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Supplementary information

Mechano-bactericidal actions of nanostructured surfaces

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Supplementary Box 1 | **Busting the myths of mechano-bactericidal surfaces**

Can the physical biocidal mechanism be 'blocked' by the build-up of either bacterial cell debris or proteins? A frequently recurrent problem with contact-based bactericidal surfaces is the build-up of bacterial debris which would essentially block surface activity and provide nutrients for other opportunistic colonisers. Recent studies have confirmed the release of bacterial cell debris following mechanical rupture on nanostructured surfaces[1,2] . Real-time imaging confirmed that dead cells could be removed from the surface in under 20 min, highlighting a cycle of killing and dead cell detachment for nanostructured mechano-bactericidal surfaces. Another question that often circulates regarding physically biocidal nanotopographies relates to the blocking of surface activity by protein adsorption (often the first step in cellular attachment to a substratum). Key feature of protein adsorption is a huge size mismatch between nanostructures and proteins. For typical black silicon pillars the accessible area for protein adsorption between pillars is much larger than at the tips. Experimental studies using albumin and fibronectin show that, at low concentrations, albumin preferentially adsorbs to the base of nanopillar features whereas fibronectin always adheres to the tip of the nanopillars, irrespective of concentration. Protein adsorption may increase the interpillar interactions, leading to pillar clustering, which may reduce affect bactericidal efficiency[3]. Theoretical practical simulations estimations using the human serum albumin calculated of the rate of the human serum albumin adsorption at blood concentrations to be in the order of 10 seconds for saturation of the surface[4]. Research has shown that bacterial adhesion on nanoporous surfaces was highly dependent on the amount of adsorbed protein. Protein adsorption may act as a passivation layer on nanostructured topographies inhibiting biofilm formation[5]. However, not all nanostructured topographies will promote protein adsorption in the same manner, and there are other topographical factors that work to prevent bacterial adhesion, as described in this Review.

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Supplementary Text Box 2 Engineered antiviral surfaces

High transmissibility and genetic variability in various viral pathogens, including influenza virus and coronaviruses, make designing effective disease control strategies particularly difficult. Respiratory viruses are primarily spread through airborne droplets that are ejected from an infected person while coughing or sneezing. However, microscopic droplets can also settle on surfaces and then be transmitted through touch. A finger that touches a virus-laden surface can then spread the virus to up to seven clean surfaces[1]. Proposed antiviral surface technologies have shown that the functionalisation of materials with glycoligands such as sialyllactose can promote binding of the influenza virus surface protein, hemagglutinin, with high efficiency[2, 3]. Researchers discovered that hydrophobic polycationic coatings that were simply painted onto surfaces can effectively kill certain influenza viruses[4]. Polyethylenimines, which are hydrophobic polycations, exhibit both antimicrobial as well as antiviral properties by damaging the viral lipid envelope. This approach could be effective toward all enveloped viruses. The antiviral potential of highly hydrophilic oxidized multi-walled carbon nanotubes (MWCNTs) in suspension functionalised with antiretroviral drugs was also recently investigated. Oxidized MWCNTs and MWCNT-antiretroviral exhibited IC_{50} values of 11.43 μg/mL and 4.6 μg/mL, respectively[5, 6]. It was proposed that carboxyl groups and, in general, hydrophilic end groups promote electrostatic and hydrogen bond interactions with the amino acid residues of reverse transcriptase involved in the viral cycle, leading to antiviral activity. Mechano-bactericidal nanostructured surfaces could potentially be optimized to irrevocably immobilize and kill enveloped viruses by rupture of the lipid

envelope by mechanical forces at the surface *via* the same biophysical principles used to achieve highly efficient killing of bacteria.

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