coatings

Editorial

Advances in Antimicrobial Coatings

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Microbial infections (bacteria, viruses, fungi, etc.) remain a wide-reaching concern in global health on account of the mortality burden and economic impact. These infections can affect humans, animals, food, medical devices, implants, amongst many other hosts. Many of these infections are often concentrated among the poorest populations in the world. However, even in high-income settings, they can cause chronic illness, disability, sequelae, stigma and exclusion of the infected person from the society. Bringing these infections to an end requires a magnified and sustained decade-long response.

During the last few decades, many researchers have been exploring antibiotics (AB), allowing us to target vital molecules for the inactivation of many pathogens. Antimicrobial peptide-based antibiotics have been extensively studied to target bacterial membranes. For Gram negative bacteria, this class of ABs targeted the major membrane component, lipopolysaccharides. These ABs can also inhibit the solutes' passage to or out of the intracellular compartment of the bacterial cell. For Gram positive bacteria, many researchers targeted bacterial enzymes, allowing the chemical conversion of phosphatidylglycerol from the anionic to the cationic or zwitterionic, which creates a bacterial resistance to ABs by blocking their penetration inside the bacterial cells.

Antimicrobial resistance towards antibiotics is growing everyday due to environmental changes and microbial adaptation abilities. This microbial resistance is devaluing many actual AB molecules. For this reason, the development of alternative solutions is urgently needed today. These new methods should target a large range of microorganisms. Further, these new methods should target the micro-skeleton of the microorganism, allowing an increase in its fluidity or its integrity. Gupta and Modak recently reviewed the possible mechanisms involved in bacterial disinfection using Advanced Oxidation Technologies (AOTs). AOTs have the advantage that they are not germ-selective, although some dualities may arise due to the microbial cell wall microstructure/composition. Photocatalytic disinfection is among the AOTs. Many antimicrobial mechanisms were reported and can be summarized as:

- Cell wall permeability leading to the leakage of potassium ions (K^+). The loss of K^+ ions will affect the enzymatic machinery, the intracellular pH, and the diffusion of some other ions from the intracellular medium to the extracellular one and vice versa.
- Photo-generated oxidative radicals were reported to attack extracellular phospholipids and lipopolysaccharides. This mechanism is called lipid peroxidation, revealed by the generation of malondialdehyde (MDA). However, this lipid peroxidation can also generate from injured cells (not dead cells). Controversial opinions arise about this mechanism and its suitability as a quantitative measurement.
- For microorganisms presenting mitochondria and respiratory chains, the breaking of proton gradient inactivates them. Thus, no ATP will be generated. The microorganism dies after exhausting its resources.
- The destruction of the nucleic acids affecting the microorganism's genome is also another mechanism of action of AOTs. The (photo)-generated reactive oxygen species (ROS) diffuse inside the cells and denaturize the genome, leading to cell death.
- The pH of the surrounding medium can strongly affect the microorganism. During illumination, photo-Kolbe like reactions happen at the interface of the bacteria/photocatalyst. Rtimi and Kiwi recently studied the photo-generated short and

long-lived intermediates during bacterial inactivation at the interface of sputtered TiO_2, Cu_xO, FeO_x and their combination.

As by the recent preparations of supported catalysts, new mechanisms were reported. The main microbial inactivation mechanisms can be classified as (a) surface contact microbial inactivation. This mechanism involves the ROS attack to the cell wall leading to the weakening of the membrane, increasing its fluidity and finishing by membrane disruption, and (b) ion diffusion through the membrane porins, leading to the inactivation of the internal cell metabolisms and its intoxication.

This field is growing every day due to the discovery and preparation of new catalytic materials, and to the advances in analytical techniques allowing the quantification of the damage caused by a photocatalytic reaction. Today, with the COVID-19 pandemic, the anti-viral ability of catalytic/photocatalytic materials is extensively investigated. However, bacterial infections remain of greater concern.

"Advances in antimicrobial coatings" is a collection of high-quality research papers and comprehensive reviews giving a critical opinion about novel antimicrobial methods, and prospective papers giving an opinion about the future orientations in this field. Klein et al. [1] investigated the preparation of lignin-derived polyurethane coatings using demethylated Kraft lignin. They used triphenylmethane derivatives as the antimicrobial substance. Their coatings showed an antimicrobial capacity against *Staphylococcus aureus* with a possibility to obtain different colors (brown to green and blue) of the coating. Bio-based polypropylene mesh fibers loaded with levofloxacin HCl and cross-linked with chitosan have been studied by Sanbhal et al. [2]. The functionalized polypropylene meshes exhibited an antibacterial activity against *Staphylococcus aureus* and *Escherichia coli*. This antimicrobial activity was seen to be sustained for six continuous days. In a similar study, polypropylene was modified by bio-inspired polydopamine (PDA) loaded with an antibiotic, levofloxacin [3]. These two preparations were seen to reduce the complications related to hernia infection during surgery. Another study by Kojima et al. investigated antifouling paints and developed a laboratory scale bioassay using a flow-through system [4]. They prepared antifouling biocide-releasing Cu_2O-based paints for the inhibition of *Amphibalanus amphitrite* adhesion to a home-made container. Nokkrut et al. prepared silver-based packaging papers to inactivate fungi [5]. Druvari et al. reported the preparation, testing and characterization of polymeric coatings based on quaternary ammonium compounds for microbial inactivation purposes [6].

Packaging materials based on chitosan and methylcellulose enriched with natamycin were prepared by Santonicola et al. [7]. Furthermore, Mathew et al. reviewed the conventional approaches and the new trends in the use of fused deposition as a potential tool for antimicrobial dialysis catheters [8]. As a practical application, Socaciu et al. reviewed the quality changes and shelf-life extension of edible films and coatings for fresh fish packaging [9]. Alhussein et al. prepared nano-architectured thin layers, allowing a controllable diffusion of highly antibacterial copper ions and nanoparticles [10]. K. Vasilev outlined the implications and effects of infections on healthcare [11]. The author highlighted the four classes of antibacterial coatings and focused on silver-based materials for antimicrobial applications.

Supported metal nanoparticles have been reported to have high antimicrobial activity [10] against bacteria, viruses, fungi and yeasts. Future research in this area should focus on the toxicity induced by antimicrobial meta-materials. The knowledge acquired in this field should be transferred to industry to design 3D devices/implants showing antimicrobial activity concomitant with high biocompatibility.

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