New method quickly IDs nanomaterials that can cause oxidative damage to cells

May 2 2012, By Jennifer Marcus

Engineered nanomaterials, prized for their unique semiconducting properties, are already prevalent in everyday consumer products — from sunscreens, cosmetics and paints to textiles and solar batteries — and economic forecasters are predicting the industry will grow into $1 trillion business in the next few years. But how safe are these materials?

Because the semiconductor properties of metal-oxide nanomaterials could potentially translate into health hazards for humans, animals and the environment, it is imperative, researchers say, to develop a method for rapidly testing these materials to determine the potential hazards and take appropriate preventative action.

To that end, UCLA researchers and their colleagues have developed a novel screening technology that allows large batches of these metal-oxide nanomaterials to be assessed quickly, based on their ability to trigger certain biological responses in cells as a result of their semiconductor properties. The research is published in the journal ACS Nano.

Just as semiconductors can inject or extract electrons from industrial materials, semiconducting metal-oxide nanomaterials can have an electron-transfer effect when they come into contact with human cells that contain electronically active molecules, the researchers found. And while these oxidation–reduction reactions are helpful in industry, when they occur in the body they have the potential to generate oxygen radicals, which are highly reactive oxygen molecules that damage cells, triggering acute inflammation in the lungs of exposed humans and animals.

In a key finding, the research team predicted that metal-oxide nanomaterials and electronically active molecules in the body must have similar electron energy levels — called band-gap energy in the case of the nanomaterial — for this hazardous electron transfer to occur and oxidative damage to result.

Based on this prediction, the researchers screened 24 metal-oxide nanoparticles to determine which were most likely to lead to toxicity under real-life exposure. Using a high-throughput screening assay (performed by robotic equipment and an automated image-capture microscope), they tested the two dozen materials on a variety of cell types in a matter of a few hours and found that six of them — those that had previously met the researchers' predictive criteria for being toxic based on their band-gap energy — led to oxidative damage in cells.

The team then tested the nanomaterials in well-orchestrated animal studies and found that only those materials that had led to oxidative damage in cells were capable of generating inflammation in the lungs of mice, confirming the researchers' band-gap hypothesis.

"The ability to make such predictions, starting with cells in a test tube, and extrapolating the results to intact animals and humans exposed to potentially hazardous metal oxides, is a huge step forward in the safety screening of nanomaterials," said senior author Dr. Andre Nel, chief of the division of nanomedicine at the David Geffen School of Medicine at UCLA and the California NanoSystems Institute at UCLA and director of the University of California Center for Environmental Implications of Nanotechnology.

According to the researchers, this new safety-assessment technology has the potential to replace traditional testing, which is currently performed one material at a time in labor-intensive animal studies using a "wait-and-see" approach that doesn't reveal why the implicated nanomaterials could be hazardous. The UCLA team's predictive approach and screening technique could speed up the ability to assess large numbers of emerging new nanomaterials rather than waiting for their toxicological potential to become manifest before action is taken.

"Being able to integrate metal-oxide electronic properties into a predictive and high-throughput scientific platform in this work could play an important role in advancing nanomaterial safety testing in the 21st century to a preventative strategy, rather than waiting for problems to emerge," Nel said.

Another major advantage of an approach based on the assessment of nanomaterials' properties is that one can identify those properties that could potentially be redesigned to make the materials less hazardous, the researchers said.

The implementation of high-throughput screening is also leading to the development of computer tools that assist in prediction-making; in the future, much of the safety assessment of nanomaterials could be carried out using computer programs that perform smart modeling and simulation procedures based on electronic properties.

"We can now further refine the testing of an important class of engineered nanomaterials to the level where regulatory agencies can make use of our predictions and testing methods," said Haiyuan Zhang, a postdoctoral research scholar at the Center for Environmental Implicatioons of Nanotechnology at UCLA's CNSI and the lead author of the study.