# Metal Nanoparticles and Their Applications

James A. Stewart

Nanoparticles are pieces of matter that are between 1 and 100 nanometers in diameter. To put this size into perspective, a nanoparticle of 50nm is about $1/2000^{th}$ the width of a human hair. Because of their size, nanoparticles have unique properties and applications depending on the material that they are made of. As an example, the small size of gold nanoparticles, combined with their non-toxicity, has enabled them to be used in medical applications because they can easily travel through the body without harm. Another example can be found in silver and its antibacterial properties. Silver nanoparticles have been found useful for everything from disinfectant creams to anti-odor socks because their size enables them to attack bacteria more effectively and inexpensively.

For other applications of nanoparticles, both the size and shape of the particle can be a factor in determining their properties. Among the most interesting properties of metal nanoparticles is localized surface plasmon resonance. Because these particles are smaller than the wavelength of light, they exhibit interactions with light that the material would not normally exhibit in their normal macro scale manifestations. These interactions include deep absorption bands into the UV and near the UV spectrum, as well as an enhanced light scattering effect known as surface enhanced raman scattering (SERS). Surface plasmon resonance is the phenomena whereby the frequency of incident photons hitting the surface of the material resonate with the frequency of the delocalized electrons on the surface, known as plasmons. Because both the incident photon and the surface plasmon have the same frequency, the photon is either absorbed or it excites the plasmon momentarily, resulting in the scattering of the photon at a different frequency as the plasmon returns to a ground state. Whether or not absorption or scattering happens depends on the size and shape of the particle.

SERS is responsible for the characteristic look of silver and gold nanoparticles in solution, whereby they exhibit an almost fluorescent appearance at low concentrations. Silver and gold in particular are interesting because their scattering and absorption happens in the visible region of the spectrum, as opposed to other metal nanoparticles in which the phenomenon happens in regions that are not visible. Researchers are exploiting these properties in various ways, but one promising area of research is in their use for biosensor development. Gold, for instance, can be made to change its absorption frequency through the interaction with electrolytes in solution. This happens because of agglomeration of particles into larger sizes and can be used as a sensing technique for electrolytes. Likewise, silver nanoparticles are under investigation for their potential role in increasing the sensitivity of fluorescence based biosensors. Because silver nanoparticles can be manipulated easily by altering their size and/or shape to yield different scattering frequencies, they can be engineered to scatter light at the same frequency that a fluorophore excites and fluoresces. This can lead to greatly enhanced fluorescence resulting in the increase of the sensitivity of fluorescence based biosensors by as much as 100-fold.

Potential applications for metal nanoparticles are just now beginning to be researched as the techniques for engineering their creation are being refined and scaled up. Despite being composed of expensive coinage metals, their small size ensures that they will maintain their economy for potential use in various applications. The future could very well see their use all throughout the products we use.