Give silver a shine

Katharina M. Fromm explains how, as well as catalysis and jewellery, silver serves a myriad of medicinal applications — some of which are even behind poetic traditions such as throwing coins in wishing wells.

Silver, number 47 in the periodic table, takes its name from the Anglo-Saxon or Germanic 'seolfor, silabar', and its symbol Ag from the Roman and Greek 'argentum' and 'argyros' (meaning white, shining). It is ductile and soft, with a face-centred cubic structure and oxidation states between 0 and +3. Places are called after it, for example Argentina or the Rio de la Plata in South America, although today's main silver-producing countries are Peru, Mexico and China.

Silver has been mined, refined and used for thousands of years in ornaments and utensils, for trade, and as the basis of monetary systems (in French there is only one word 'argent' for both silver and money). Egyptians already implanted silver plates into skulls as far back as 2500 BC, and Ancient Greeks and Romans used silver containers to keep liquids fresh. Thus, the tradition of throwing silver coins into wishing wells and fountains comes from keeping water free of germs and people healthy. The first silver paste for tooth restoring was reported in China in 659 AD, and today's amalgams are still made of 20–35 weight% of silver (the rest being mainly mercury, and some additional tin, copper and zinc).

Silver production worldwide reached more than 2,700 tons in 2009 — there is now an estimated reserve of 550,000 tons in the Earth's crust. About 700 tons serve annually in heterogeneous catalysis (for example, production of ethylene oxide and formaldehyde, purification of diesel emission gases), more than for jewellery.

Although we traditionally think of silver as 'second best' after gold, as distributions of medals still reflects today, silver holds three world records: the best electrical conductivity (used for audio cables, electric power switches and circuit breakers) and the highest brilliance (which lead to mirrors and optical applications) of all elements under standard conditions, and the best thermal conductivity of all metals. Silver is stable against oxygen but tarnishes to form silver sulfide if hydrogen sulfide and water are present (such as in wool, latex, eggs or onions) — a well-known phenomenon for silverware and jewellery. Pure silver is too soft to make objects, and is generally alloyed with other metals; 'sterling silver 925' for example contains 92.5 weight% of silver, and typically copper, or alternatively germanium, zinc or platinum, to render it stronger while preserving its ductility, also to reduce casting porosity, and increase resistance to tarnish.

© ISTOCKPHOTO.COM/LIZARDEYE

An important part of silver's history is black and white photography, developed by Niépce and Daguerre in the 1830s. Initially based on a mixture of silver nitrate and chalk, it still relies today on films made of light-sensitive silver halides, stabilized in a gelatine matrix. Silver is used in art and medical radiography but also for quality control. One exotic application of silver iodide is cloud seeding; it relies on a good match in lattice constants between the ice and silver iodide crystal lattices, as discovered by Bernard Vonnegut (the crystallography of ice later played a role in his younger brother Kurt Vonnegut's novel *Cat's Cradle*)[1].

Silver nanoparticles have been known for centuries as red, yellow and orange stains for glass. They now mainly serve as antimicrobial agents in biotechnology and bioengineering, textile engineering, water treatment, and in some consumer products (such as for washing machines or refrigerators). The long-term effect of their release into the environment is currently under investigation[2].

Although silver ions are highly toxic to bacteria at low concentrations (ng l^{-1}), eukaryotic cells withstand concentrations 10 to 100 times higher[3] — overexposure leads to an irreversible grey colouring of the skin (argyria) but causes no severe harm. Silver nitrate is routinely used in eye drops for newborn babies, silver sulfadiazine is found in topical creams for burn wounds, preventing infections and catalysing skin renewal, and other species are found in a variety of products such as surgical fabric materials, cosmetics or antibiotic creams. Long-term catheters — an ideal entrance gate for bacteria and therefore prone to bacterial biofilm formation — have been made of silver alloy or nanoparticle-loaded polymer to reduce such infections[4]. Coatings of implant materials with Ag^0 or Ag^+ coordination compounds — tunable for solubility, structure and stability — have also been successfully implanted in the body, killing bacterial infections while remaining biocompatible for cell growth[5].

Thus, although the mechanism of such action of silver ions remains to be uncovered, 'use of a silver spoon a day keeps the doctor away'… ❐

References

1. Vonnegut, B. & Chessin, H. *Science* **174,** 945–946 (1971).
2. http://go.nature.com/GBFn5k
3. Silver, S. *FEMS Microbiol. Rev.* **27,** 341–353 (2003).
4. Brosnahan, J., Jull, A. & Tracy, C. *Cochrane Database Syst. Rev.* **1**, CD004013 (2004).
5. Vig Slenters, T. *et al. Materials* **3,** 3407–3429 (2010).

KATHARINA M. FROMM is at the Department of Chemistry and the Fribourg Center of Nanomaterials of the University of Fribourg, Chemin du Musée 9, CH-1700 Fribourg, Switzerland.
e-mail: katharina.fromm@unifr.ch

Ru Rh Pd **Ag** Cd In Sn Sb Te I Xe Cs Ba La Ce Pr Nd Pm Sm Eu Gd