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A CONSTRUCTIVE CONTRIBUTION TO THE RESPONSIBLE DEVELOPMENT AND USE OF ENGINEERED NANOMATERIALS

nanoRISK

OPTIMIZING THE BENEFITS OF NANOTECHNOLOGY WHILE MINIMIZING AND CONTROLLING THE RISKS

Insider Report

Researchers demonstrate that the functionalization of noble metal nanoparticles with multi-ligands can be used for cellular targeting and that the toxicity of silver nanoparticles can be reduced by chemical modification.

SURFACE MODIFICATION OF NANOSILVER PARTICLES AND THEIR INTERACTIONS WITH LIVING CELLS

Silver nanoparticles can now be found in all kinds of products, from socks to food containers to coatings for medical devices. Valued for its infection-fighting, antimicrobial properties, silver, in its modern incarnation as silver nanoparticles, has become the promising antimicrobial material in a variety of applications because the nanoparticles can damage bacterial cells. Due to their plasmonic properties and easy surface chemistry silver nanoparticles are also beginning to attract interest among nanomedicine researchers.

"The surface chemistry of nanoparticles that governs their interactions with other constituents in their environment has critical importance," Mustafa Culha, an associate professor who leads the Nanobiotechnology Group at Yeditepe University in Istanbul, Turkey, explains. "Therefore, chemically altering the surface properties of nanoparticles with polymers, biological ligands and macromolecules is actively being explored. With the surface modifications, improvement in targeting and enhancement in cellular uptake are also achieved."

Novel use for therapeutic applications

Noble metal nanoparticles such as gold nanoparticles and silver nanoparticles have previously been modified with numerous ligands including oligonucleotides, carbohydrates and peptides for various applications. So far, though, there has not been any reported work using silver nanoparticles and functionalized silver nanoparticles for therapeutic applications.

Culha notes that this is mostly due to the fact that the silver nanoparticles are considered toxic for eukaryotic cells. However, their wound healing properties have been known for many centuries. "We wanted to demonstrate the possibility of employing silver nanoparticles for therapeutic applications and, if they are toxic, reduce the toxicity though the surface modifications."

In a recent study ("Interaction of multi-functional silver nanoparticles with living cells"), Culha and his team have demonstrated that the functionalization of noble metal nanoparticles with multi-ligands can be used for cellular targeting. They further demonstrated that the toxicity of silver nanoparticles can be reduced by chemical modification, and they showed the possibility of using lactose-modified silver nanoparticles for selective targeting of eukaryotic cells.

"This provides the opportunity to develop silver nanoparticle-based therapeutics for multi-purposes and imaging tools" says Culha. "The silver nanoparticles are plasmonic structures and they absorb and scatter a portion of the impinging light. While scattered light can be used for imaging, the absorbed light can be used for thermal killing of cancer cells after their selective uptake into the cancer cells."

Main findings support lower toxicity

There are three main findings from the study by the Turkish team:

1) Biomacromolecules such as carbohydrates and oligonucleotides can be simultaneously attached to nanoparticles to achieve multifunctionality such as selective targeting of different types of cells;

2) Attaching the right ligands to the nanoparticles can help reduce the cytotoxicity of the nanoparticles; and

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Effort to minimize the amount of formaldehyde in nanoparticle synthesis could lead to a 100-fold reduction of the toxic substance.

Avoiding Excessive Use Of Toxic Materials In Nanomedicine

Metal nanomaterials are often synthesized using the toxic reagent formaldehyde at concentrations thousands of times higher than necessary. Many of these same nanomaterials are being investigated for use in cancer treatment – however, there is a risk that they could do more harm than good. The large excess of formaldehyde that is used originates from methods developed 100 years ago. Because these methods work well, they have stood the test of time. By better understanding the role that formaldehyde plays in nanomaterial synthesis it will become possible to reduce or eliminate this toxic reagent. By eliminating formaldehyde it will become safer to prepare these nanomaterials and safer to use them in cancer treatment.

"The observation that previous synthetic routes for nanoshell and core-shell nanoparticles utilize a large excess of formaldehyde suggested an opportunity for minimizing the quantity of formaldehyde used," Scott Reed, an assistant professor of chemistry at the University of Colorado at Denver, says. "However, the synthesis of gold-core, silver-shell nanoparticles that are active in the near-infrared requires the polymer that forms by reaction of formaldehyde and ammonium hydroxide. Until a replacement polymer is found, formaldehyde is required to obtain the desired optical properties."

In a recent paper in the May 19, 2010 online edition of *Chemistry of Materials* ("Minimizing Formaldehyde Use in the Synthesis of Gold-Silver Core-Shell Nanoparticles"), Reed's team and colleagues from Portland State University describe an effort to minimize the amount of formaldehyde used for coating silver onto gold nanoparticles. They describe a strategy where formaldehyde use can be reduced 100-fold from prior routes and this minimization strategy can be applied to other nanoparticle syntheses.

"We discovered that most of the formaldehyde used in preparing silver nanomaterials is consumed by formation of a polymer" Reed explains. "Formaldehyde reacts with ammonium hydroxide to form a previously unnoticed polymer. When we decreased the ammonium hydroxide concentration it became possible to decrease the formaldehyde concentration, too."

At the same time, these materials maintain optical activity in the near-infrared, the property that makes them attractive for treating cancer with light.

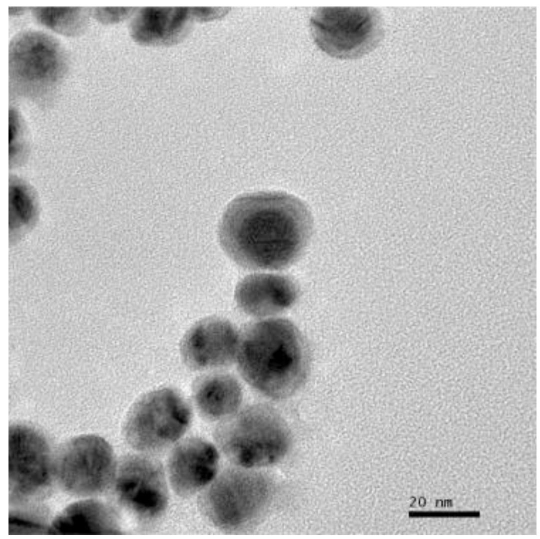
The excessive use of toxic formaldehyde in fabrication processes for nanomaterials is particularly worrisome in the area of nanomedicine where these materials are deliberately injected into the body for diagnostic or therapeutic purposes. Many of the synthetic routes to nanoshells and core-shell metal nanoparticles use a large excess of the toxic reagent formaldehyde as a reducing agent.

Reed notes that one of the early methods reported for coating silver on silica spheres made use of 1 mmol of formaldehyde for reduction of a 0.15 mM solution of silver ("Silver Nanoshells: Variations in Morphologies and Optical Properties").

He estimates that a 3000-fold more formaldehyde is used to prepare silver nanoshells than necessary.

"This large excess is based on Zsigmondy's original silver nanoparticle synthesis reported in 1927 and is typical of coating procedures" he continues. "Other reports have used a 1000-fold excess for coating silver on polystyrene beads or gold nanoparticles, up to 320-fold excess for coating silver on silica nanowires, a 346-fold excess to coat silver onto latex spheres, and a 24000-fold excess for layering silver onto tin-coated silica nanoparticles."

Demonstrating an approach to developing greener synthesis methods, Reed and his team fabricated silver-coated



Representative TEM image of core-shell nanoparticles prepared using a mixture of formaldehyde and ascorbic acid.

gold nanoparticles suitable for phototherapy. Although formaldehyde still is an essential component of this process, they were able to reduce its amount 100-fold compared to previous processes. Part of this minimization resulted from the discovery that ascorbic acid (vitamin C) can be used as a reducing agent in combination with formaldehyde.

"Understanding this previously overlooked polymer formation is a good starting point for minimizing formaldehyde use in the synthesis of nanoshells and other core-shell nanomaterials" says Reed. "We expect that this will result in greener syntheses and more biocompatible nanomaterials suitable for medical applications."

As Reed and his collaborators show, by designing greener synthetic routes it will become possible to more safely prepare metal nanoparticles without creating hazardous waste. An issue that is particularly important for applications in nonomedicine.

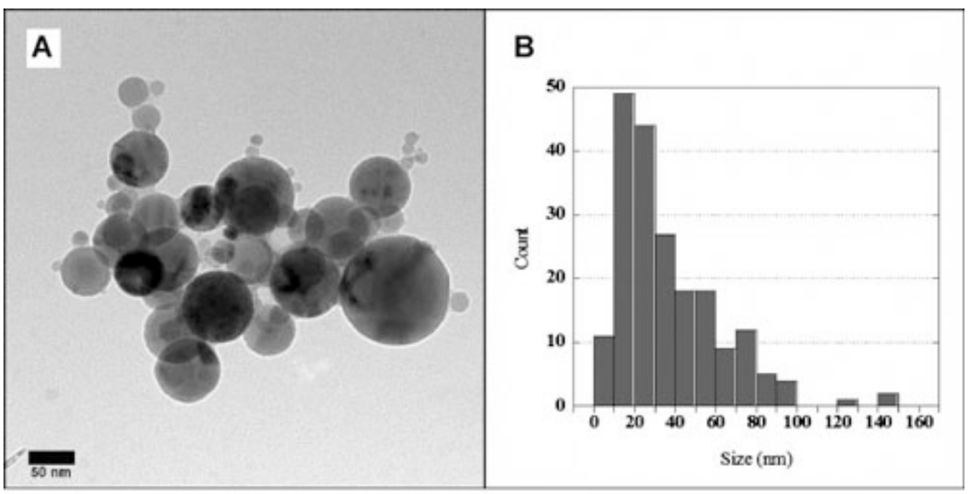
As this particular example shows, this new understanding of formaldehyde will allow for changes in how many types of nanomaterials are synthesized. Nanoparticles prepared using green methods are more likely make it through the regulatory hurdles associated with medical applications.

A new study shows that even the most basic set of data, the nanomaterial characterization information provided by the manufacturer, can't be relied on.

Independent Nanomaterial Characterization Essential For Meaningful Nanomaterial EHS Research

One of the key issues in the young field of nanotoxicology is the lack of standards and definitions. Although there have been some international efforts like the International Alliance for NanoEHS Harmonization (which since its inception in 2008 and an initial January 2009 newsletter, hasn't posted much on its website, though) there still is no coherent international approach to determining if and what risks are posed by what kind of nanotechnology materials. At the core of the problem are the serious challenges that are created when comparing test results and drawing conclusions without adequate standardization and nanomaterial characterization.

What we are currently seeing is that individual research groups are picking certain areas of toxicological concern and forge ahead with – often highly specific – toxicology studies. Unfortunately, for lack of a common standard system, these studies are difficult to compare and sometimes they even appear to contradict each other; a situation that is especially confusing in risk assessments of carbon.



(A) Transmission electron microscopy (TEM) images of commercial aluminum oxide nanoparticles. (B) Size distribution obtained from TEM images.

Exemplifying this set of problems further, a new study shows that even the most basic set of data, the nanomaterial characterization information provided by the manufacturer, can't be relied on – something which shouldn't come as a complete surprise given the existing problems with characterization data. Nevertheless, the study drives home the fact that there is an important need for independent characterization data in environmental health and safety (EHS) studies of purchased nanomaterials.

"What we found in our work is that nanomaterials purchased from commercial sources may not be as well characterized as indicated by the manufacturer," says Vicki H. Grassian, a professor in the Department of Chemistry at the University of Iowa. "For example, it might be stated that a certain nanoparticle is being sold as 30 nm in diameter and, although '30 nm' might be close to the average diameter, there is usually a range of particle sizes that can extend from as much as small as 5 nm to as large as 300 nm."

Reporting their findings in *Environmental Toxicology and Chemistry* ("Commercially manufactured engineered nanomaterials for environmental and health studies: Important insights provided by independent characterization"), among other problems Grassian and first author Heaweon Park also discuss the issue of batch-to-batch variability during the production of nanoparticles and that some nanomaterials which were being sold as having spherical morphology could contain mixed morphologies such as spheres and rods.

Grassian points out that among scientists in fields that have traditionally been involved in nanotechnology, for example physics, chemistry, chemical engineering and materials science, it is well known that materials characterization is really important. However, in fields of study that are more new to the field of nanoscience and nanotechnology, for example scientists who are focused on the environmental and health impacts of nanomaterials, this may not be as well known and understood. This paper was written for that group of scientist. It also underscores many of the reports and recommendations that have been made on the importance of nanomaterials characterization as a component of any environmental and health study.

"Over the past few years, I have heard talks from a number of researchers investigating the environmental and health implications of nanomaterials that had often times not been fully characterized or the characterization was taken off of the vendor's website without verification," says Grassian. "Our paper underscores several points and provides case studies of select examples of the need to provide an independent

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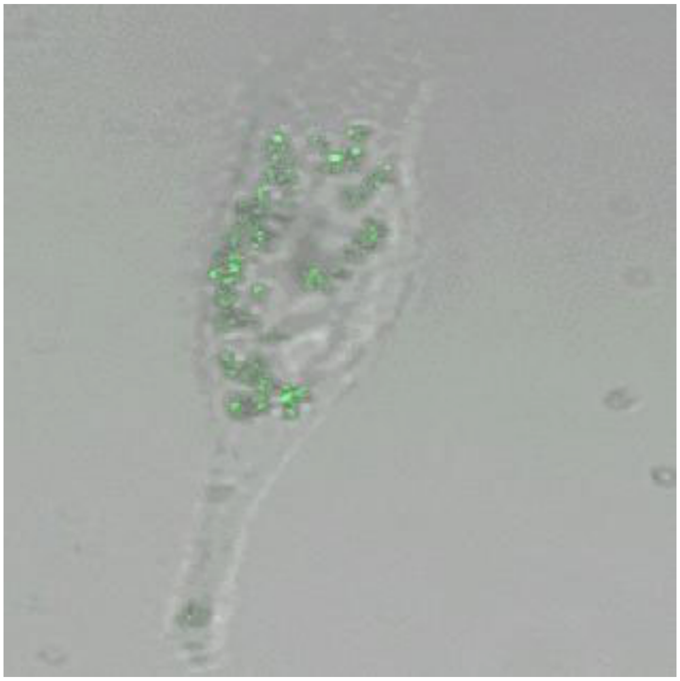

Confocal microscopy image of lactose modified silver nanoparticles in an A549 cancer cell. (Image: Dr. Culha,

3) Although further *in vivo* studies have to be conducted, *in vitro* preliminary results indicate that carbohydrate based ligands can be used for selective targeting of cancer cells either with thermal therapy or delivering/silencing.

For their experiments, the researchers exposed L929 and A549 cancer cells to both naked and modified silver nanoparticles.

"We found that the cellular uptake and cytotoxicity of glucose- or lactose-modified silver nanoparticles were almost at the same level in L929 cells while the levels in A549 cells are rather different" says Culha. "Our results indicate that the use of carbohydrates significantly enhances the cellular uptake of silver nanoparticles into A549 cells. The lactose-modified silver nanoparticles entered the A549 cells at a faster rate. In addition, we observed that the first five hours are important for the cellular uptake of nanoparticles and the nanoparticles were mostly seen localized in the cytoplasm. The cytotoxicity study revealed the presence of glucose, lactose and oligonucleotide or their combinations on the nanoparticle surface might help to diminish the toxicity."

This study suggests that careful evaluation of modified silver nanoparticles may provide new tools that can be used in novel applications in clinical cancer diagnosis and treatment, and other therapeutic applications, in particular: Selective targeting of cancer cells, possible gene silencing through the oligonucleotides attached to silver nanoparticles, heat based killing targeted cell (photo-thermal therapy), cellular and biomedical imaging.

NANOMATERIAL EHS RESEARCH...

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characterization of nanomaterials. The results discussed in this paper will provide an understanding of why independent characterization is important."

The study's results show that the information provided by the manufacturer may be incomplete and nonrepresentative of the entire sample and, in some cases, the data provided are incorrect. Grassian and Park describe three basic areas that can be the cause for these problems:

1) Nanomaterials can be inhomogeneous and unlike molecules with exact formulae, nanomaterials are typically made up of a sample that contains a distribution of sizes.

2) There are no standard methods for measuring properties such as particle size and surface area; thus different methods are used to report these physical properties, some of which are more accurate than others. In fact, much of the equipment needed to characterize nanoscale materials is expensive and/or specialized and therefore not readily available. This is especially true for small startup companies.

3) There is batch-to-batch variability in the manufacturing of nanomaterials and not all batches are characterized.

The conclusion from this is that it is important that independent characterization of commercially manufactured materials be performed in EHS studies of nanomaterials if the results are to be of use to the scientific community.

Grassian notes that in her own work, her group is using an integrated approach of utilizing methods and techniques in surface chemistry, surface science, colloid chemistry, aerosol science, and materials science to characterize nanomaterials so as to better understand the behavior of metal and metal oxide nanoparticles in air and water.

"Through EPA funding, we are investigating the 'state' of metal and metal oxide nanoparticles in water. We are interested in whether metal and metal oxide nanoparticles will be present as isolated nanoparticles, will they aggregate to form larger particles or will they dissolve into ions. This is an important question for a science that is "all about size" as the size regime that needs to be considered or modeled e.g. in water transport models is very different for ions, isolated nanoparticles or aggregates of nanoparticles." The group has published a paper in *Langmuir* which shows that dissolution of isolated iron-containing nanoparticles was enhanced on the nanoscale relative to larger particles but when the nanoscale particles were aggregated the dissolution was quenched ("Nanorod Dissolution Quenched in the Aggregated State").

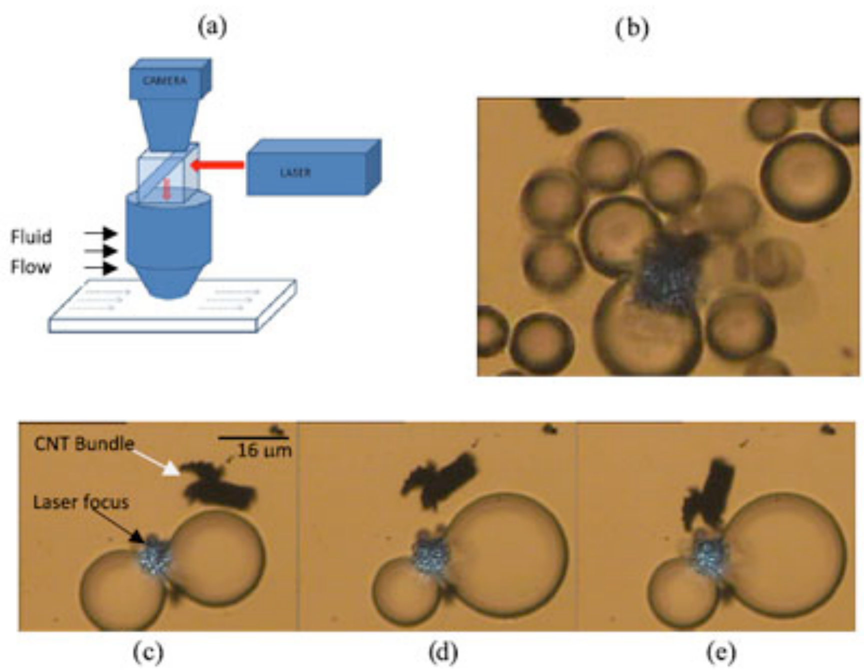
"In NIOSH-funded research, we are trying to better understand the toxicity of inhaled metal and metal oxide nanoparticles, to determine if 'nanodust', i.e. dust from the production of engineered nanomaterials, is particularly hazardous relative to other types of dust that people in general and workers in production facilities in particular are exposed to. In these NIOSH studies, we have partnered with our colleagues in public health to combine careful nanomaterials characterization with inhalation toxicity studies."

Researchers demonstrate novel, optical tweezers based approach to scavenge CNTs from biological fluids such as blood.

Removing Carbon Nanotubes From Body Fluids With Microbubble Scavengers

The toxicity concerns surrounding carbon nanotubes (CNTs) are highly relevant for two reasons: Firstly, as more and more products containing CNTs come to market, there is a chance that free CNTs get released during their life cycles, most likely during production or disposal, and find their way through the environment into the body.

Secondly, and much more pertinent with regard to potential health risks, is the use of CNTs in biological and medical settings. CNTs interesting structural, chemical, electrical, and optical properties are explored by numerous nanomedicine research groups around the world with the goal of drastically improving performance and efficacy of biological detection, imaging, and therapy applications. In many of these envisaged applications, CNTs would be deliberately injected or implanted in the body, for instance as intercellular molecular delivery vehicles.



a) Schematic depiction of the experimental apparatus in which a fluid flow-cell is incorporated into an optical tweezers set-up. (b) Multiple microbubbles formed upon absorption of 1064 nm light by CNT bundles. (c)–(e) Formation of microbubbles and the attraction of a proximate CNT bundle towards the tweezer focal volume. Each of the frames is temporally separated from the preceding one by 40 ms. These snapshots were taken under static conditions wherein the fluid velocity in the flow-cell was zero. The bright patch at the junction of two bubbles is due to laser light scattered from the CNT bundle at the laser focus.

One of the issues researchers have been exploring is how – once the primary role of CNTs in a therapeutic application is fulfilled – they can promote the rapid removal of CNTs from the body, or the dispersal of aggregated clusters to sub-micron size in order to mitigate the harmful effects.

Researchers in India have now demonstrated a novel, optical tweezers based approach to scavenge CNTs from biological fluids such as blood. This method may potentially be of use in scavenging, transporting and dispersal of potentially toxic CNTs in biologically relevant environments.

"We have succeeded in using a low-power infrared laser in an optical tweezers set-up to generate micro-bubbles in flowing, biologically-relevant fluids, including human whole blood," says Deepak Mathur, a Professor in Atomic & Molecular Sciences at the Tata Institute of Fundamental Research in Mumbai. "These micro-bubbles are formed upon very localized heating of small bundles of carbon nanotubes that are suspended in the flowing fluid. The localized nature of the heating causes enormous temperature gradients to be set up in the fluid and these, in turn, set up surface tension gradients that give rise to complex flow patterns in the immediate vicinity of the microbubble. A consequence of this is that proximate CNTs are attracted towards the microbubble and appear to "adhere" to the bubble surface."

The physical manipulation of such CNT-encrusted bubbles enables the physical manipulation of CNTs by optical means – something that is generally not feasible under normal circumstances as it is not possible to optically trap CNTs using infrared laser light. As a matter of fact, CNTs are vigorously repelled from the focal volume of a tightly focused infrared laser beam; a dramatic illustration of this, along with a scientific rationalization, has recently been published by Mathur's group ("Bright visible emission from carbon nanotubes spatially constrained on a micro-bubble").

By extending this earlier work, the Tata Institute team went on to examine the formation of microbubbles in a variety of biologically relevant fluids, including human whole blood; the adhesion of proximate CNTs onto the bubbles; the optical micro-manipulation of the cargo-laden bubbles through the fluid; and dispersal of CNT bundles by controlled explosion of CNT-encrusted microbubbles. They report their findings in the May 20, 2010 online edition of *Nanotechnology* ("Optical-tweezer-induced microbubbles as scavengers of carbon nanotubes").

"We managed to trap carbon nanotubes in fluid flow and demonstrated scavenging action by collecting the nanotubes onto an optically trapped microbubble and then moving the CNT-encrusted bubble both along and against the flow" explains Mathur.

The team also demonstrates shattering of a large cluster of CNTs by exploding a bubble. This leads to the possibility

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of using microbubbles as CNT scavengers in biomedical applications, that is, the use of microbubbles as a vehicle to aid CNT removal from the body once their intended task of drug-delivery or tissue-ablation has been completed.

Mathur points out that a key feature of his team's experiments is the use of very low power (5 mW) light in the infrared region (1064 nm wavelength) obtained from a continuous wave laser.

"Both the wavelength and power present obvious advantages from the point of view of potential applications in biomedical environments," he says. "We also found that CNT-encrusted microbubbles can be made to emit copious amounts of white (broadband) light. There may well be applications for such broadband light for photodynamic therapy type of work but conducted in spatially localized fashion, in physiological conditions, under full optical control."

Investigating Mammal Cells' Nanoparticle Uptake

A Taiwan research team has developed a new approach for investigating the amount of nano-/microparticles taken up by mammalian cells.

Conventionally these tiny particles have been measured using certain types of mass spectrometry (an analytical technique for the determination of the elemental composition of a sample or molecule) including Inductively Coupled Plasma Atomic Emission Spectroscopy and Inductively Coupled Plasma Mass Spectrometry (ICP-MS). However, these methods of measurement are limited to elemental particles such as gold nanoparticles.

For this study, scientists used a different type of spectrometer called the Charge-Monitoring Mass Spectrometer (CMS), a device which was itself developed by a group at the GRC and the Institute of Atomic and Molecular Sciences at Academia Sinica in 2007 to measure single cancer cells at higher speeds. This time, researchers from the GRC Physical and Computational Genomics group used this recently-developed device to measure the masses of cells of nano-/microparticle, a novel approach for investigating the amount of nano-/microparticle uptake into mammalian cells.

The group's findings indicate that the CMS is an adequate tool for time-resolved measurements of nanogold uptake by cells. They also found that the CMS could measure particles over a larger size range from 30nm to 250 nm. In addition, as the CMS only takes two-steps to examine the nanogold and the ICP-MS takes five-steps, the CMS analysis is more time-efficient. Most importantly, however, the CMS will also be able to measure non-metal nano particles, including polymeric nanoparticles, carbon nanotubes, diamond nanoparticles, viruses, micelles and liposomes in addition to elemental particles.

The research was published online in *Angewandte Chemie* ("Quantitative Measurement of Nano-/Microparticle Endocytosis by Cell Mass Spectrometry").

Upcoming Events

Looking At The Risky Side Of Nano

Nanotoxicology 2010
June 2-4, 2010, Edinburgh (UK)
The conference will take place over 3 days, and will be divided into sections that allow focus on specific types of nanomaterials.

2nd iNTeg-Risk Conference 2010
June 14-18, 2010, Stuttgart (Germany)
Dealing with multiple and interconnected emerging risks.

Greener Nano 2010
June 16-18, 2010, Portland, OR (USA)
GN10 will feature advances in the design and production of greener nanomaterials.

XII International Conress of Toxicology
July 19-23, 2010, Barcelona (Spain)
The Congress will encourage the interaction between Academia, Industry, Regulators, Expert in Human (clinical and epidemiology) and Environmental Toxicology.

NIOSH Conference: Nanomaterials and Worker Health
July 21-23, 2010, Keystone, CO (USA)
The aim of the conference is to identify gaps in information and address questions focusing on occupational health surveillance, exposure registries, and epidemiologic research involving nanotechnology workers.

Second Nanosafety Autumn School
October 4-8, 2010, Venice (Italy)
The school will focus on emerging nanosafety aspects, concerning human and environmental exposure to engineered nanoparticles. The second cycle of the Nanosafety Autumn School will provide the update of the state-of-the-art on scientific knowledge and technical tools available for an integrated assessment of nanotechnology products.

Nordic Tour 2010: Health Effects and Risks of Nanoparticles
October 27 – November 16, 2010, various locations
The goal of this seminar series is to introduce the latest in nanotechnology to a wider audience and to discuss the possible health risks. Specialists in the area will gain from attending and hearing of the latest developments in the area. Each one-day seminar is comprised of morning sessions, which will be similar in each Nordic country.

NanoSafe 2010
November 16-18, 2010, Grenoble (France)
The objectives of the conference will be to make available the major progresses and future trends in the domain of the safe production and use of nanomaterials.

In Short – Papers, Initiatives & Updates

INITIATIVE: OECD Publishes its 2009-2012 Safety of Nanomaterials Program

The OECD program on the safety of manufactured nanomaterials aims to ensure that the approach to hazard, exposure and risk assessment is of a high, science-based, and internationally harmonized standard. This program promotes international co-operation on the human health and environmental safety of manufactured nanomaterials, and involves safety testing and risk assessment of manufactured nanomaterials. This document compiles the operational plans (2009-2012) for the implementation of each project of the Working Party on Manufactured Nanomaterials (WPMN). At the 6th meeting of the WPMN (October 2009), the operational plans 2009-2012 for each project were proposed and discussed. This document compiles the operational plans, which include information on their respective objectives, expected outputs, and linkages with other OECD bodies and other activities. The document can be downloaded (pdf) from the OECD website.

REPORT: Risk Assessment of Manufactured Nanomaterials in a Regulatory Context

At the 5th meeting of the Working Party on Manufactured Nanomaterials (WPMN), it was agreed to hold an OECD Workshop on Risk Assessment of Manufactured Nanomaterials in a Regulatory Context. The objectives of the workshop were: 1) to obtain expert input into the critical issues specific for the risk assessment of manufactured nanomaterials in a regulatory context; 2) to identify possible approaches for risk assessment based on the current state of knowledge; and 3) to identify issues which may be addressed through the sponsorship program. The workshop took place September 16th – 18th, 2009 in Washington D.C. and was cohosted by the Business and Industry Advisory Committee (BIAC) and the Society for Risk Analysis. Seventy participants representing OECD member countries, non-member economies, industries, academia and environmental NGOs attended. The document can be downloaded (pdf) from the OECD website.

REPORT: Questionnaire on Regulatory Regimes on Manufactured Nanomaterials

This document presents the information obtained from the WPMN Questionnaire on Regulatory Regimes for Manufactured Nanomaterials. Twenty-four responses were received from nine jurisdictions for Legislations covering a wide variety of chemical substances and/or products including industrial chemicals, pesticides, fertilizers, agricultural compounds, fuels and fuel additives, food and food additives and veterinary medicines. Other Legislations reported included those covering occupational health and safety, consumer products, control of major accidents and labeling and packaging. Although a wide variety of sectors are represented in the data obtained, it is noted that responses from the industrial chemical sector were in the majority for those Legislations reporting pre-market and/or post-market registration/notification and assessment. The document can be downloaded (pdf) from the OECD website.

INITIATIVE: NanoSafety Consortium for Carbon

12 leading companies involved in the commercialization of carbon nanomaterials and products announced the formation of the NanoSafety Consortium for Carbon ("NCC") to address global legal, regulatory, environmental, health, and safety issues related to the responsible commercialization of their products. Their website is designed to inform the public about NCC's activities.

PAPER: Interaction Between Nanoparticles And Cytokine Proteins

The aim of this study was to investigate whether nanoparticles which may enter the body could adsorb proteins and whether this interaction affects both the particle and the protein function. The results suggest that nanoparticle–protein interaction results both in a decrease in protein function and particle activity in the cellular assays tested and this is currently being investigated.
doi: 10.1088/0957-4484/21/21/215104

REPORT: Emerging Risks and New Patterns of Prevention in a Changing World of Work

As every year, SafeWork, the Programme on Safety and Health at Work and the Environment of the International Labour Office (ILO), has prepared a booklet to serve as a background to this theme. This year, it discusses the current global challenges and the new context of occupational safety and health practice. It highlights technological advance, emerging workplace risks, and changing patterns of employment and workforce.

PAPER: Recovery of Nanoparticles Made Easy

Here is demonstrated a novel approach to reversible control over nanoparticle stability, permitting facile recovery for the reuse of inorganic nanoparticles. For the first time, the separation of nanoparticles is achieved by suspending the nanostructures in a background-supporting colloidal fluid, which itself shows a liquid-liquid critical-type phase transition at a temperature instead of using a normal molecular solvent. doi: 10.1021/la100111b

PAPER: Investigations on the Structural Damage in Human Erythrocytes Exposed to Silver, Gold, and Platinum Nanoparticles

Human erythrocytes or red blood cells, which constitute 99% of blood cells, perform an important function of oxygen transport and can be exposed to nanoparticles entering into the human body during therapeutical applications involving such nanoparticles. The findings suggest that platinum and gold nanoparticles are haemocompatible compared to silver nanoparticles. Erythrocytes exhibit significant lysis, haemagglutination, membrane damage, detrimental morphological variation, and cytoskeletal distortions following exposure to silver nanoparticles at a concentration of 100mg per mL. doi: 10.1002/adfm.200901846

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OPTIMIZING THE BENEFITS OF NANOTECHNOLOGY WHILE MINIMIZING AND CONTROLLING THE RISKS

The nanoRISK newsletter is dedicated to providing objective and accurate information about critical issues and developments related to the risks arising from engineered nanomaterials. nanoRISK appears bi-monthly (ISSN 1931-6941). For a complete list of all published nanoRISK newsletters please go to www.nanorisk.org.

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