Why silver?

Silver has long been known to have antimicrobial properties. However, traditional forms of Silver, like ionic silver and colloidal silver, exhibit inconsistent efficacy and have associated problems. For example, silver or silver sulfide may accumulate in the skin causing argyria if taken in large amounts and which may manifest itself as blue or grey discoloration of the skin.

In recent years, the advent of new technology, especially nanotechnology, has led to a resurgence of interest in silver. The number of papers and patents on silver has been rising exponentially, and with better research and technology, silver has been made safe and more effective. There are now many silver containing products on the market which are used as disinfectants, wound dressings and so on.

What is Silver Sol?

Silver Sol contains nanoparticles of size 5-15 nm which comprise an interior of metallic silver and an exterior of silver oxide[1] including multivalent silver(I,III)oxide, Ag_4O_4. Silver Sol incorporates the patented nanotechnology as well as various patented technologies pertaining to the manufacture of Silver Sol, which render Silver Sol very unique, efficacious at low dosage and safe.

Unlike conventional silver compositions, Silver Sol is completely colorless and stable to light and chemical changes without use of any additives. This means that Silver Sol remains in solution and is not deposited in the skin and thus will not cause argyria[9].

How does Silver Sol work?

1 Mode of action of oxidized silver: Precedent[3]

Silver(I) or silver(III) in the oxide layer initially behaves in a manner analogous to the action of ionic silver.

1.1 Binding

The affinity between oxidized silver and amino acids with sulfur and nitrogen atoms in the side chains is very well established[3]. The binding of oxidized silver to proteins in the microbial cell wall and cytoplasm blocks the surfaces of the proteins and hence interferes with their functions. This loss of protein functions results in the death of the microbe.

1.2 Acceptance of electron from microbial proteins

The oxidized silver then accepts an electron from the microbial proteins. The affected portions of the proteins become reactive, and are involved in processes which alter the protein structures. For example, in the case of the amino acid cysteine, disulfide bonds are formed. The disruption of protein structures (Note: Structure is related to function) is irreversible and more detrimental than interference as the proteins are permanently deactivated, and death of the microbe ensues.

1.3 Reactive oxygen species (ROS)

Reactive oxygen species like the superoxide radical, O_{2^-} and hydrogen peroxide, H_2O_2, are lethal to microbes because they produce reactive species in, and cause oxidation of, microbial proteins, resulting in their denaturation. ROS constitute part of the strategy of macrophages and neutrophils to kill engulfed bacteria[11].

Additional ROS is generated in the presence of silver, further adversely affecting the viability of microbes. About half the bactericidal activity of silver ions can be attributed to reactive oxygen species[4]. The major form of ROS generated is the superoxide radical.

1.4 Catalytic cycling

The modes of action of silver as described above are part of a catalytic cycle[3]: Ionic/oxidized silver is regenerated in the process. This means that silver accelerates the processes involved in the killing of microbes without being consumed.

2 SilverSol and surface Ag_4O_4

Ag_4O_4 has been detected in Silver Sol by mass spectrometry[1,6].

Once the microbe is bound to the Silver Sol particle, silver(I,III)oxide begins to exert its effect. The mechanism of Ag_4O_4 involves the acceptance of an electron by trivalent silver ions (in analogy to point 1.3) and ejection of an electron from monovalent silver ions through the aqueous media. The pathogen becomes "electrocuted" by electrons emanating from all Ag_4O_4 in the vicinity[5].

In a separate study[10], it has been found that nanostructured Ag_4O_4 films have enhanced antibacterial activity, thus supporting the premise that the presence of Ag_4O_4 is advantageous with regard to microbecidal properties.

3 Metallic silver vs Ionic Silver

3.1 Reactive oxygen species

One of the effects of silver nanoparticles is the generation of reactive oxygen species[7], which contribute to antimicrobial activity, since ROS are lethal to microbes (see 1.3).

3.2 Charging-discharging model[8]

Metallic silver plays a major role in the catalytic cycling and continual generation of ROS. This is because metallic silver can absorb electrons to become negatively charged, and also later donate these electrons to positively charged species, *e.g.* Ag(I) or Ag(III). The superoxide radical is involved. The speed of catalytic cycling could increase fourfold in the presence of metallic silver, thereby greatly enhancing the efficacy of Silver Sol.

4 Resonance

Silver Sol resonates at 890-910 THz, *i.e.* 330-337 nm, which is in the UVA range. This frequency allows Silver Sol to kill bacteria and viruses by destroying proteins.

UVA light is abundant in the environment. Resonance of Silver Sol facilitates absorption of an electron from a microbial protein. However, once the electron is accepted, a very high energy situation arises, and this energy is transferred to an electron which is fired at the microbe, causing electrocution [9] in the presence of oxygen.

Advantages of Silver Sol

Silver Sol combines the modes of action of ionic silver and Ag_4O_4. Enhancement is attributed to metallic silver present in the particle, as the damage to the microbe due to reactive oxygen species is greatly intensified. At the same time, resonance can kill pathogens; resonance also facilitates absorption of an electron from microbial proteins, and the firing of electrons is much more potent.

The Silver Sol particles present many oxidized silver atoms at a time, thus increasing the effective concentration of active silver.

The action of Silver Sol is not a one-off "single shot" phenomenon; because of the multimodal action, the onslaught on the microbes is sustained, in analogy to the action of a "machine gun"[9].

Conclusion

Silver Sol is a highly effective antimicrobial product which leverages on the latest nanotechnology. Silver Sol incorporates the potency of silver(I,III) oxide combined with the synergistic effects of metallic silver, which significantly accelerates the destruction of microbes. The multiple modes of action guarantees that the microbes are relentlessly bombarded and thus annihilated.

References

1. Holladay JR et al, US Patent 7,135,195
2. Lok CN et al, J Biol Inorg Chem (2007) 12:527-534
3. See, for example, "Silver as an Antimicrobial Agent", MicrobeWiki
4. HJ Park et al, Water Research (Oxford) (2009) 43(4) 1027-1032
5. Antelman MS, US Patent 5,676,997 and associated material
6. Analytical Report: ASAP 22 ppm silver colloid in water, prepared by NDE Analytical
7. See for example, Foldbjerg R et al, Toxicol Lett (2009) 190(2):156-162
8. Jones AM et al, Environ Sci Technol (2011) 45, 1428-1434
9. "The Silver Bullet", technical video by Dr Gordon Pedersen
10. Dellasega D et al, Nanotechnology (2008) 19(47), 475602
11. See, for example, http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/R/ROS