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Colloidal Nano Silver-Its Production Method, Properties, Standards and its Bio-efficacy as an Inorganic Antibiotic

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Abstract

The past 80 years has seen a plethora of different methods used to produce pretend colloidal silver that more often than not, consists mainly of ionic silver and other chemicals. Generally, little or no colloidal material is seen. Normally, only a ratio of Ionic to Colloidal Silver of 85:15% is quoted as the best obtainable result.

Colloidal silver generally consists of nano sized clusters of silver atoms in an aqueous solution. We should not refer to them as particles. These atomic clusters are of a neutral polarity, but their suspension in the water causes a highly negative (interfacial) electrostatic charge called the Zeta potential. It is this highly negative Zeta potential of the clusters that causes a mutual repelling action resulting in an almost permanent suspension. This interfacial electrical charge is vulnerable to high temperatures and contamination by ionic substances. Even small amounts of ionic silver can interfere with this normal repelling action. Any of these contaminations may cause a drop in the interfacial charge causing aggregation and the release of attraction forces, such as the Van der Waals force, present in all materials. What follows is an uncontrolled growth of ever larger clusters to a point where gravity takes over and metallic silver drops out of the suspension. It has been determined that Colloidal Silver clusters should not be referred to as metallic, as at 10 nm size and below, they do not behave like a metal or controlled by standard physical laws. Because of this, nano sized silver clusters exhibit characteristics that are not present in bulk metallic silver. Some of these characteristics of nano sized colloidal silver can only be explained as being quantum phenomena.

In this paper, we will show by using only the purest water and silver commercially available (99.998%), and by precisely controlling temperature, light and electrical conditions, and stable high grade, colloidal silver can be consistently produced using electrochemical principles. Some of our material has shown little signs of deterioration over many years. By also controlling the actual atomic cluster to a narrow size distribution and concentration, a highly effective antibacterial substance is created.

That blue, indigo, violet and UV light plays such a most crucial role in the formation of colloidal silver has only recently been recognised by some scientists. It is ironic to realise that knowledge of the capabilities of short wavelength electromagnetic radiation, over and above 2.64 electron volt (eV), has been known for decades, even for nature and life itself. Few, if any, have paid any attention to the significance of these short wavelengths of light on colloidal silver production. One example of this is the role of UV on the skin promoting the production of Vitamin D. Similarly, UV exposure on silver halide deposited on B&W film produces a latent (photographic) image.

In this paper, we will illustrate that blue, indigo, violet light, and in particular, where light has the greatest penetration of water and light is absorbed by silver, i.e. 418 nm, pure colloidal silver can be produced most efficiently.

Keywords: Nano sized silver clusters; Particles; Zeta potential; Electrochemistry; Stern layer; Diffuse layer; Hydrated electrons/Solvated electrons; Photon electron transfer; Cross polarization; Light scattering; Spectro-photometer; Colloidal silver characterization; UV/Visible light; Quantum physics; Absorption

Quote: "The enormous range of electrical conductivities of solid materials is an example a property of matter which cannot be reasonably explained in terms of classical ideas. For instance, the conductivity of silver is more than 1024 times larger than that of fused quartz". Quantum Mechanics by John L. Powell and Bernd Crasemann, University of Oregon 1961 [1,2]

Preamble

There is much confusion amongst many laymen and many scientists alike, as to what constitutes colloidal silver. In particular, this relates to the electrochemically produced colloidal silver, without the presence of ionic silver and other chemistry. This state of affairs is evidenced by a lack of scientific literature and other published knowledge on that subject to date.

For the past 80 years, both chemically and electrochemically produced colloidal silver has been plagued by a lack of proper science. This lack of knowledge has created much confusion and often unpredictable results. We are not aware of the existence of any accepted or recommended standards, as to what constitutes colloidal silver to this date. Instead of producing colloidal silver under strict conditions, such as (a) in complete darkness; (b) at low temperature, and (c) subjected to very specific high energy photonic radiation, no such controls have ever been exercised. Instead batches of silver products are produced in broad daylight, without regard to constant changes in light

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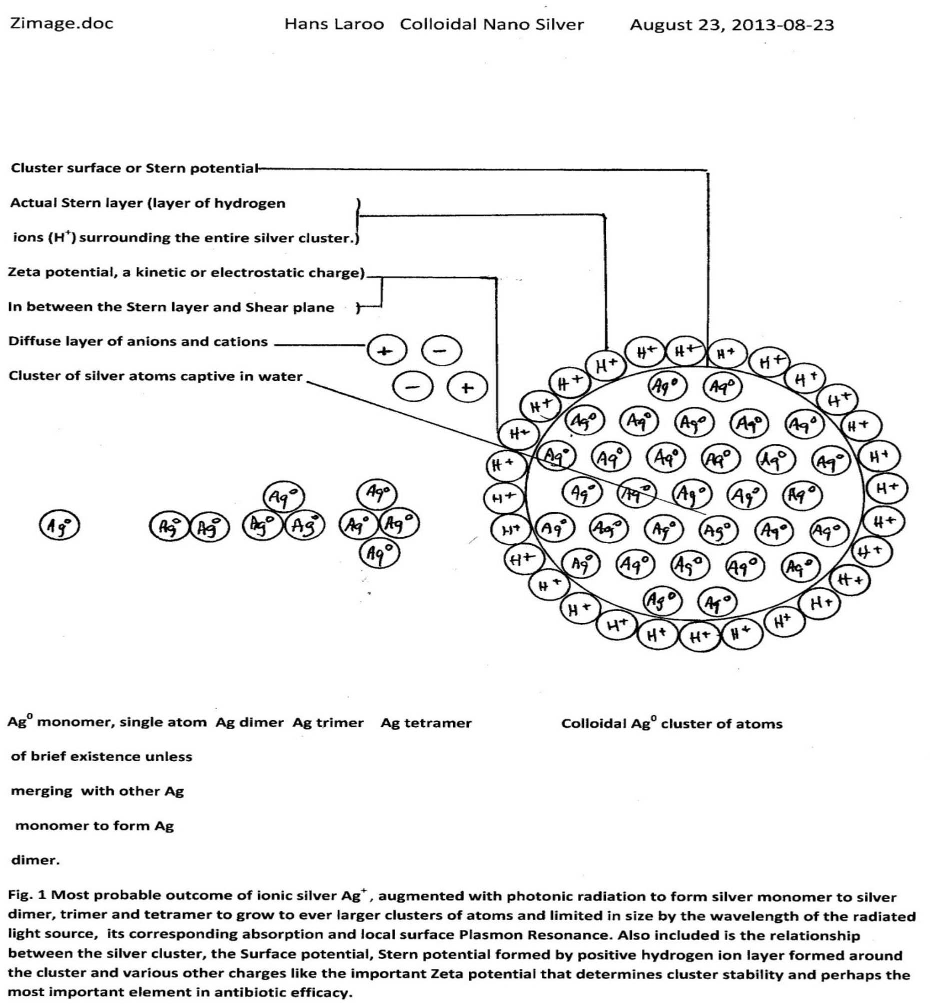
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Fig. 1 Most probable outcome of ionic silver Ag$^+$, augmented with photonic radiation to form silver monomer to silver dimer, trimer and tetramer to grow to ever larger clusters of atoms and limited in size by the wavelength of the radiated light source, its corresponding absorption and local surface Plasmon Resonance. Also included is the relationship between the silver cluster, the Surface potential, Stern potential formed by positive hydrogen ion layer formed around the cluster and various other charges like the important Zeta potential that determines cluster stability and perhaps the most important element in antibiotic efficacy.

Figure 1: Representation of a charged silver particle in an aqueous solution.

and temperatures. Light can vary from low to bright light levels during the day. Temperatures also can vary from minus 10°C during winter months and to +40°C in summer. As a direct result, no two batches of silver products are ever the same. Even the chemically produced silver products, using silver salts, combined with chemical reducing agents, have proven to be inconsistent. In a number of experiments conducted, we were able to prove that by just placing silver nitrate solution in sunlight, a sufficient amount of photo reduction was available for colloidal material to form. These experiments prove that by applying the appropriate irradiation, the need for a chemical reducing agent is NOT required.

The sole purpose of our paper is to create an awareness of the physics involved in colloidal silver synthesis by electrochemistry, as well as the physical properties of this material, how it is produced, how it differs from colloids produced by other means and its potential as an inorganic antibiotic [3-5]. To make the information contained in this paper available to as broad an audience as possible, obscure technical names and scientific expressions have been either avoided or explained in simple language to promote a general and concise understanding on this topic for anyone.

Introduction

With the existing kaleidoscope of different methods in producing colloidal silver and the fact that at present, there appears to exist no specific standard for colloidal silver, little in the way of testing is also not economically available. This means that the haphazard way of producing colloidal silver will continue to remain until a standard is introduced and proper testing facilities become available. Even to the date of drafting this paper, few if any of those involved in colloidal silver have acquired any real insight as to what constitutes electrochemical produced colloidal silver. How to produce this material in a consistent and predictable manner, according to strict specifications, is still some time away [6-13].

Initially we were not adequately prepared either, but with intensive research and experimentation for around six years, we have made rapid progress in both perfecting the process and the design and building of economical prototype production and test equipment. We started from a humble beginning to a quite an advanced technology that incorporates very precise and consistent controls of production and testing.

Our most important discoveries were the implication in the use of very specific portions of the electro-magnetic spectrum, the existence of hydrated electrons held captive by water and their liberation from the water by short wavelengths of light, as well as the peculiarities of the water itself. In addition, it proved necessary to apply control over many environmental factors, including the precise control of current and temperature. Those attempting to produce colloidal silver over the decades failed because of ignoring these requirements. To make matters worse, often only unstable ionic silver with dangerous toxicity levels was ever produced [14-16].

We chose to use a variation of the standard concept of electrolysis and refer to it as electrochemistry. Our techniques do not use any electrolytes, only the purest commercial available water, 99.998% silver rod, precise and controlled direct current and voltage potentials, refrigerated conditions, total absence of extraneous broad band light and very specific high energy photon electron transfer irradiation instead.

Colloidal Silver-Facts and Fallacies

Contrary to the popular belief that electrochemistry or electrolysis produces colloidal silver, is incorrect. It does nothing of the sort. It only produces ionic silver when the two electrodes have a voltage potential across them and current is allowed to flow. Also, the entire process must be shielded from broadband light. This current is then responsible for extracting silver atoms from the silver anode and during that process, one or more conduction electrons are removed. This then results in the silver atom turning into a positive cation, which will be attracted to the silver cathode if in close proximity. The fact that some colloid formation is initiated anyway is due to the presence blue, indigo, violet and UV light forming part of existing ambient light conditions.

Why most attempts at producing colloidal silver have gone awry, is due to the ignorance about the need of short wavelengths of light in reducing ionic silver to neutral silver. For a start, the colour blue at around 420 nm is absorbed by silver, and this causes colloidal silver at around 420 nm to present a yellowish hue. There is a reason for this. Blue is missing from the visible spectrum. Darker blues, such as indigo, violet and ultra-violet from 420 nm to around 320 nm (penetration limit of UV to glass) have an ever increasing energy component expressed in electron volts. Electron volt levels (eV), ranging from 2.64 eV in the blue (470 nm) to 6.2 eV in the Far UV (200 nm) have the ability to effect this transfer. These frequencies are of a sufficient strength to collide with hydrated electrons (captive in the water), to whom they impart most of their energy during such collisions. Imagine any electrochemical operation in ambient light conditions subject to the full extent of the visible spectrum from violet 400 nm (3.0eV) to infrared 1000 nm (1.24 eV), perhaps with some artificial lights thrown in, and it becomes obvious that there will never be any predictable outcomes. The result of using broadband light is a motley of varying size clusters (poly-suspended), the result of this which will not conducive to the making of an effective antibiotic. Light and temperatures change from moment to moment, are never the same, and as such, also needs to be controlled [8-10,16,17-20].

We found that the best results for producing high grade colloidal silver (without also producing ionic silver content), is to work in complete darkness and at a low temperature. We used a domestic refrigerator, set to maximum 10°C. During the subsequent electrochemical process, we simultaneously radiate the ionic silver produced with high energy, short wavelength blue, indigo, violet or UV light. The photons so produced, then collide with captive hydrated electrons in the water and liberating them. This is referred to as Photon Electron Transfer or photo reduction and responsible for turning ionic silver (Ag^{+}) into neutral silver clusters of atoms (Ag^{0}). The current view on this procedure is that the frequency of the photons is a deciding factor in the number of atoms in the cluster, and thus its size in nano metres. Contrary to existing views that atoms come together to form clusters, it is the water that forces the atoms to cling together in clusters. As some scientists put it, "light sculptures nanoparticles" On the matter of irradiation of ionic silver by blue, indigo, violet and ultraviolet light, we wish to hark back to the technology of Black & White film exposure in vogue decades ago [21-23]. Exposure to these high energy photons, ionic silver (silver halides) deposited on the film material are exposed, and a latent image is formed. This image, although real, cannot be seen until the film and the exposed silver halide are developed by chemistry (Developer and Fixer). A deciding factor in these exposures is the number of photons that collide with the silver ions. It stands to reason that an insufficient number of photons will not expose every silver ion, but a sufficient number of photons will. Likewise, it is with electrochemically produced ionic silver. The level of exposure depends on the concentration of silver ions making their way from the anode to the cathode. An insufficient number of photons may not collide with a sufficient number of hydrated electrons in the water or worse, the ions may not be evenly distributed due to contamination or matrix formation of the water molecules. The result is that some ionic silver remains and the end product is an undetermined ratio of both ionic and colloidal silver. Other deciding factors that arise are from contamination in the water and its ability to create molecular matrixes. It is claimed that there are three types of molecular matrixes for water. These are appropriately named the crate, the prism and open book configuration. It is further claimed that the first two (crate and prism) are able to contain matter other than itself. That is certainly the case when these matrixes hold hydrated electrons captive. Submersed silver atoms in a cluster present a negative electrical charge. This is due to the unpaired single conduction electron in the outer shell. Positively charged hydrogen ions in the water, orientate themselves onto the negative appearing atomic silver clusters and literally hold the cluster captive. This is referred to as the Stern layer, the innermost of the double layers. Beyond the Stern layer, a second layer called the diffuse layer consists of a mixture of negative and positive ions. Between these two layers, an interfacial electrostatic charge called the Zeta potential is created. For silver, that charge is negative. This Zeta potential is located between the Stern layer and diffuse layer (Double layer). Generally, if all clusters are all of a same small size and shape (mono suspension) and the concentration (ppm) low, the Zeta potential [24], is bound to be high. At around -25 mV, the Zeta potential starts to exert a repulsive action against the attractive forces of the Van der Waals Force. When the concentration is low, the Zeta potential can theoretically reach a level of -100 mV. Likewise, if all clusters are of the same minus potential, there will be a maximum repelling action, and thus, a true nano sized and stable colloidal suspension exists. However, too high a concentration (beyond saturation level), instability may set in due to clusters being compressed.

A Silver Colloid

Colloids are clusters of silver atoms that all carry the same electrical charge, and thus mutually repel each other. Clusters can consist of just a hundred to as many as 250,000 atoms, ranging in size from just a few nano meters to as much as 100 nm. Any clusters larger than 100 nm in one dimension are no longer considered to fall in the category of nano clusters. Contrary to popular expression, colloidal silver does not consist of particles but clusters of atoms, much like a bunch of grapes. The importance of the repelling action of the electrical charges is to overcome the natural attractive forces of the 'Van der Waals force' inherent in all matter. At around -25 mV Zeta potential and over, the 'Van der Waals force' [25], loses its grip and matter is now in suspension. The use of the term nano relates to a value of 10^{-9}, which equals to 1 billionth of a metre. Nano sized particles or clusters smaller than a micron (millionth of a meter) cannot be resolved by the optics of optical microscopes.

The Vulnerability of Colloidal Silver

A high Zeta potential and the associated mutual repelling action of the colloidal silver, ensures a long term relative stability. Unfortunately, colloidal silver is susceptible and vulnerable to any form of heat, either from thermal agitation caused by long wavelengths of light (green, yellow, orange and red), infrared and microwaves, as well as from the heat of a fire. The thermal agitation simply disrupts the colloidal clusters by vibrational forces, bringing them into contact and causing aggregation into ever larger clusters. At some point, the cluster reaches a critical mass and due to the effect of gravity, comes out of suspension. To prevent this from happening, colloidal silver should always be kept refrigerated.

Contamination by Ionic material, including ionic silver, can also interfere with the stability of colloidal silver. In particular, positive ions (cations) getting in between negatively charged colloidal clusters. This will cause electrical bridging and disrupt the repelling action. The result is again, an undesirable aggregation into ever larger clusters.

The Simplicity of Electrically Produced Colloidal Silver

As compared to all other techniques, the production of colloidal silver by electrochemistry and Photon Electron Transfer would be the least difficult, least labour intensive and most economical of all methods. Just switch it on, walk away and come back when it is ready for pouring into suitable containers. There is no chemistry, no need for supervision and unnecessary handling needed during the entire production process. Of course, nothing is ever that simple.

To produce colloidal silver by way of electrochemistry requires the use of pure water, pure silver rods (electrodes) and suitable containers. Proper electronic equipment for controlling the voltage potential and current flow to precise values is a must. The production needs to occur in complete darkness and at low temperatures. Temperatures from 4 to 10°C are recommended. The electrochemical synthesis of ionic silver to colloidal silver is due to short wavelength irradiation. This irradiation must be of sufficient quantity, to ensure all silver ions are converted into colloidal clusters. It should be noted that in Black & White photography, the silver halides used on the film material also required exposure to high energy irradiation.

The Actual Process of Colloidal Silver Synthesis

A voltage potential applied between the two partially submerged electrodes causes a DC current to flow. This current will remove silver atoms from the anode, in quantities related to the amount of the current that is used. This quantity was formulated in the early 1800s by Michael Faraday in his Second Law of Electrolysis. Due to this process, the silver atoms coming away from the anode, lose one or more electrons and become ionic silver (Ag^+) in the process. Ionic silver is totally dissolved in the water and cannot be observed. Since a silver ion has a positive charge, it is called a cation, and thus attracted to the cathode electrode.

The electron that came away from the silver atom is also in the water, and since all electrons are negative, the positive hydrogen ions that were formed simultaneously orientate themselves on these hydrated or solvated electrons and virtually keep these electrons captive. This situation will remain so until a photon of sufficient energy, i.e. a photon producing any of the lights mentioned in this paper, will collide with such a hydrated electron. During this collision, most of the photonic energy is imparted to the electron. It is now called a photon-electron. With the additional energy, the electron can escape and join a silver ion, and both will convert into a neutral silver atom (Ag^0). [26-32]. As a consequence of this action, the photon-electron electron loses its photonic energy in a brief flash of light of a lower frequency. This is not the end however. A single silver atom is not stable due to its single unpaired electron in the outer shell, and unless it finds another single silver atom, its newly gained neutrality will be lost again. However, if two of such atoms bond, they form a Dimer, and by doing so, remain stable. A dual silver atom (Dimer) measures about 0.66 nm, the smallest silver cluster possible.

This process will continue from a dimer to a trimer, subsequently into ever larger clusters, until a maximum size is reached. This will depend on the frequency of the radiated light used. To keep clusters small, short wavelengths of light are required. This is one way to manipulate the size of clusters. Likewise, longer wavelengths of light will allow aggregation into larger clusters.

The Actual Process

Like everyone else, we too started out with two silver electrodes immersed in distilled water in a soda glass jar and using an AC/DC electric charger rated at around 100 mA/h. Because pure water is an insulator, it actually opposes the flow of current. In fact, the higher the current, the more difficult this flow becomes. Unknown to most, for some time little or no current will flow between the two electrodes. Current will only flow when ions are formed and become charge carriers. This delay in current flow will often prompt experimenters to add salt. Unbeknownst to them, this will interfere with the formation of colloids and produce silver chloride instead. Our experimentation has shown that only a token of current will flow in pure water. This level is set by whatever else is in the water. Under favourable circumstances, pure water can allow several hundred micro amperes/h of current to flow. Another problem that causes inconsistencies is the use of alternating voltage potentials (AC), and/or incorrect electrical loading (impedance mismatch).

These uncertainties are not acceptable and instead we opted for a method where voltage potential and current are set to an exact level, i.e. a production method that would precisely continue from start to finish. By reducing the current to a level that would flow in pure water (500 micro amperes), and simultaneously elevating the DC voltage potential to 300 VDC, we found this to be an ideal production method. Since our controls are very stable, we can even run the process for a week, at currents as low as 20 micro amperes and still maintain regulation within a few percent. This also has the advantage that the submersion of the electrodes only needed a few millimetres, even just breaking the surface, instead of the standard submersions of 100 to 150 mm. In one of our experiments, we were able to prove that under uncontrolled current conditions, submersing the electrodes further, current increased exponentially and soon went out of control at a submersion of 250 mm. This was evidenced by a corkscrew effect in the water. Silver was literally being stripped from the anode in large quantities.

We also tried different containers and eventually settled on 2 litre boro silicate glass beakers. Pyrex glass also worked well. Just recently, we obtained some rectangular acrylic containers designed for use in electrophoresis research. However, because of various plastics and acrylics blocking Ultraviolet light, we had to modify the arrangement and irradiate the vessel from above, instead of from the sides. Even Pyrex and borosilicate do not allow much UV penetration below 320 nm. Initially, we produced just ionic silver in complete darkness and then synthesized the colloidal silver by photonic reduction. However, this took twice as long. Eventually, we produced ionic silver and irradiated the newly formed ionic silver with the UV simultaneously. It is interesting to note that an initial batch of ionic silver produced in complete darkness, and kept in a fridge over night, nevertheless had turned into a colloidal material the next morning. We soon realised that at that particular time, there was a violent outburst from the sun. It is even more interesting to realise that any of the silver salts like silver nitrate, silver acetate and silver sulphate will all turn into a colloidal substance when exposed to UV light. It basically makes the use of chemical reducing agents obsolete. The sad part of photon reduced silver salts is the retention of some of its chemistry, making it less pure and with little or no control over colloidal cluster size.

We have observed during earlier investigations that the use of multiple electrodes in the one container is of no benefit. Due to voltage potential rise or drop between multiple electrodes, current between multiple electrodes may flow in an unpredictable way, such as current flow between two anodes, and/or two cathodes. We also experimented with three containers and the electrodes in each connected in series. Voltage and current drops caused inconsistencies in concentration of the three vessels. Only if the current flow between two electrodes is controlled to a set limit, can predictable concentrations of colloidal silver be produced.

Colloidal Silver and the Water it is Suspended in

Colloidal silver, ionic silver and water are three quite distinct materials that really have nothing to do with each other. Ionic silver is made up of atoms that have lost one or more electrons, and for that reason readily combine and form compounds with any available chemistry that has an excess of electrons (anions). For example, salt (Sodium Chloride) and ionic silver form silver chloride. If there are no salts in the water, silver ions are totally dissolved and cannot be observed visually. Colloidal silver can be seen by the way it scatters visible light.

Water molecules consist of two hydrogen atoms and one oxygen atom (H2O). Since the hydrogen atoms have a positive charge relative to the oxygen, water molecules can be seen as having a dipolar character. Any flow of current caused by a DC voltage potential at 1.23 Volt and over, creates a disturbance between the cohesion of hydrogen and oxygen atoms, and a break-up occurs. Separate hydrogen gas and oxygen gas are thus formed.

Colloidal silver is made up of any number of neutral silver atoms that form clusters in a variety of shapes, such as spherical clusters, elliptical clusters and triangular clusters, all relative to their size. Silver being hydrophobic, avoids direct contact with the water. As a direct result, an interfacial kinetic/moving electrostatic charge forms between the water and the clusters or anything else for that matter. Initially, positively orientated hydrogen atoms or their positive ions surround the cluster. This is called the Stern layer. Beyond the Stern layer is the diffuse layer, a mixture of both positive and negative ions. Together these two layers are identified under the Double Layer Theory, proposed by Derjaquin, Landau, Verwey and Overbeek, during the early part of the 20th Century. Between these two layers is the Zeta potential located as a moving electrostatic charge that in the case of colloidal silver, can reach a negative voltage potential as high as -100 mV. There is still great debate about the role the repelling Zeta potential has in relation to silver's propensity as an antibiotic. It must be clear from the forgoing explanations that ionic silver and colloidal silver are totally different entities and must never be compared or used together.

The Physics of Colloidal Silver

Colloidal silver consists of loose silver atoms forced by the tensions of the water to adhere into clusters in suspension. To refer to nano sized colloidal silver clusters as being metallic, is incorrect. Only bulk metal qualifies for that description. Scientists are now becoming aware that when silver nanoparticles sizes are reduced to 10 nm or less, classical physics break down and quantum mechanics takes over. Under these conditions, nano sized silver clusters, respond distinctly differently to electrons and photons than would bulk silver metal. The following characteristics for colloidal silver will indicate these differences:

1. Cluster/particle size generally measured in nanometres 10^{-9} to 10^{-11}.

2. Cluster/particle shape is related to its size, which is related to the irradiating wavelength.

3. An automatic mutual repelling action between clusters brought about by a Zeta potential to ensure stability.

4. Other parameters, such as (a) surface potential, (b) Stern potential and (c) Nernst potential. All are indictors of what constitutes colloidal silver.

5. Absorption of electromagnetic radiation at around 420 nm and re-emission of electromagnetic radiation at a lower frequency. In most photon-electron reactions, some energy is generally lost.

6. Colloidal silver, in particular, is a strong photo-active material, as evidenced in early B&W photography. It has no equal. The general scientific statement that silver Per se has the highest reflection of visible light of all metals (at 97%), is scientifically incorrect when considering that most of the visible darker colour blue is absorbed with a maximum absorption occurring at 417 nm. One phenomenon exhibited by nano meter sized colloidal silver is its ability to respond to long wave length light much larger than itself. A collision between a low frequency electromagnetic wave, e.g. green at 563 nm and a colloidal cluster at 50nm will cause a local oscillation called a Local Surface Plasmon Resonance (LSPR) [33]. A Plasmon is a quantum of plasma oscillation. The plasmon is a virtual quantum, and when coupled with a photon of the right frequency, another virtual particle called the plasma polariton is created. LSPR depends on the density of free electrons. For silver that criteria is met at Violet and UV wavelengths [34]. Free conduction electrons at the surface cause the electron to momentary oscillate at a substantially higher resonant frequency within the confines of the cluster size. When this local oscillation ceases, the electron loses its photonic energy. As some energy is inevitably lost, the wavelength of this departing photon (re-emission) is of a lower energy and longer wavelength, than what initiated the oscillation in the first place. It is claimed in several scientific papers that the energy of the plasmon resonance in silver may be as high as a factor of 10, as compared to the energy of the incoming long wavelength of the incident light. All matter reflects, absorbs and re-emits light in different ratios, depending on whatever frequency of light it is interacting with. It is not unlike Raleigh scattering, when small molecules in the atmosphere absorb much of the visible light, causing our familiar blue sky away from the sun. Looking toward the sun, less of the other colours are absorbed and become

more visible. It is called the Raleigh scattering and named after Lord Raleigh, who first described this phenomenon. Here too, there are long wavelengths of light being absorbed and only the shorter wavelengths, such as blue being scattered and made visible as the familiar blue sky. This occurs in an approximate ratio of 10:1 ratio, e.g. particles and/or molecules measuring 40 nm, scattering light at 400 nm. We have also observed anomalies and artefacts, when irradiating colloidal silver with different LED and Laser light sources. Red Lasers scatter red light and green lasers scatter green light, but only if the colloidal clusters are large enough. White LED light will turn colloidal silver blue, if clusters are small and yellow, if they are large. Blue laser light however will turn colloidal silver blue in some cases and a mauve/purple colour in others. We have produced photographs of these events. However, more research is needed to explain some of these anomalies [35].

7. Non-metallic colloidal silver can return to a metal by way of aggregation, and/or when oxidised to silver oxide.

8. Once taken out of its aqueous medium, it is no longer a silver colloid. Returning it to the water will not restore its earlier characteristics.

9. Exponentially increasing surface area of silver nano clusters as they get smaller and smaller [36].

10. Experiments with longer wavelengths of light (photonic), as well as the still longer wavelengths (RF) frequencies have illustrated their propensity to cause aggregation into ever larger clusters by vibration. The same appears to be true that the use of ever shorter wavelengths of light (Ultra violet) have the opposite effect by breaking up large clusters into smaller clusters relative to the particular wavelength of the ultra violet, like some form of resonance engineering. It is claimed that placing a spherical colloidal silver sample of 20 nm clusters in a Microwave oven and heating it for a few seconds, will increase the cluster size to 100 nm and its shape to that of somewhat of a pyramid [37].

The Physics of Water

Water is, by definition, a dielectric and thus, an insulator. It is claimed that ultra-pure water in a sealed container and not in contact with air, has a resistivity of 18.18 or 18.24 million Ohm or equal to 0.0548 uS/cm. However, as soon as this ultra-pure water is exposed to air, that resistivity factors drops to around 1 million Ohm due to the formation of carbonates. Compared to this value for clean water, albeit containing carbonates, the average tap water would have a resistance 10 times lower, e.g. 100.000 Ohm (and a reciprocal of increased conductance). This lowered resistance and increased conductivity would depend on the extent of contamination.

In our process, we use commercially available deionised water, but do not use the standard pH and conductance meters. Instead we have developed an analogue resistance meter with a negligible loading on the water of 10,000 million Ohm at 1 Volt DC. This 1 Volt DC value is below the 1.23 Volt level, and not capable of decomposing water into it gas constituents, Hydrogen and Oxygen. It is thus a test that is non-destructive. A number of tests have indicated that on a scale of 100, 18 million Ohm water reads 1, deionised water reads 2/4 and tap water reads between 70 and 80 depending on the level of contamination. A 100 micro ampere meter movement was used. All of this testing is without the water containing colloidal silver. A new type of water testing with current flow as its basis is on the drawing board.

Setting a Standard for Colloidal Silver

As far as we know, there exists no official standard for colloidal silver or a standard procedure for its production. Neither are specifications and industry self-regulations in place for quality control. Most likely, this is the result of the 'ad hoc' trial and error method used by most to produce something, without knowing why or how. To really figure out how to produce colloidal silver consistently and according to a standard (for proper quality control) is not in the sole domain of chemistry or even electrochemistry. It requires an understanding of Physics, and in particularly, electronics, optics and photonics. From our perspective, the production procedure is purely based on physics and some incidental chemistry (exposure to air and carbonate formation) thrown in.

Physics keeps it clean as no reducing agents (for example, sodium boro hydride) are needed to neutralise salts like silver nitrate, silver acetate and silver sulphates. The less chemistry is used the cleaner will be the end product.

We have to realise that the main purpose is to produce colloidal silver to a standard and specifications. This will enable scientists interested in conducting clinical trials to know the quality and specifications of the material, even when these clinical trials only involve 'in vitro' testing. For clinical trials, 'in vivo' it is an absolute requirement that the quality and quantity of the silver be precisely known. That few if any clinical trials 'in vivo' have made it to publication may in fact be caused by these shortcomings.

One such standard might list the method of production, e.g. produced chemically or electrochemically. Secondly, the cluster/particle size and shape may be known as well as Zeta potential, the particle size distribution, concentration and level of toxicity and other contamination. It should be noted that silver is found with many other metals and elements, and it is only the level of purification that determines the level of other materials, such as lead and arsenic in ppm or ppb. It is also likely that clusters of one size and shape may be a more effective antibiotic against a particular pathogen than clusters of other sizes and shapes. The only one recommendation for a standard has come from a nanotechnology association in the USA, recommending the adoption of a maximum size for nano particles. This recommendation states that when a cluster is larger in one dimension than 100 nm, it will not be recognised as a nano particle. If this size limit has been accepted is not known. At least, it is a start.

If ever we expect the scientific community to consider Colloidal Silver as a feasible alternative to organic antibiotics for any form of clinical trials, it will be up to those producing the colloidal silver to introduce, to guarantee and adhere to acceptable standards and specifications.

Testing and Characterization

Our research is ongoing. Much of the real physics involved in electrochemically produced colloidal silver and the water it is suspended in, are obscure and not well understood. Water and its constituent elements, hydrogen and oxygen (in a ratio of two to one), is of an extremely complex nature that science is only now slowly starting to unravel. Add colloidal silver in the mix and you will have an even more complex substance. Science is still trying to understand its intricacies. Only recently, scientists have discovered that water forms a small variety of water clusters, such as the Crate, Prism and open book matrixes. They have discovered that the first two can, in addition to holding captive hydrated/solvated electrons, also contain foreign matter [38-42].

Water absorbs most of the electromagnetic energy radiated on it, except for a small window in the visible spectrum with the colour violet experiencing the lowest absorption, and thus, the greatest penetration. This occurs at 418 nm (violet colour). Photons of longer wavelengths from 500 to a 1000 nm and longer, i.e. yellow, orange, red, and Infrared, as well as microwave and radio waves, are all absorbed at different increasing levels. Photons ranging from yellow to Terra Hz cause vibrations (thermal agitations) and those in the lower Giga Hz range, subject water molecules to rotational forces, such as occurs in a microwave oven that heats and cooks our foods and drinks.

At shorter wavelengths from 400 nm (edge of the visible light) and into the Ultraviolet to 100 nm and beyond, electromagnetic waves are also absorbed at ever increasing levels.

It is intriguing to note that although pure water is most clear (highest penetration) to visible violet light at 417 nm, it is at approximately that same frequency, that silver completely absorbs the violet light that pure water so easily passes.

Adding foreign matter and other chemistry will generally cause a red shift, such as what occurred with silver halides used in B&W photographs. This is indicated by a graph published in [24]. Basic Photography on page 195, which shows a graph indicating shifts for AgCl (420-430 nm); AgCl+42% AgBr (460-470 nm); AgBr (465-480 nm) ; AgBr+3% Ag Iodide (520-530 nm). The chart indicates that adding Bromide, Silver Bromide on its own, and a combination of Silver Bromide and 3% Iodide all cause a shift to longer wavelengths. To avoid such red shifts, we need to keep our water pure and free from chemicals.

We use commercially obtainable deionised water. This is water from which inorganic solids have been removed. However, that does not mean that there is nothing else in there. This is where light scattering becomes a useful tool. Much of what is in the water, even microbes and bacteria and other organic matter will scatter light that can be seen by the naked eye. This type of scattering is referred to as turbidity testing, and which can be quantified by electronic photo sensing. If the light source produces parallel light, it will be seen as a beam, but when the light is squashed through a pinhole or special optics, it will, when it hits the cell containing the water, spread out into a cone of light. This is called the Tyndall effect [43-45].

To determine other properties of water, such as acidity or alkalinity, pH and conductance, pH and conductance meters are used. They generally measure hydrogen ions with the pH meter and total ionic matter with the Conductance meters. A more sophisticated test is done with a spectrophotometer (absorption at specific frequencies in nm wavelengths) and the Mass Spectrophotometer for determining concentration of solids. However, this second instrument cannot distinguish between ionic and non-ionic matter and just gives a total value.

We prefer to use our own Water Resistance Tester with a very low loading of 10,000 m Ohm and a voltage potential of only 1 volt DC. This is below the 1.23 v DC, the equilibrium voltage of water. Our tester tells us immediately if our water is clean enough or not.

Testing of Colloidal Silver

We have rejected most of the simple absorption and scattering techniques, and have instead opted for a number of other technologies. The most promising of these other options, which include Nano Particle Shadow Casting, Schlieren Photography for Liquids, Birerefringe and Retardation of Light and Nuclear Magnetic Resonance, cannot match the speed that Cross Polarization Light Scattering Spectro-photography/photometry offers.

Cross Polarization Light Scattering Spectro-photography/photometry has many advantages over anything else. For a start, it can distinguish between organic matter, silica, water and Colloidal Silver. Cross Polarization will extinguish light scattering of any matter, which has a refractive index like water and glass and show continued light scattering from colloidal silver unimpeded. Adding to the instrument, a rotatable prism or diffraction grating will provide Cross Polarised Light Scattering at different UV/Vis wavelengths. With that, a number of parameters of colloidal silver can be approximated:

1. Concentration in ppm/ppb.
2. Cluster/particle size and shape.
3. Amount of foreign matter.

Further advantages are: (a) visible observation, (b) able to record scattering on digital or video camera, (c) photo-electric measurement and (d) economically to construct.

Antiseptic Properties of Silver

Throughout history, there have been claims of silver being able to destroy a large variety of pathogens and fungi. Stories of throwing a silver dollar in your milk for keeping it fresh for longer and rich people with a ‘silver spoon in the mouth’ never getting a cold, are often the subject of conversation, but have never been scientifically confirmed. Nevertheless, before antibiotics such as penicillin were introduced in the 1940’s, many clinical trials ‘in vitro’ some years earlier had confirmed silver’s propensity to serve as a potent antibiotic, albeit as an inorganic one.

We mention in this paper that the publication of clinical trials (in vitro and in vivo) are scarce, and only related to silver salts produced colloidal silver, which in many cases is not without ionic silver content and often contaminated with other chemical residues [46]. Whilst there are a few in vitro clinical trials around, in vivo trials (colloidal silver as a medicine inside the body) have not been located other than one conducted by a local Brisbane researcher.

As a totally independent researcher, we are personally not involved in any form of medical clinical trials other than providing specific free samples.

Most of the research we know of is the research on ionic silver, such as Silver Nitrate in bandages, and as an antiseptic on the skin of burn victims. The problem with that is its toxicity and corrosiveness. Compared to that, our electrochemically produced colloidal silver is absolutely neutral.

Whatever type of silver is used, it is not really known what aspect of colloidal silver actually is responsible for the eradication of pathogens and fungi. An independent laboratory report by AMS Laboratory in New South Wales commissioned on our material on Enterococcus faecalis (ATCC 19433) and Candida albicans (ATCC 10231) was concluded as follows: The sample “Ag Water Solution” has successfully demonstrated antimicrobial activity against Enterococcus faecalis and Candida albicans by achieving greater than 5.2 log reduction (or more than 99.999% kill) and 3.57 log reduction (or more than 99.9% kill), respectively.

Similarly, in the paper, Collloidal Silver (CS) as an Antiseptic: Two opposing viewpoints by Cock et al. [2] (http://phcogcommn.

org/2012/v2/i1/47.full). It states in its abstract that Argyrol and HLY (our sample) displayed the broadest specificity, inhibiting the growth of all 14 bacteria tested, as well as the growth of 3 (100%) and 2 (67%) of the fungal species tested. In yet a more recent report on a one of our samples of colloidal silver, our sample identified as NMS=LR-0492 and tested in a pre-clinical study: ex vivo Anti-proteus activity showed an Minimum Inhibitory Concentration (MIC) of less than 3 ppm as compared to:

Silver Nitrate MIC=72 ppm

Silver Acetate MIC=75 ppm

NMS=Ag0-Citrate MIC=less than 22 ppm

NMS=LR-0492 MIC=less than 3 ppm

Note! We were later to learn that the actual MIC was found to be even lower at 0.6 ppm. Source of this and other information [47,48]. We were also handed a clinical study conducted by EMSL Analytical, Inc Milpitas California CA 95035 on a Certificate of Analysis for Mesosilver versus Sovereign Silver on the following bacteria:

Escherichia coli (ATCCS No. 25922) and supplementary charts on the antimicrobial effectiveness of Staphylococcus aureus, Canndida albicans, MRSA, Escherichia coli, Pseudomonas aeruginosa and Enterococcus faecalis [46]. All showed a sharp decline in these cultures within 5 hours, as compared to controls taking 25 hours or more. For more information, connect with the WEB site of Colloidal Science Laboratory in the USA.

There are many attributes to Colloidal silver, and in particular, that type what is produced electrochemically. It may be a high Zeta potential or it astronomically large surface area that only gets larger as the cluster size diminishes further. The larger the relative surface area of a cluster, the more it can react with its environment and the pathogens in it. However, my thoughts orientate on a high Zeta potential with a maximum level of minus 100 mV. However, this can only occur when the clusters are very small, e.g. around 10 nm or less. Also, concentration needs to be kept low so as to avoid crowding.

As most of the information on antibacterial properties has been sourced from Ionic silver, silver nitrate and other silver salts, it has been established that these products are indiscriminate, killing all bacteria. It needs to be realised that our body cells have a symbiotic relationship with the majority of bacteria in our body, and it would be counter-productive and even fatalistic to use colloidal silver, without knowing what reaction there will be. This is where the targeting of specific bacteria comes into its own domain. Research will have to establish how to target specific troublesome bacteria and leave the probiotic/symbiotic species alone. Perhaps clinical trials with ion free electrochemically produced colloidal silver may be more suitable. This was certainly the case recently when unbeknownst to us a sample was deliberately ingested and later we learned that a particular type of Proteus bacterial strain that can cause Rheumatoid Arthritis had been completely eliminated from the gut. This happened almost a year ago and so far as we know, there have been no signs of any ill effect. But as we say, we only research all the facets of colloidal silver production and only provide free samples and information about our research.

Conclusion

Our research into the electrochemical production and the water used has driven home the concept that "the devil is in the detail". Although the principle and operation of its production are relatively simple, to make it well, requires extreme caution and precision. Many factors, such as cleanliness of electrodes and flasks, all can contribute to it all going wrong or right. We do not take anything for granted. Most of the time, the end product is much as what we expected it to be.

Many disciplines of science are involved and most of these are based on physics and not chemistry. We even introduce an in-line series connected diode at the anode to remove residual AC and change the separating distance between the electrodes from 25 mm to as much as 200 mm for specific colloidal silver production runs. From the start, we have avoided chemistry due to its ability to contaminate and cause red shifts, and thus, alter absorption factors.

Due to the peculiarities of water, only a very narrow band of the visible light spectrum is able to penetrate its properties, with a maximum penetration depth at 417 nm. Just 30 nm into a shorter wavelength at 380 nm (UV), and already the absorption is 2.5 times higher. Such behaviour has enormous implications for colloidal silver production. On the one hand, the higher electron volt, the more hydrated electrons are released from the water. On the other hand, penetration depth simultaneously increases sharply, making that task more difficult. From this, it becomes obvious that a compromise between wavelength and least natural absorption must be made. Most likely that may turn out to be around 418 nm @ 2.95 eV for an optimum performance. However, that would also produce a specific cluster size.

Once the metamorphosis from bulk silver to colloidal silver is complete, it will still be necessary to keep colloidal silver in the dark and at a low temperature. However, if that is not maintained, all of its original characteristics and specifications may not be preserved.

From the start also, we have tried to keep ionic silver out of the equation, although many have tried to persuade us to make a mixture of both ionic and colloidal silver, and suggesting that one augments the other and vice-versa. We have an opposing outlook on this matter. From our point of view, it makes sense to compare colloidal silver on its own and ionic silver on its own, in order to determine which of the two has the highest bio efficacy in the eradication of pathogens. To use a mixture of colloidal silver and ionic silver would never settle this argument. A further reason for the first approach is the fact that colloidal silver by way of light scattering can be observed, whilst ionic silver cannot. Besides, ionic silver is unstable and corrosive and attracts anions in order to neutralise itself. By simply shining a light of the right frequency into ionic silver will bring about photo synthesis and a poly-suspended colloid formation will follow.

Much of nano sized colloidal material and the water it is contained in requires substantial more research, in order to explain hitherto unexpected phenomena, such as Local Surface Plasmon Resonance, Photo-luminescence and electro-luminescence, as well as radiation effects from the Sun and Outer Space. Even when all this is able to be explained, there is still the research required, as to if or how colloidal or ionic silver effects life and the environment, and if that occurs in a benevolent or malevolent way.

There is an irony in the fact that much of the science and technology principles related to silver were already known for most part during the first half of the 19th Century, starting with Michael Faraday. Later in the early part of the 20th Century, the science of photonic electron transfer in the production of Black & White photography and its silver salts (silver halides) that created latent images awaiting development.

If indeed, specific colloidal silver ever proves to be an effective alternative to the present way of dealing with the so-called superbugs and drug resisting bacteria, it will be absolutely mandatory to introduce the much needed standards in an effort to assist those prepared to conduct the required clinical trials.

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Dedicated to: Michael Faraday (September 22, 1791 to August 25, 1867). English Scientist and Father of electrolysis and electro-chemistry. In one his well recorded unique experiment, the atomic weights of silver, hydrogen and copper were for the first time established.

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