HIGH PURITY NANOPARTICLES EXCEED STOICHIOMETRY LIMITS IN REDOX CHEMISTRY: THE NANO WAY TO CLEANER WATER

R. L. D. Whitby[1*], S. V. Mikhalovsky[1], K. Katok[2], A. B. Cundy[2]

1) School of Engineering, Nazarbayev University; 53) , Kabanbay Batyr Avenue, Astana, Kazakhstan; *raymond.whitby@nu.edu.kz; 2) Nanoscience & Nanotechnology Group, Faculty of Science and Engineering, University of Brighton, Lewes Road, Brighton, BN2 4) GJ, United Kingdom

A potentially cheaper and more effective way of cleaning wastewater has been discovered by scientists at Nazarbayev University and the University of Brighton researching nanotechnology [1]. It is well established that when particles are reduced to the nanoscale unexpected effects occur. Silver, for example, interacts with mercury ions in a fixed ratio of atoms (stoichiometry), typically 2:1, which presents a limit that has never been exceeded. In this project we used an alternative chemical procedure based on modified quartz sand to immobilise silver nanoparticles (NPs) with control over their size. We found that when the size of the silver NPs decreased below 35 nm the amount of mercury ions reacting with silver increased beyond the long-held limit and rose to a maximum of 1:1.2 for 10 nm sized silver.

Conventional technologies for treatment of aqueous Hg include precipitation, coagulation, reduction, membrane separation, ion exchange, and adsorption. However, these technologies have a number of limitations depending on the method used, the level of contamination, total dissolved solids, etc, and adsorption in low concentrations of mercury. Treatment of large bodies of mercury-polluted water requires large quantities of treatment material, which in turn generate large quantities of toxic waste, albeit in a more manageable form. When considering Ag (0) redox chemistry with Hg (II), the maximum reaction stoichiometry proceeds in a 2:1 ratio, where the larger the silver particle size the slower the reaction proceeds, plus there is a release of silver into solution. We have found that a hyperstoichiometric interaction of silver NPs, generated through reaction of silicon hydride groups and silver solution, with inorganic mercury increases the amount of mercury (II) converted to mercury (0) from its 2:1 ratio (silver to mercury) to 1.1:1 (Fig. 1), in rapid reaction times, leading to stable amalgams and little loss of silver into solution. Due to the hyperstoichiometric effect, a 30-fold reduction in the mass of silver can be achieved when using 11-nm NPs versus macro-scale silver (0.01 mm by 5 mm rods in mercury nitrate solution). The added advantages of lower material costs, quicker extraction times, smaller waste footprint, far lower silver released into solution and the formation of stable silver-mercury composites making the waste material easier to handle, clearly demonstrate the exciting capability of this technology.

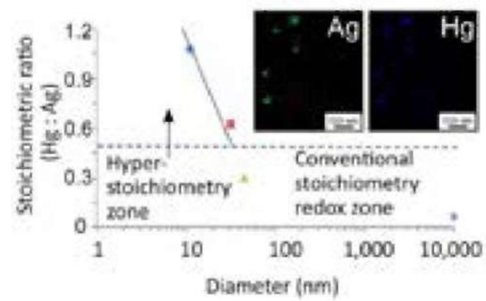

Fig. 1. Hg:Ag stoichiometry changes with the size of Ag NPs. Insert show EDX mapping of Hg onto Ag NPs only.

References.

1. K.V.Katok, R.L.D.Whitby, T.Fukuda, T.Maekawa, I.Bezverkhyy, S.V.Mikhalovsky, A.B.Cundy, Hyperstoichiometric Interaction Between Silver and Mercury at the Nanoscale, Angewandte Chemie International Edition, 51,: 2632-2635 (2012).