Q1-2020 Newsletter: Antibacterial and antiviral nanostructures

April 2020

The coronavirus pandemic highlights the urgent requirement for novel public health strategies. In this SUN-PILOT newsletter, we consider the role that nanotexturing could play in the realisation of natively self-sanitising injection moulded objects.

Antibacterial nanostructures in Nature

Due to the nature of their environments, many insects have a requirement to minimize their contamination by foreign particles to retain functionality. These contaminants may be dust or dirt, or bacterial cells that may seek to colonize and infect the insect. As such, these insects have evolved various strategies or mechanisms for coping with contamination. Several have evolved to possess superhydrophobic surfaces, particularly on their wings, which not only enable them to remain dry and minimize weight, but also bestow a self-cleaning effect.

Early studies focussed on the relationship between surface wettability and anti-biofouling effects. It was generally hypothesised that superhydrophobic nanotextured surfaces would repel microbes and thereby prohibit bacterial growth. More recent studies have shown that such natural nanostructured surfaces can kill bacteria by rupturing the cell wall, a mechanism known as contact killing (Elbourne et al., 2017).

One of the first studies of the naturally occurring bactericidal surface of cicada wings against *P. aeruginosa* (gram negative) was reported in 2012 (Crawford et al., 2012). Unlike previous reports, they showed that, despite the superhydrophobic nature of the cicada wing, there was significant bacterial adhesion on the nanotextured surface. On contact, the adhered bacteria underwent a rapid morphological change and were killed within 5 minutes. It was concluded that the anti-biofouling nature of cicada wings was not due to its ability to repel the bacteria, but its ability to fatally impale microbes on the nanostructure pillars.

Image credit: Warren photographic

Antibacterial nanostructure cicada

Gram negative bacteria killed through physical contact with 60-nm wide nanocones on wing surface

Ivanova et al later studied the bactericidal efficacy of the dragonfly wing surface. Unlike the cicada wing, the nanostructures present on the dragonfly wing are randomly distributed in terms of their shape, size and distribution. The dragonfly wing was shown to be highly effective in killing both gram negative (*P. aeruginosa*) and gram positive bacteria (*S. aureus and B. subtilis*) as well as endospore (*B. subtilis*).

It seems reasonable to conclude that natural nanosurfaces possess antibacterial properties through a combination of superhydrophobic self-cleaning and contact killing mechanisms.

Engineered antiviral nanostructures

Responding to the coronavirus pandemic and the associated quest for effective yet robust antiviral solutions, researchers from the Queensland

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University of Technology recently examined the antiviral properties of a nanotextured aluminium alloy (Hasan et al., 2020). Common respiratory viruses, respiratory syncytial virus (RSV) and rhinovirus (RV), were investigated for antiviral activity on the wet-etched surfaces.

RSV is a medium-sized (120–200 nm) enveloped virus, whereas RV is among the smallest known viruses, with diameters of about 30 nm. Notably coronaviruses are enveloped and comparable in size (120–140 nm) to RSV.

Nanostructures (23 nm ± 2 nm) etched into the surface of aluminium sheets packed randomly along ridges (161 nm ± 26nm wide) caused a 1,000 to 10,000 reduction in the viability counts of RV after 24 hours on the nanostructured surfaces, and practically no RV in presence of nanostructured surfaces after 24 hours.

These initial results hint at the potential for nanotextured surfaces to combat the progression of coronavirus and other nanoscopic pathogens.

SUN-PILOT nanotexturing

The development of antimicrobial nanotextures is not a formal objective of SUN-PILOT. Nevertheless, the prospect of injection moulded nanostructures arising from this project may vicariously offer both industrial and consumer users a route towards natively self-cleaning and antiviral products. Imagine door handles that sterilised themselves within an hour or two.

Commercial antibacterial surface solutions already exist. Adhesive micropatterned films from Sharklet Technologies Inc can be applied to many surfaces to confer germ resistant properties. Although these structures are very small (3µm tall and 2µm) and therefore effective against bacteria strains, they may prove less effective against virus such as the coronavirus.

Conceivably SUN PILOT will help foster the development and application of injection-moulded products and surfaces that are natively antiviral. Self-santisizing fomites such as door handles and touch panels are just two examples.

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ISO TC330 considers biocidal surfaces

Appreciation of the potential for nanotexturing to contribute towards public health efforts through natively biocidal surfaces is reflected in the recent formation of ISO Technical Committee 330.

TC330 considers the standardization of test methods used to assess the biocidal performance and efficacy of any surfaces with antimicrobial activities, including their compatibility with different families of disinfectants and cleaning agents. Such methods aim at evaluating the biocidal activity (i.e. that which irreversibly inactivates microorganism) and at differentiating it from the biostatic activity (i.e. the inhibition of the growth of microorganisms).

Crawford, R.J., Webb, H.K., Truong, V.K., Hasan, J., Ivanova, E.P., 2012. Surface topographical factors influencing bacterial attachment. Advances in Colloid and Interface Science 179–182, 142–149. https://doi.org/10.1016/j.cis.2012.06.015

Elbourne, A., Crawford, R.J., Ivanova, E.P., 2017. Nano-structured antimicrobial surfaces: From nature to synthetic analogues. Journal of Colloid and Interface Science 508, 603–616. https://doi.org/10.1016/j.jcis.2017.07.021

Hasan, J., Xu, Y., Yarlagadda, T., Schuetz, M., Spann, K., Yarlagadda, P.K., 2020. Antiviral and Antibacterial Nanostructured Surfaces with Excellent Mechanical Properties for Hospital Applications. ACS Biomater. Sci. Eng. 6, 3608–3618. https://doi.org/10.1021/acsbiomaterials.0c00348