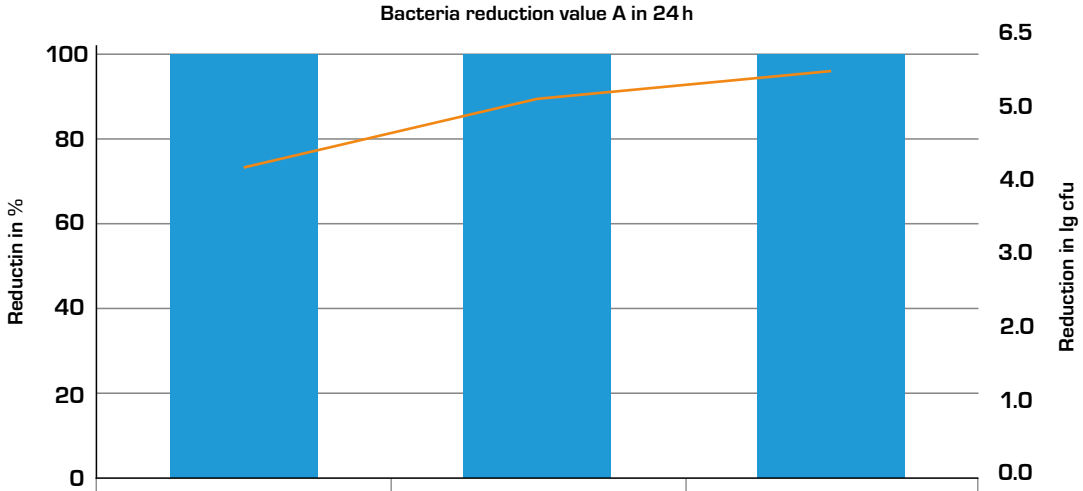


b)



Results from antibacterial tests under ISO 22196:2011-08 standard for Escherichia Coli demonstrates the highest level of bactericidal performance even after 50 autoclave cycles or 50,000 touches (figure 3). These results significantly expand the applicability of the developed antibacterial coatings into a broad range of components and applications. Numerous examples from healthcare system and healthcare acquired infections (HAI) thereof to frequently touched surfaces in public space can be considered.

Figure 3. antibacterial performance against Escherichia Coli according to ISO 22196:2011-08 standard; status before (as-deposited) compared to after 50 autoclave cycles and 50'000 touches. In all cases, the highest level of bactericidal performance defined by ISO standard have been achieved:



	as-deposited	after 50 autoclave cycles	after 50,000 touches
Reduction %	99.9 %	99.9991 %	99.9997 %
lg cfu	4.2	5.1	5.5

Ref.

[1] M. Heron et al. "Deaths: Leading Causes for 2009", National Vital Statistics Reports 2012, vol.61, No.7, Agency for Healthcare Research and Quality, Patient safety primers: healthcare-associated infections 2012.

[2] M. G. Schmidt et al. "Sustained Reduction of Microbial Burden on Common Hospital Surfaces through Introduction of Copper", Journal of Clinical Microbiology vol. 50, No. 7, 2012, P. 2217.

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