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Antimicrobial coatings

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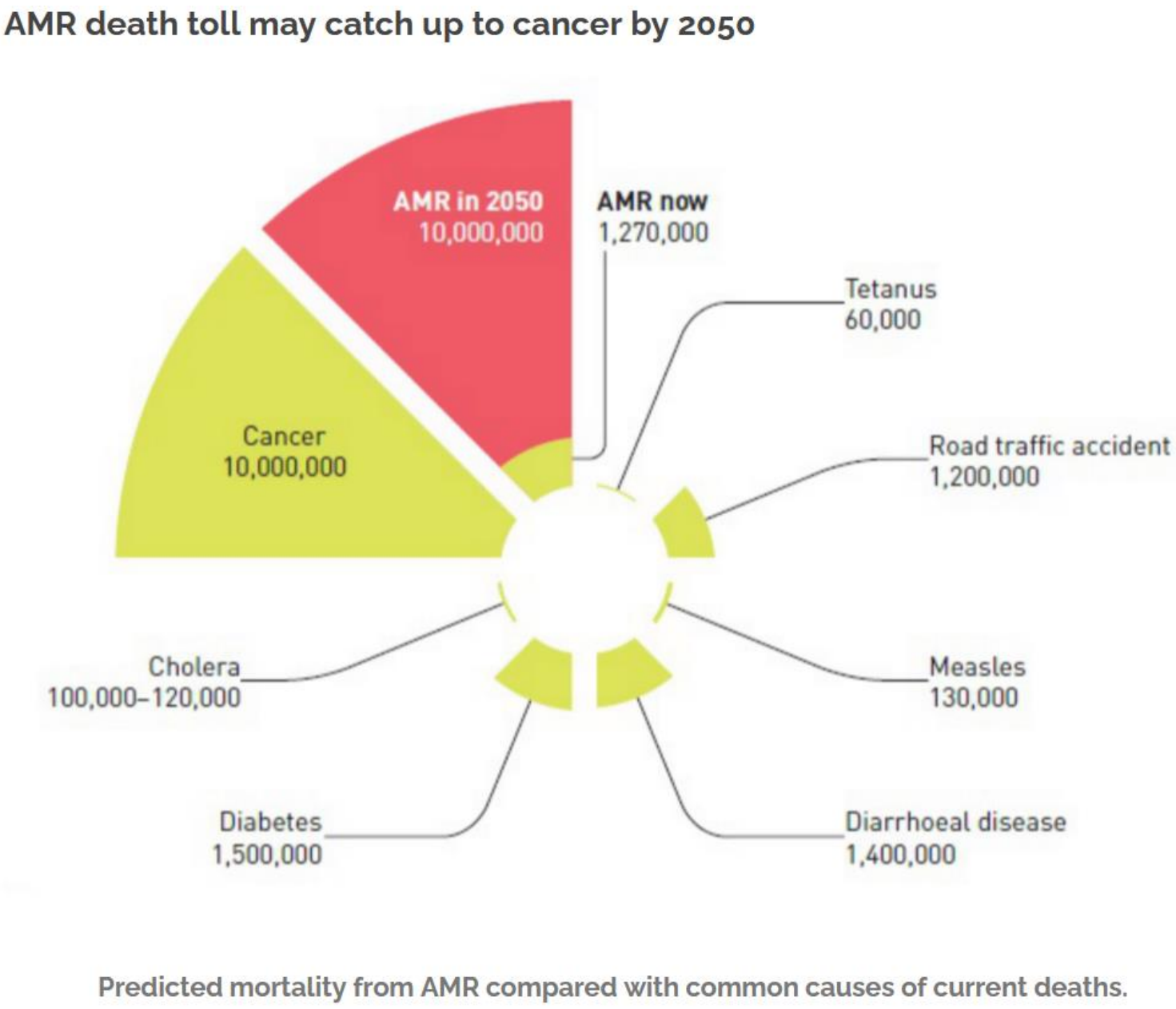
Antimicrobial surfaces and coatings

To reduce the number of microbes on frequently touched surfaces (or medical devices) and thereby help prevent the spread of various diseases.

Relevance: the growing spread of AntiMicrobial Resistant (AMR) bacteria



https://healthpolicy-watch.news/antimicrobial-resistance-deaths-cancer/

- **Antimicrobial surfaces and coatings** are designed to reduce the number of microbes on frequently touched surfaces (or medical devices) and thereby help prevent the spread of various diseases.
- Relevance: the increasing spread of antibiotic-resistant bacteria
- Classical agents: copper and copper compounds (such as brass), silver – they still work !!!

Doorknobs - copper compounds

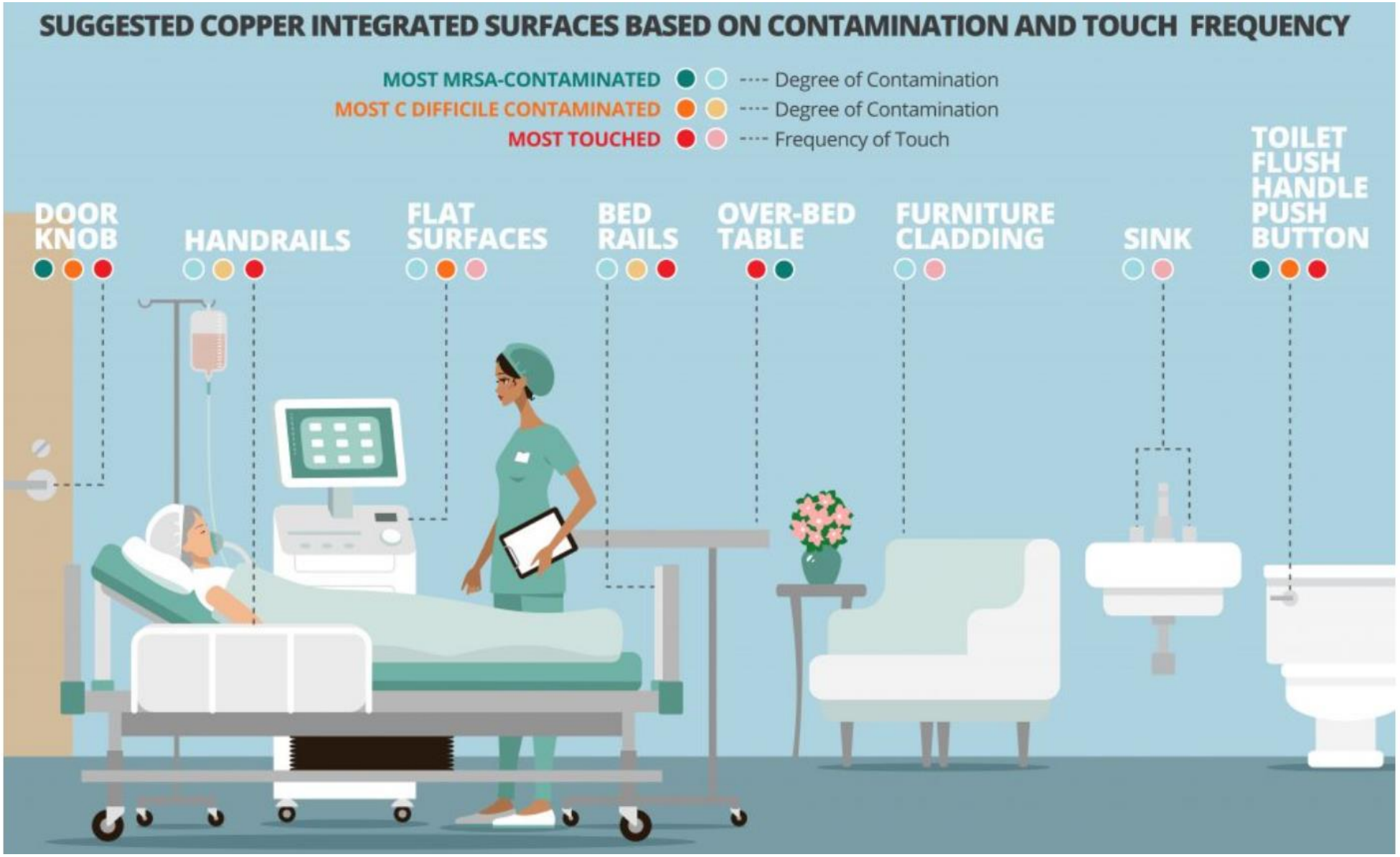
Silver-Coated 2-Way Silicone Urinary Catheter

Copper compounds

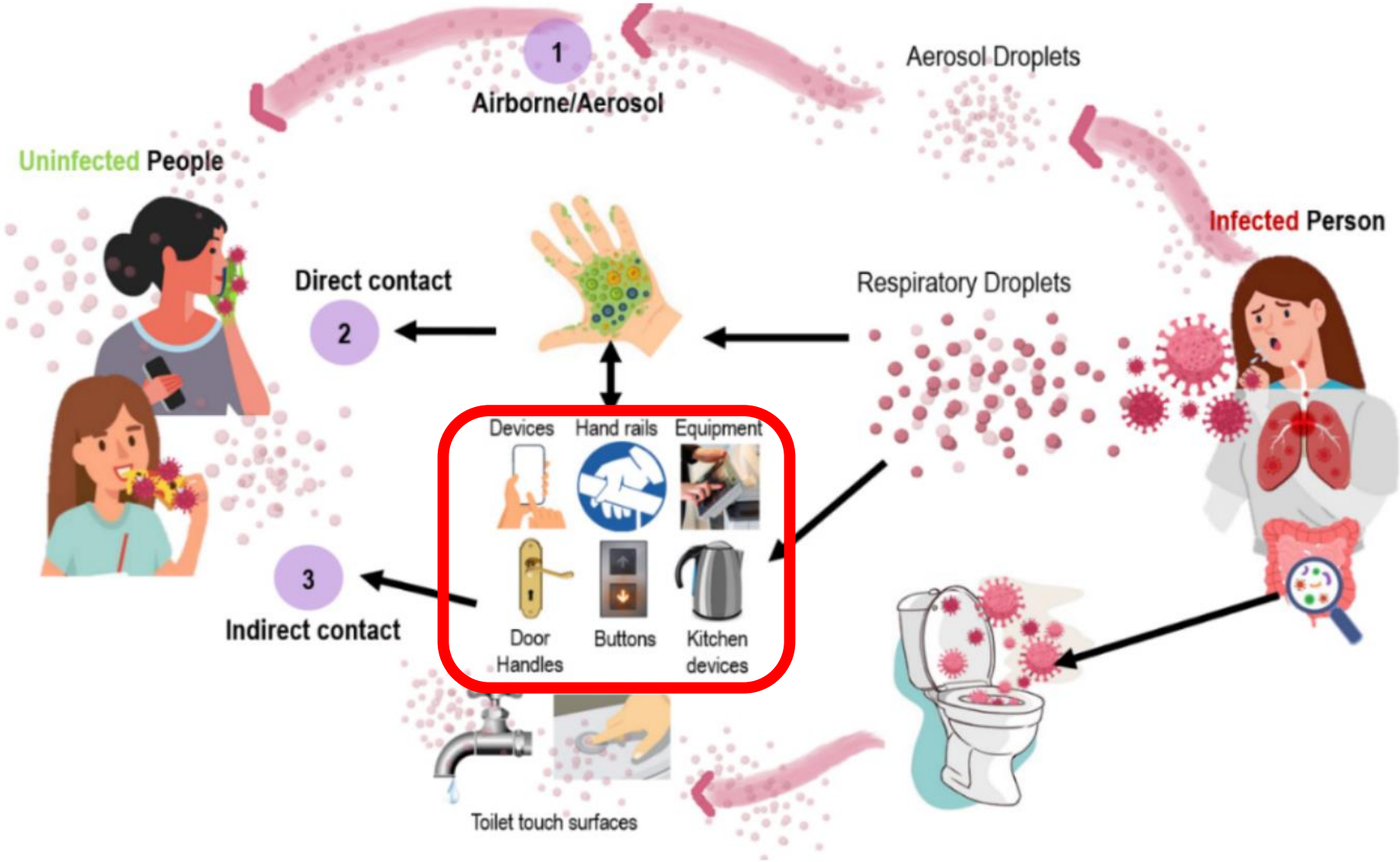
Silver

Copper

HAI - hospital acquired infections



Modes of transmission of infectious diseases

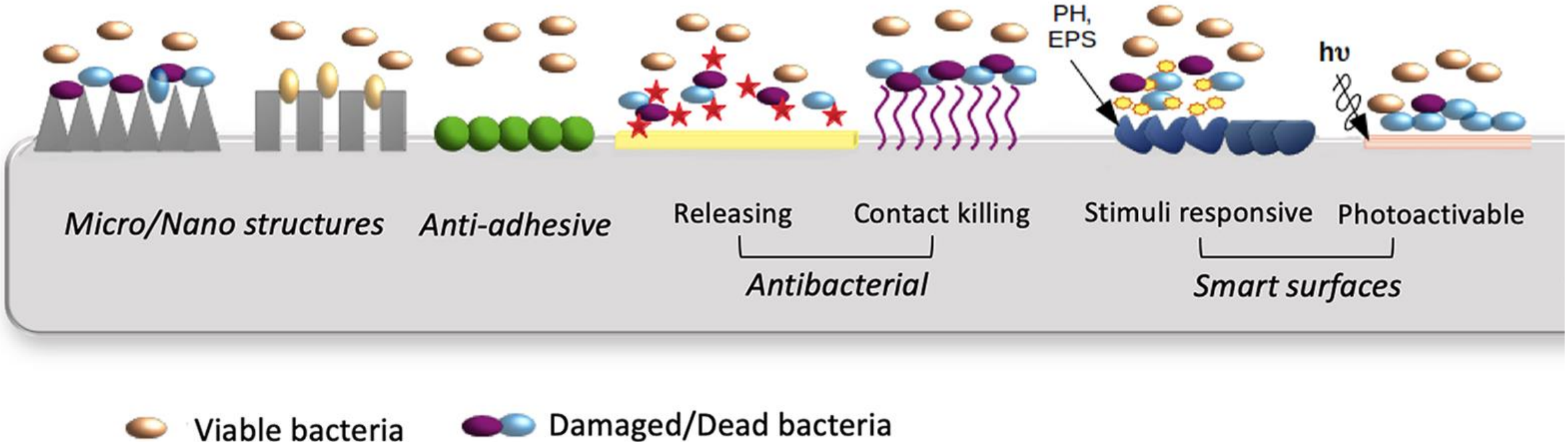


Sustainability **2023**, *15*(4), 3394; https://doi.org/10.3390/su15043394

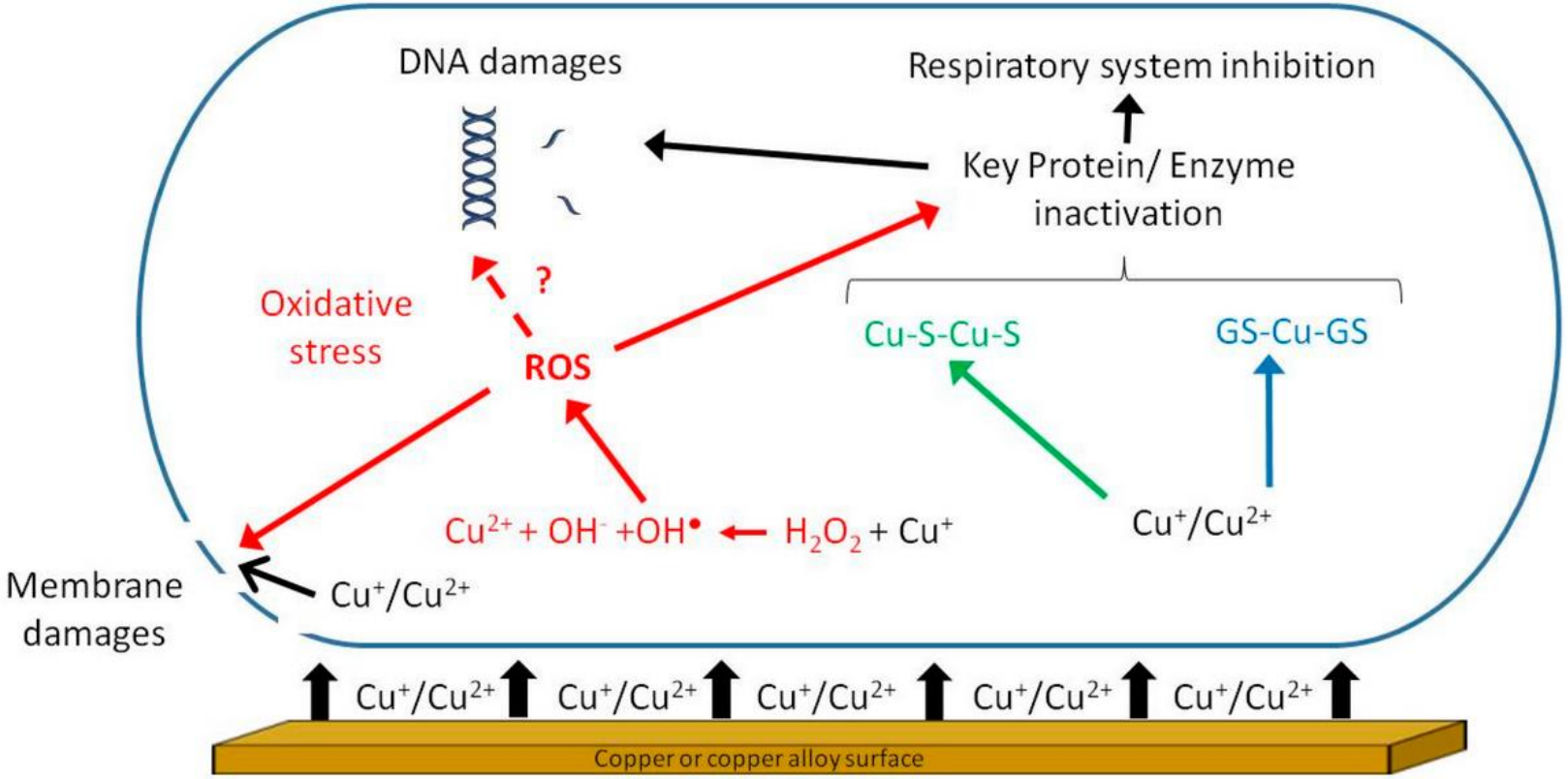
Different surface modification strategies

Surface topography
Ramdom, ordered and dynamic topographies

Chemical modifications
Polymers, dendrimers, cationic peptides, QS disruptors, smart surfaces, hydrogels.



DOI: 10.1021/acsbiomaterials.9b00849



Antimicrobial mechanisms of copper surface

Antibiotics **2021**, 10, 286.
https://doi.org/10.3390/antibiotics10030286

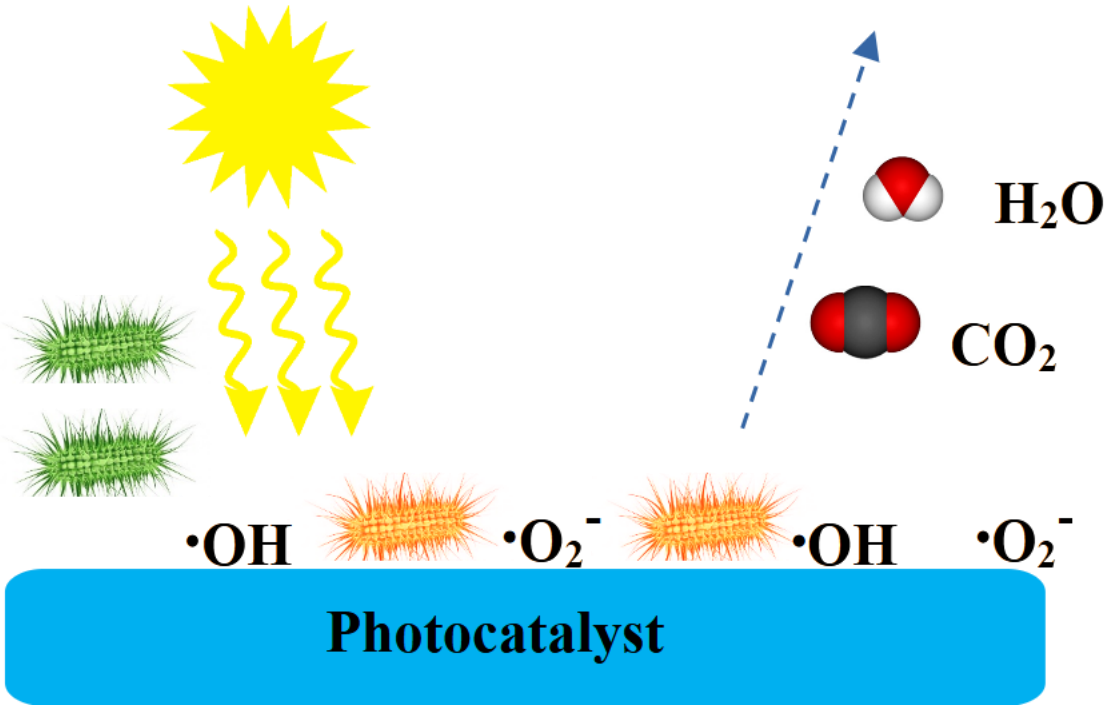
- **direct destruction of the membrane by Cu^+ and Cu^{2+} ions (black pathway);**
- **hydrogen peroxide-dependent oxidation of Cu^+ in the cell under aerobic conditions generating reactive oxygen species (ROS) (red pathway);**
- **interactions between copper ions and glutathione under anaerobic conditions (blue pathway) and displacement of iron from iron-sulfur clusters (green pathway). Inactivation of key proteins/enzymes, among which are those involved in the respiratory system as well as membrane and DNA damages.**

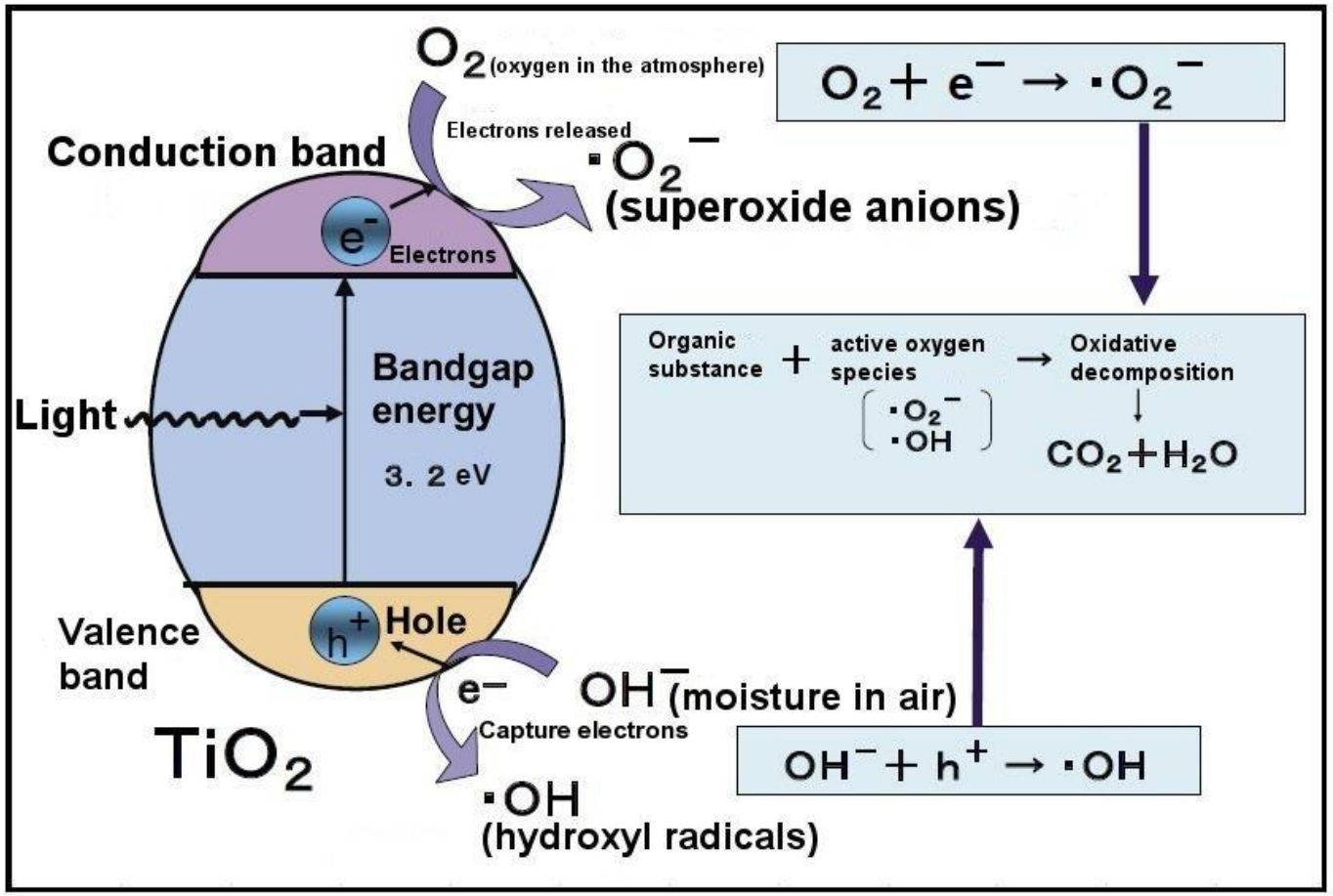
Problems with classical compounds

- Fingerprints (i.e. eccrine sweat) – water
+ organics (proteins, glucose, lactate etc.)
+ inorganics
- All kind of dirt
- Bacteria, residues of dead bacteria
- Oxidation of metals

We need to clean surfaces often to keep them active !!!

One modern solution: Photocatalytic degradation

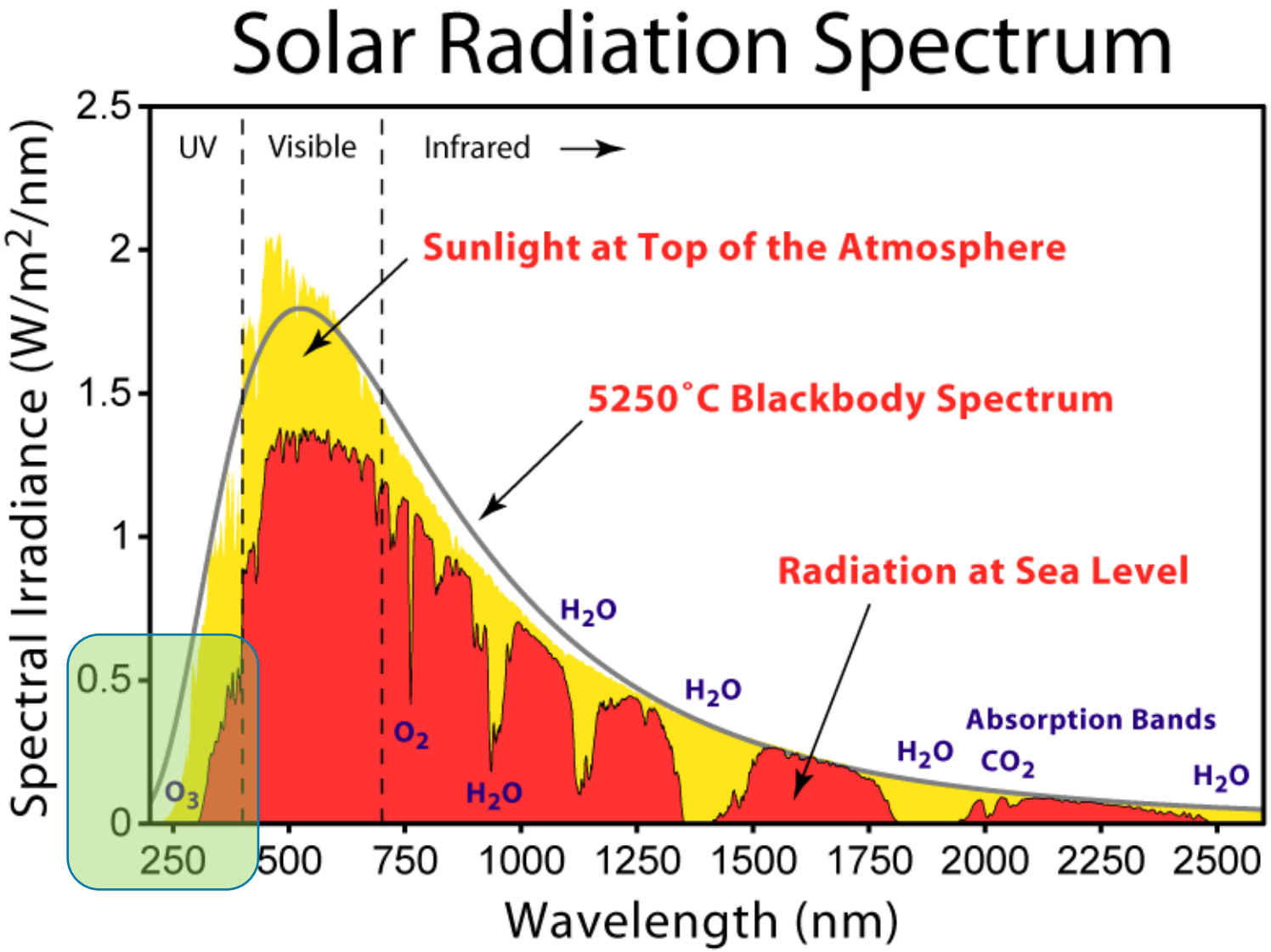




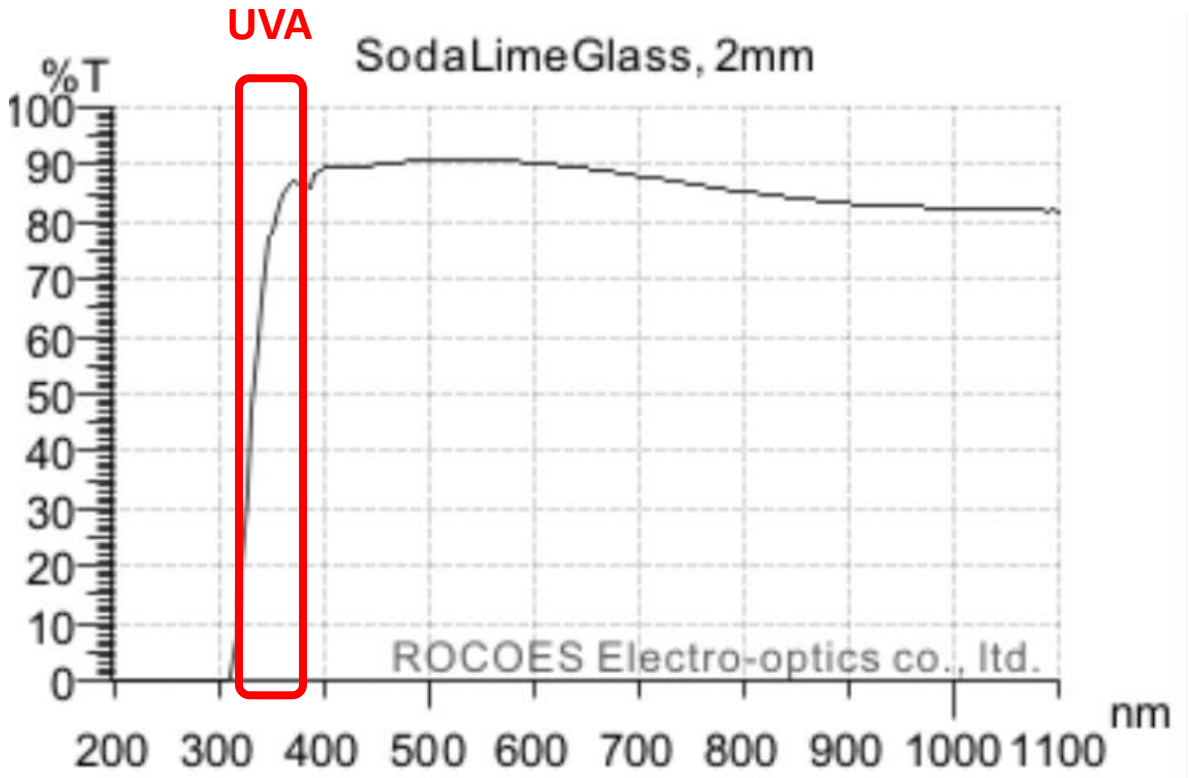
ROS: Reactive Oxygen Species (·OH, $\cdot O_2^-$, etc.)

Complication:
solar photons versus TiO_2 band-to-band excitations

TiO_2 anatase crystal phase
(band gap E_g= 3.2 eV ,
respective wavelength 387 nm)



More complications: Can UVA pass through window glass?



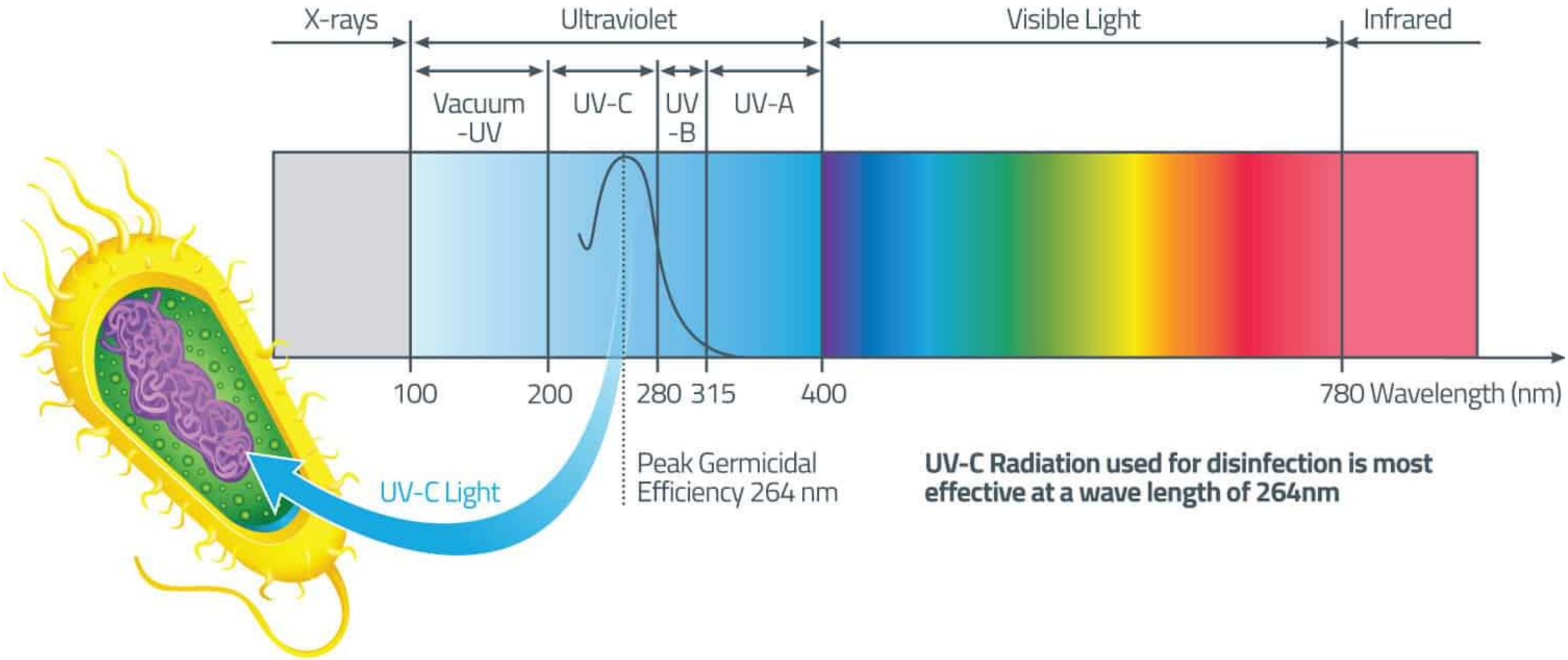
https://rocoes.com.tw/2glass/sodalime2.html

Sunny summer day:

UVA outside room – approx. 3 W/m²

UVA inside room (through window) – approx. 2 W/ m²

Why not use germicidal UVC lamps ?



https://uvguard.com/knowledge-centre/

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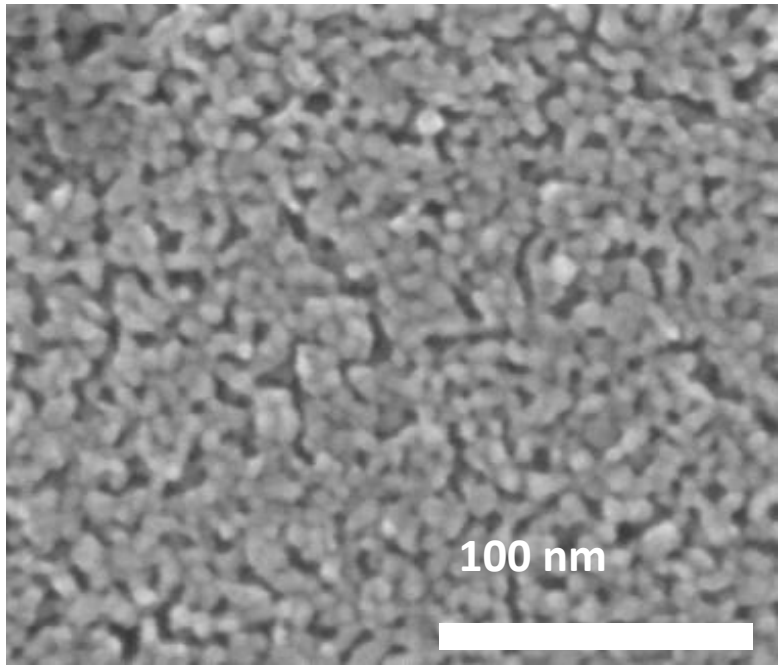
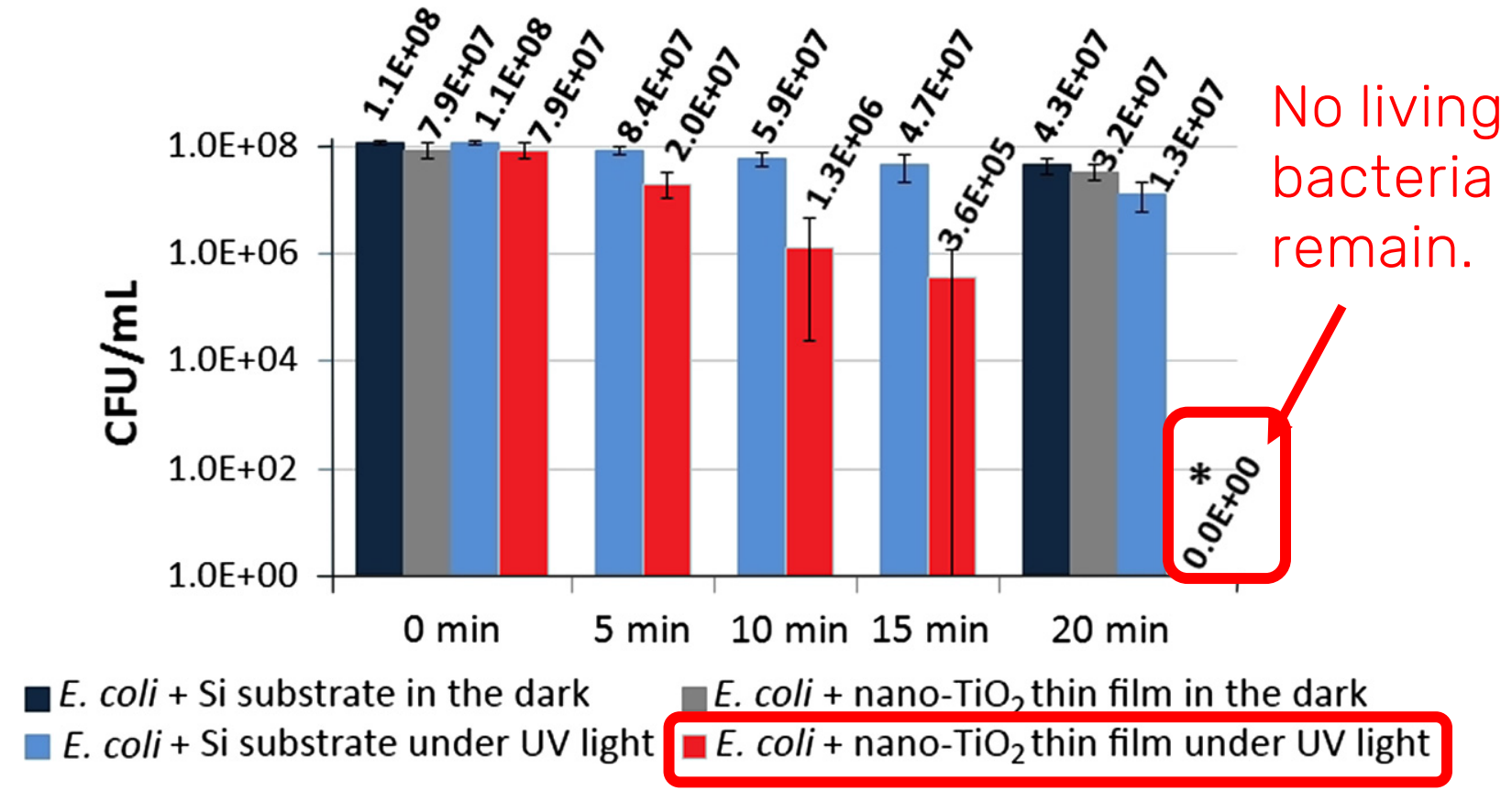


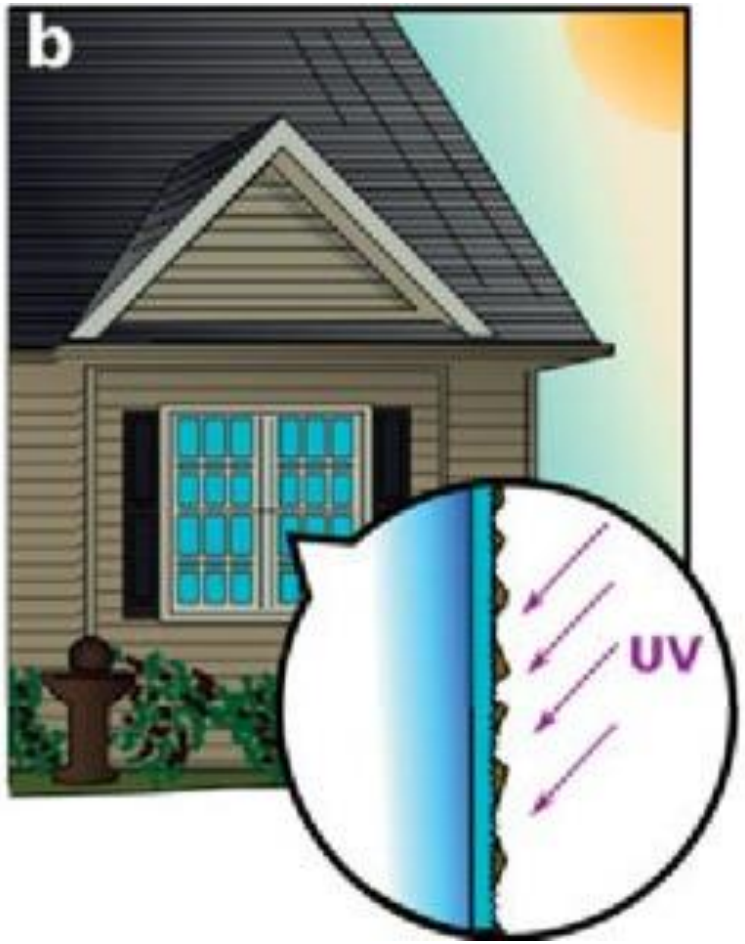
SEM image: thin nano-TiO_2 coating on glass



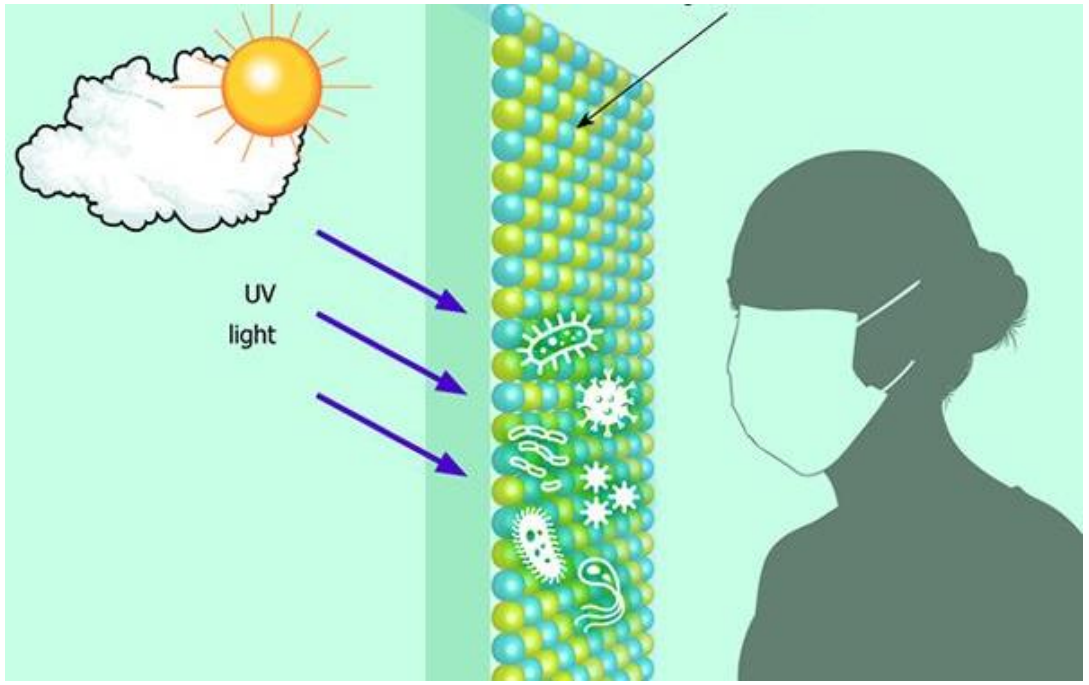
After 20 minutes of UV-A activation of the nano-TiO_2 thin film (partly covered with bacteria), no vibale bacteria remained. CFU - colony forming unit

Joost, Juganson, Visnapuu, Mortimer, Kahru, Nõmmiste, Joost, Kisand, Ivask
Journal of Photochemistry and Photobiology B: Biology 142 (2015) 178–185

Investigations of antibacterial properties of commercial TiO_2 coated SaniTise™ window glass

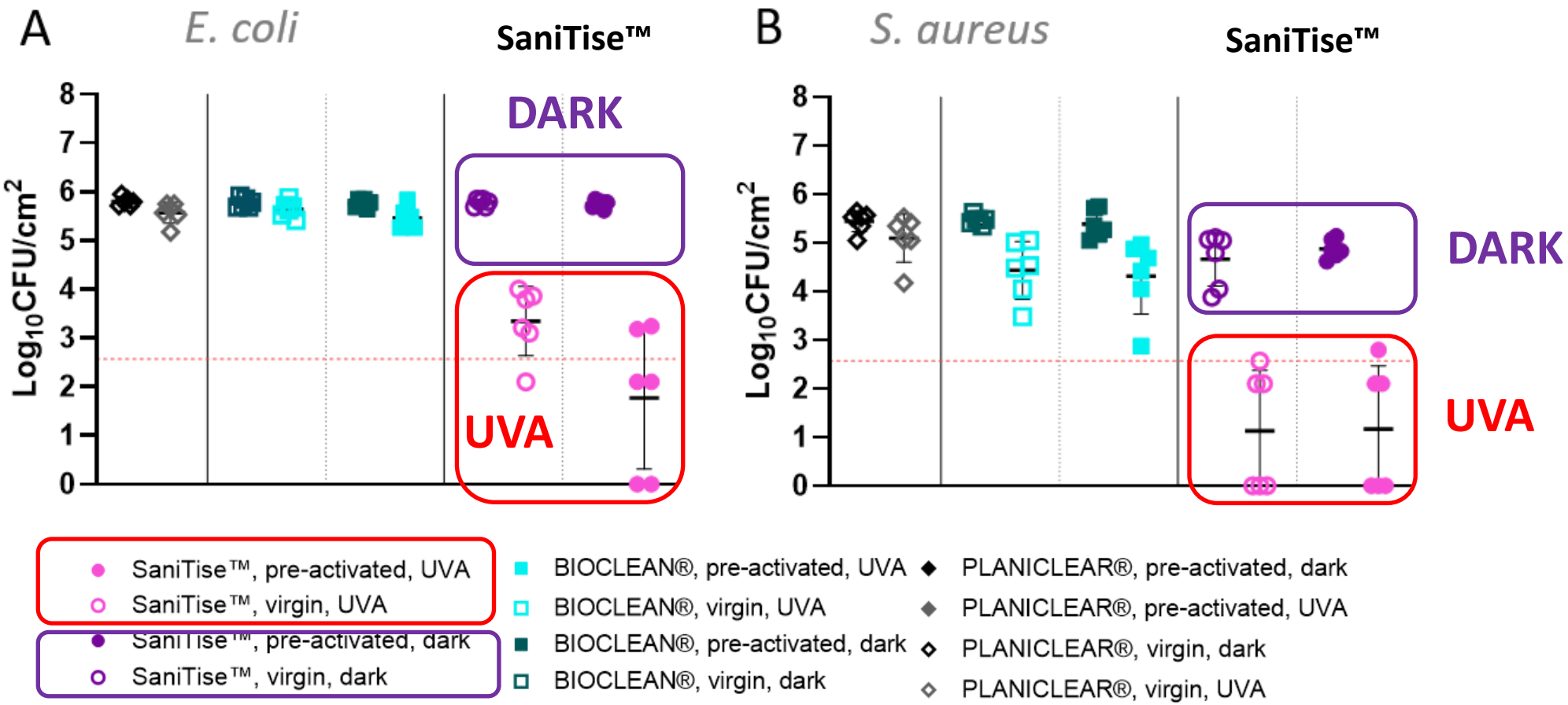


Self cleaning window:
TiO_2 thin film is applied on the OUTSIDE



Antimicrobial window glass:
TiO_2 thin film is applied on the INSIDE

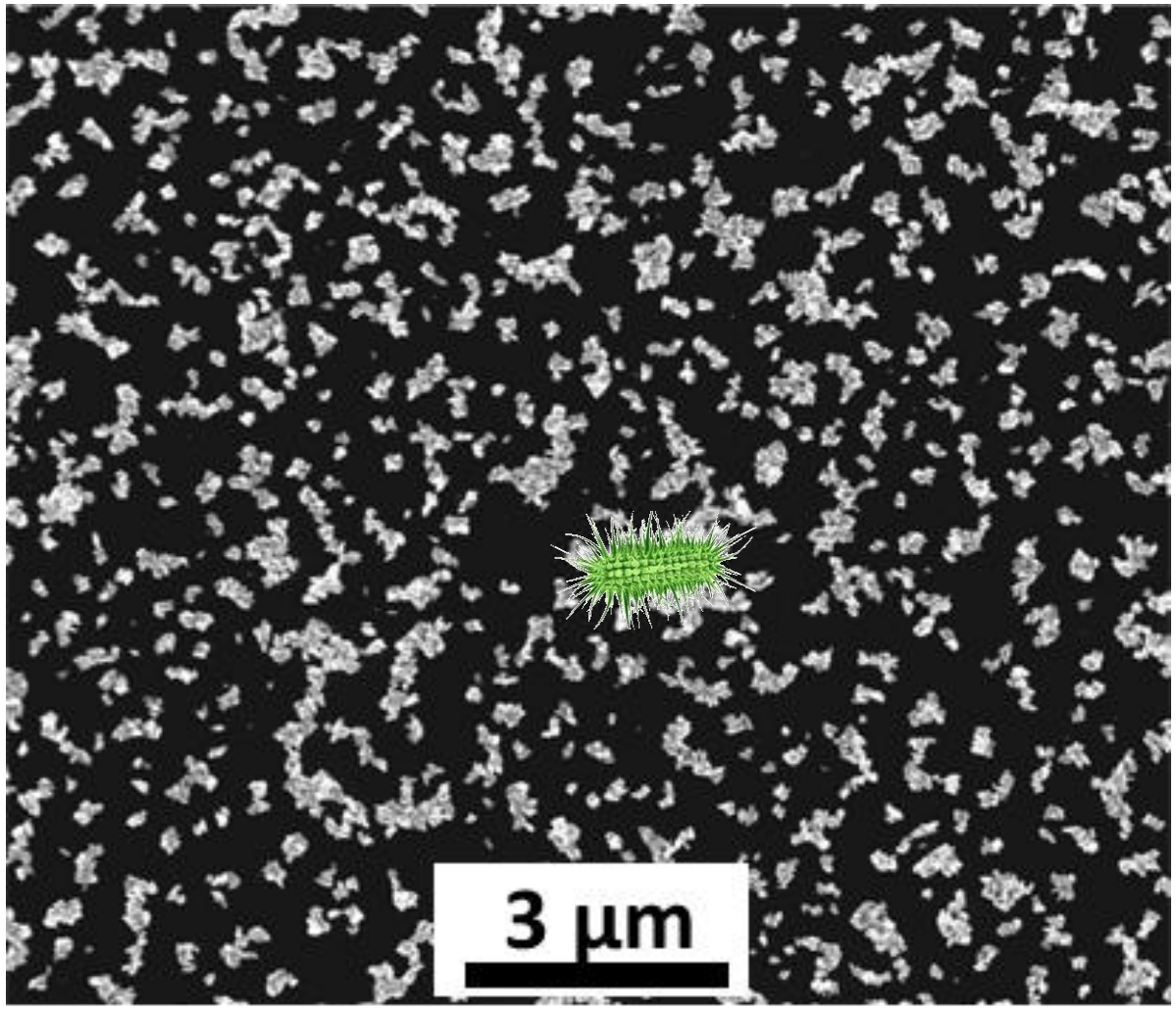
Antibacterial properties: commercial TiO_2 coated SaniTise™ window glass



The ISO 27447 method: a small volume of bacterial inoculum is spread over the surface in a thin layer covered by UVA-transmissive film and exposed to UVA in saturated relative humidity (RH) conditions (4 hours).

V. Kisand, M. Visnapuu, M. Rosenberg , D. Danilian, S. Vlassov, M. Kook, S. Lange, R. Pärna, A. Ivask
Catalysts (2022), 12, 197 https://doi.org/10.3390/catal12020197

ZnO/Ag nanoparticles on silicon monocrystal



ZnO is also well known photocatalytic material

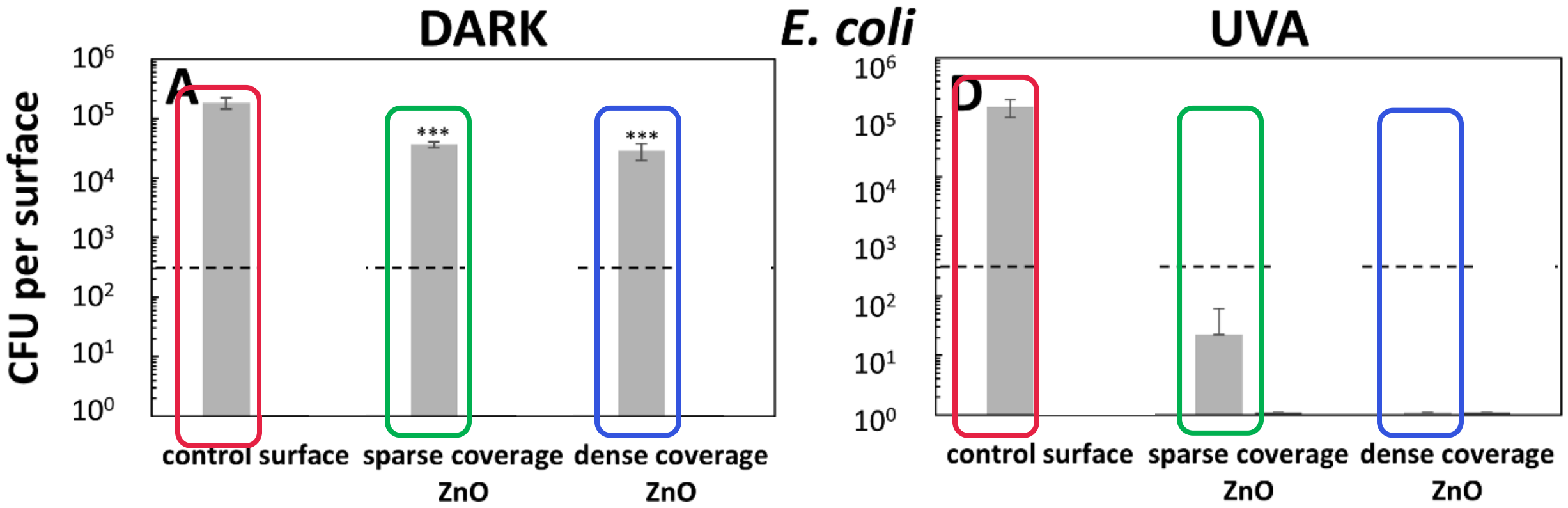
(partly) covered with nano-ZnO/Ag particles

Distribution is important

Reference: *Escherichia coli is* roughly 2.0 µm long and 0.25–1.0 µm diameter

Visnapuu, Rosenberg, Truska, Nõmmiste, Šutka, Kahru, Rähn, Vija, Orupõld, Kisand, Ivask
Colloids and Surfaces B: Biointerfaces (2018) https://doi.org/10.1016/j.colsurfb.2018.05.009

Antimicrobial activity of ZnO nanoparticles on silicon monocrystal



Antimicrobial activity of ZnO surfaces (grey boxes). Decrease in CFUs of *E. coli* after 60 minutes of incubation either without illumination or under UV-A illumination.
CFU - colony forming unit

Visnapuu, Rosenberg, Truska, Nõmmiste, Šutka, Kahru, Rähn, Vija, Orupõld, Kisand, Ivask
Colloids and Surfaces B: Biointerfaces (2018) https://doi.org/10.1016/j.colsurfb.2018.05.009

Long lasting antimicrobial coatings

Acrylic clear matt commercial two-component topcoat meant for wooden surfaces was used as the acrylic matrix to embed the prepared nano-ZnO particles.

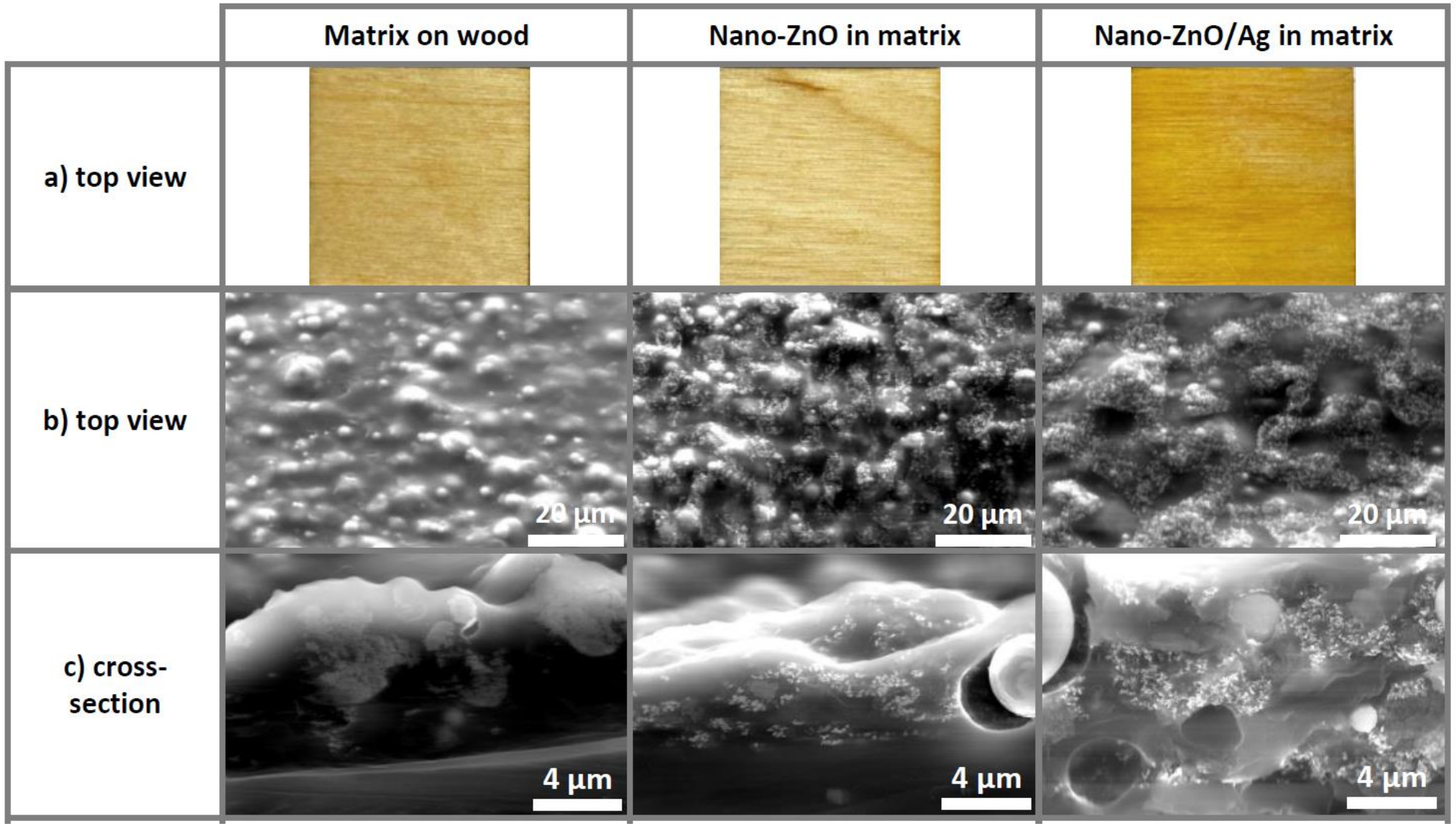
Embeded particles – effectivity is suppressed

The particles were first dispersed in the solvent used in the topcoat mixture and then mixed with the rest of the topcoat components.

Do not mix ZnO with lacquer itself – mixture will heat up

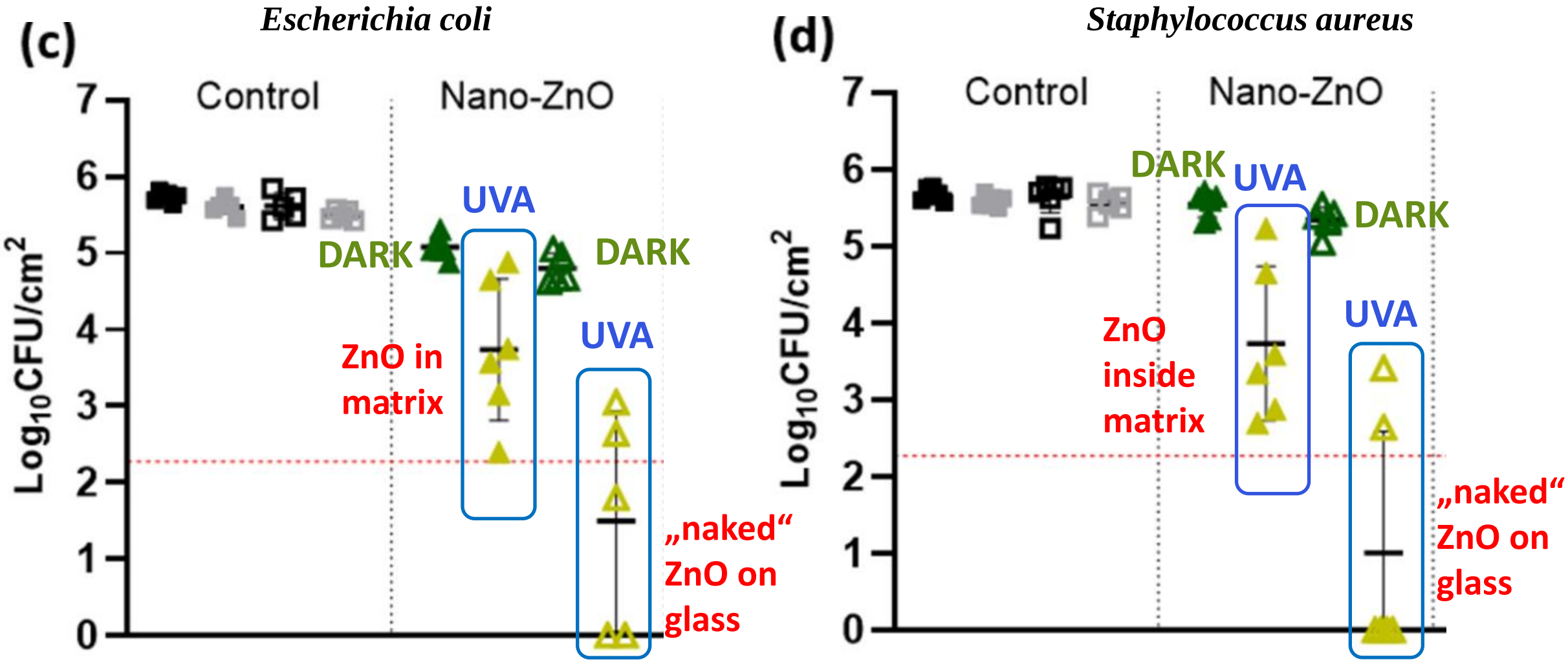
Ultrasonic homogenizer UP200Ht

Preparation of stable antimicrobial coatings based on ZnO and ZnO/Ag nanorods on wooden surfaces



Rosenberg, Visnapuu, Saal, Danilian, Pärna, Ivask, Kisand ***Nanomaterials*** **2021, 11, 3384.**

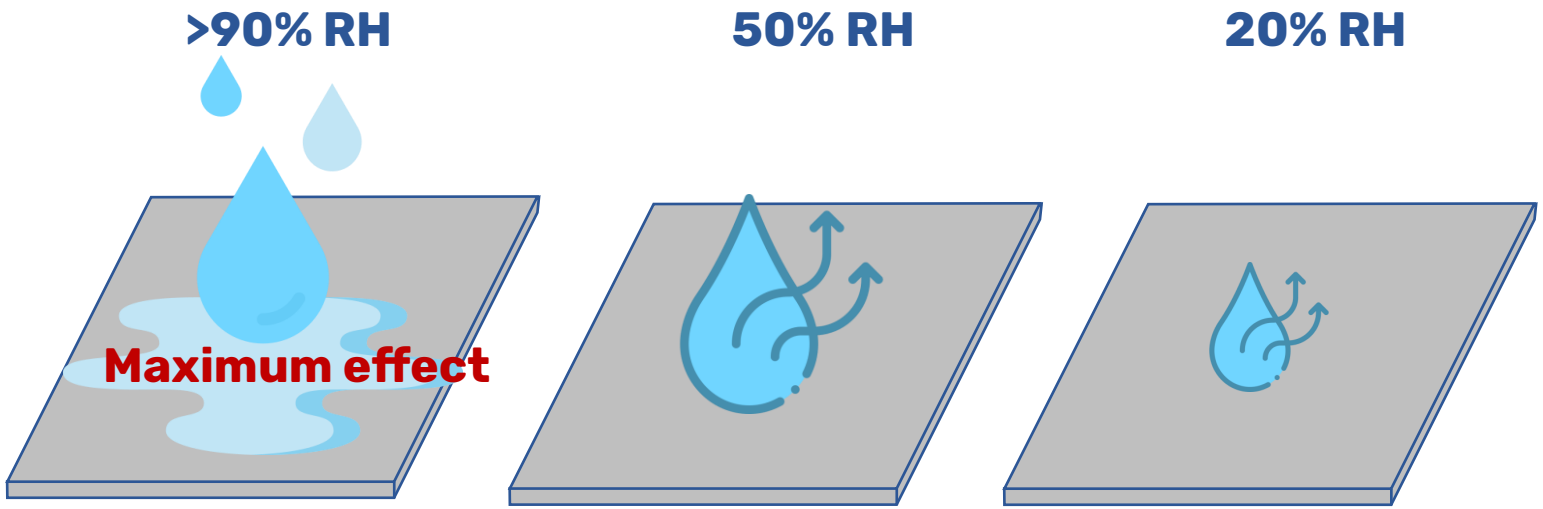
Antimicrobial coatings based on ZnO inside matrix *versus* „naked“ ZnO particles on glass surface



Antibacterial activity towards *E. coli* and *S. aureus*.

Rosenberg, Visnapuu, Saal, Danilian, Pärna, Ivask, Kisand *Nanomaterials* 2021, 11, 3384.

Antimicrobial coatings and relative humidity (RH)



Antibacterial activity of the tested surfaces (copper , silver , and quaternary ammonium) against *E. coli* and *S. aureus* decreased with decreasing relative humidity.

NB !!! Dry conditions slow microbial growth in general, which partly offsets the slower coating activity

Harleen Kaur, Merilin Rosenberg, Mati Kook, Dmytro Danilian, Vambola Kisand, Angela Ivask
FEMS Microbes , 2024, **5** , 1–13

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Challenges:

- Fixation of antimicrobial agents on the surface/matrix, maintaining antimicrobial properties
- Proven and effective action !!!
- Durability of the coating in real life use
- Better safe than sorry: possible side effects

Thank you for your attention !!!












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Estonian Research Council: PRG1496, TK210, TEMTA-55
Horizon Europe: „Surface Transfer of Pathogens“ and „Twinning on Functional Antimicrobial Surfaces Testing and Evaluation for Real-world Performance and Sustainability“

- https://cpci.voog.com/icapi-sep-2025