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Gold nanoparticles and catalytic DNA produce colormetric lead sensor

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CHAMPAIGN, Ill. — Detecting the presence of hazardous lead paint could become as simple as pressing a piece of paper against a wall and noting a color change.

Scientists at the University of Illinois at Urbana-Champaign have developed a highly sensitive and selective biosensor that functions in much the same fashion as a strip of litmus paper. The researchers report their discovery in a paper that has been accepted for publication in the Journal of the American Chemical Society, and posted on its Web site. The colorimetric sensor is based upon DNA-gold nanoparticle chemistry, and could be used for sensing a variety of environmental contaminants.

Using gold nanoparticles laced with DNA, Illinois chemistry professor Yi Lu and graduate student Juewen Liu are able to hybridize the nanoparticles into aggregate clusters that have a characteristic blue color. In the presence of a specific metal ion, the catalytic DNA will break off individual gold nanoparticles, resulting in a dramatic color shift to red. The intensity of the color depends upon the initial concentration of contaminant metal ions.

By applying the DNA-gold nanoparticle solution to a substrate, the researchers can create a biosensor that functions in the same manner as litmus paper. "These simple colorimetric sensors eliminate the need for additional instrumentation, and are well suited for on-site, real-time detection and quantification," Lu said.

To obtain the necessary catalytic DNA for their biosensors, Lu and Liu use a combinatorial approach called in vitro selection. Simple and cost-effective, the selection process can sample a very large pool of DNA (up to 1,000 trillion molecules), amplify the desired sequence by the polymerase chain reaction and introduce mutations to improve performance.

While most DNA is double stranded, the catalytic DNA Lu and Liu use has a single strand that can wrap around like a protein. In that single strand, the researchers fashion a specific binding site – a kind of pocket that can only accommodate the metal ion of choice.

"In addition to lead, the selection process can be customized to select catalytic DNA that would be active for other metal ions, such as mercury, cadmium and zinc," Lu said.

The dynamic response of the sensor solution can be tuned over a wide range by introducing inactive catalytic DNA into the mix, Lu said. Incorporating more of the inactive DNA will shift the sensor's sensitivity to higher contaminant concentrations without saturation. By using various combinations of active and inactive catalytic DNA, the sensor could be packaged as a colorimetric array to detect different contaminant concentrations.

"There are many old houses around the world that still contain leaded paint," Lu said. "According to the U.S. Environmental Protection Agency, leaded paint test kits that are currently available have shown high rates of both false positive and false negative results when compared to laboratory results. Our catalytic DNA-gold nanoparticle sensor can overcome these shortcomings."

Lu is also working with colleagues at the National Science Foundation's Nanoscale Science and Engineering Center for Directed Assembly of Nanostructures (a partnership among Illinois, the Rensselaer Polytechnic Institute and the Los Alamos National Laboratory) to further develop the biosensor technology. For example, Lu is working with Illinois collaborators Paul Braun and Gerard Wong to produce nanoparticles from different materials.

"Our ultimate goal is to develop a microchip array with different color schemes for simultaneously detecting many different metal ions," Lu said.

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