Local Environment Effects on Silver Nanoparticle Antimicrobial Activity

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Statement of Purpose:

Silver has been long known to have antimicrobial properties. Although in bacteria the mechanisms of silver activity are not completely established, it is thought that the Ag+ ions are the active species that disrupts critical cell functions and is hence the source of antimicrobial activity, while metallic silver is inert [1].

With the nanotechnological age, nanoparticulate silver systems have been increasingly used as antimicrobial agents for medical device applications, such as wound dressings and implant coatings [2]. Decreasing the size of silver particles to the nanoscale regime increases particle curvature and hence the silver ion solubility in solution, thereby enhancing their potential antimicrobial efficacy relative to their bulk counterparts.

In this presentation, we explore the effect of the local environment on the antimicrobial efficacy of nanoparticulate silver. In the case of device materials, a change of the substrate upon which the antimicrobial nanoparticulate silver is deposited may affect the intended efficacy of the device. In addition to the substrate, the silver may interact with the local biological environment, which may also affect the intended antimicrobial efficacy.

Methods:

Silver nanoparticles were synthesized in the laboratory by citrate reduction of silver nitrate [3] and also purchased commercially. Nanoparticle size was characterized by dynamic light scattering and electron microscopy. Particles were deposited onto various material surfaces representative of relevant medical devices and in the presence of biologically relevant media. Available ion concentration (i.e., efficacy) was measured using an ion selective electrode and meter.

A mesoscale field model was developed to predict the response of nano-dimensional systems in electrochemical environments in order to identify, understand, and quantify the physico-chemical phenomena associated with nano-structuring and the potential clinical implications [4]. Calculations based on the model for silver nanoparticles in ionic solutions were used to elucidate the impact of substrate on ion release and surface charge, which impact the antimicrobial efficacy and system stability.

Results:

Figure 1 shows the measured concentration of available silver ions (efficacy) for several medically-relevant materials. We find that for the same silver deposited, different surfaces will result in different antimicrobial efficacy. For instance, the release of silver is much different on latex than on silicone due to surface charge and the affinity of the substrate surface for silver ions. Similarly, we find that the local biological environment has an effect on the long term efficacy of the silver nanoparticles, partially by inducing a restructuring of the particles.

In both cases of substrate and biological environments, simulations based on a thermodynamically consistent, multi-phase field electrochemical model are in quantitative agreement with the experimental observations.

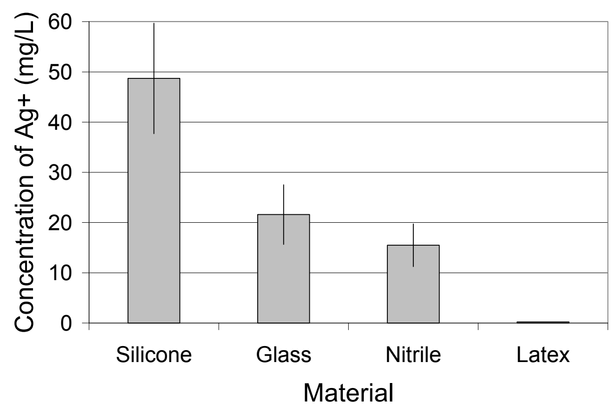

Figure 1: Concentration of available silver ions on different medically relevant material surfaces.

Conclusions:

We observe that the local environment, including the substrate upon which silver nanoparticles are deposited and the biological environment in contact with the nanoparticles affects the efficacy of nanoparticulate antimicrobial silver. These differences can also be predicted by computer simulations based on mesoscale field model calculations, for these and other medically relevant environments.

References:

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2. Kim JS, et al. Nanomedicine: Nanotechnology, Biology, and Medicine, 2007; 3:95– 101.
3. Lee PC and Meisel D. Journal of Physical Chemistry, 1982; 86; 3391-3395.
4. Saylor DM, Dair BJ, Warren JA, and Guyer JE. *In preparation.*