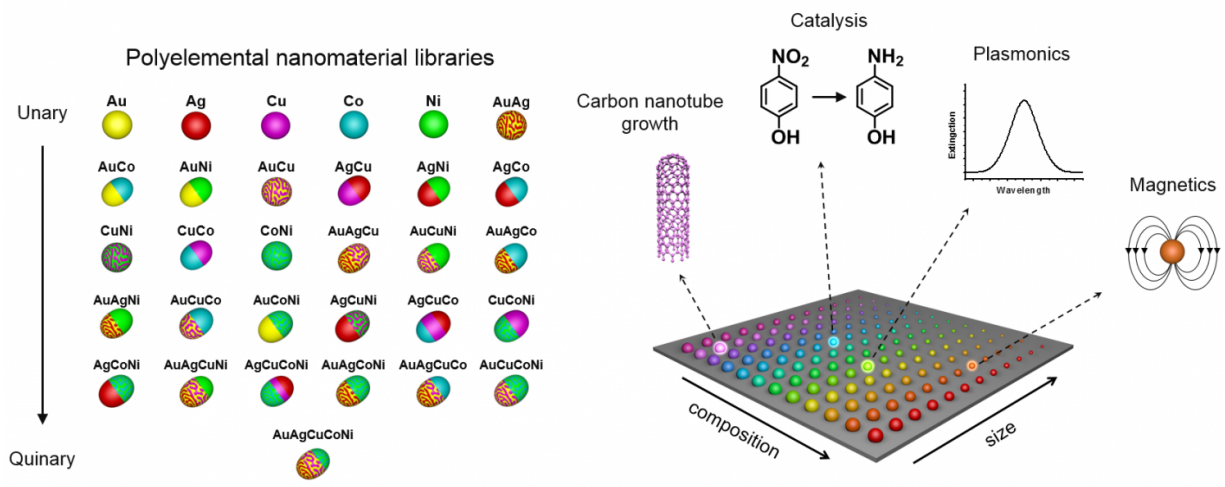


# Nanoscientists develop the 'ultimate discovery tool'

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A combinatorial library of polyelemental nanoparticles was developed using Dip-Pen Nanolithography. This novel nanoparticle library opens up a new field of nanocombinatorics for rapid screening of nanomaterials for a multitude of properties. Credit: Peng-Cheng Chen/James Hedrick

The discovery power of the gene chip is coming to nanotechnology. A Northwestern University research team is developing a tool to rapidly test millions and perhaps even billions or more different nanoparticles at one time to zero in on the best particle for a specific use.

When materials are miniaturized, their properties—optical, structural, electrical, mechanical and chemical—change, offering new possibilities.

But determining what nanoparticle size and composition are best for a given application, such as catalysts, biodiagnostic labels, pharmaceuticals and electronic devices, is a daunting task.

"As scientists, we've only just begun to investigate what materials can be made on the [nanoscale](#)," said Northwestern's Chad A. Mirkin, a world leader in nanotechnology research and its application, who led the study. "Screening a million potentially useful nanoparticles, for example, could take several lifetimes. Once optimized, our tool will enable researchers to pick the winner much faster than conventional methods. We have the ultimate discovery tool."

Using a Northwestern technique that deposits materials on a surface, Mirkin and his team figured out how to make combinatorial libraries of nanoparticles in a very controlled way. (A combinatorial library is a collection of systematically varied structures encoded at specific sites on a surface.) Their study will be published June 24 by the journal *Science*.

The nanoparticle libraries are much like a gene chip, Mirkin says, where thousands of different spots of DNA are used to identify the presence of a disease or toxin. Thousands of reactions can be done simultaneously, providing results in just a few hours. Similarly, Mirkin and his team's libraries will enable scientists to rapidly make and screen millions to billions of nanoparticles of different compositions and sizes for desirable physical and chemical properties.

"The ability to make libraries of nanoparticles will open a new field of nanocombinatorics, where size—on a scale that matters—and composition become tunable parameters," Mirkin said. "This is a powerful approach to discovery science."

Mirkin is the George B. Rathmann Professor of Chemistry in the Weinberg College of Arts and Sciences and founding director of

Northwestern's International Institute for Nanotechnology.

"I liken our combinatorial nanopatterning approach to providing a broad palette of bold colors to an artist who previously had been working with a handful of dull and pale black, white and grey pastels," said co-author Vinayak P. Dravid, the Abraham Harris Professor of Materials Science and Engineering in the McCormick School of Engineering.

Using five metallic elements—gold, silver, cobalt, copper and nickel—Mirkin and his team developed an array of unique structures by varying every elemental combination. In previous work, the researchers had shown that particle diameter also can be varied deliberately on the 1- to 100-nanometer length scale.

Some of the compositions can be found in nature, but more than half of them have never existed before on Earth. And when pictured using high-powered imaging techniques, the nanoparticles appear like an array of colorful Easter eggs, each compositional element contributing to the palette.

To build the combinatorial libraries, Mirkin and his team used Dip-Pen Nanolithography, a technique developed at Northwestern in 1999, to deposit onto a surface individual polymer "dots," each loaded with different metal salts of interest. The researchers then heated the polymer dots, reducing the salts to metal atoms and forming a single nanoparticle. The size of the polymer dot can be varied to change the size of the final nanoparticle.

This control of both size and composition of nanoparticles is very important, Mirkin stressed. Having demonstrated control, the researchers used the tool to systematically generate a library of 31 nanostructures using the five different metals.

To help analyze the complex elemental compositions and size/shape of the nanoparticles down to the sub-nanometer scale, the team turned to Dravid, Mirkin's longtime friend and collaborator. Dravid, founding director of Northwestern's NUANCE Center, contributed his expertise and the advanced electron microscopes of NUANCE to spatially map the compositional trajectories of the combinatorial nanoparticles.

Now, scientists can begin to study these nanoparticles as well as build other useful combinatorial libraries consisting of billions of structures that subtly differ in size and composition. These structures may become the next materials that power fuel cells, efficiently harvest solar energy and convert it into useful fuels, and catalyze reactions that take low-value feedstocks from the petroleum industry and turn them into high-value products useful in the chemical and pharmaceutical industries.

**More information:** Chad A. Mirkin et al, "Polyelemental nanoparticle libraries," *Science* (2016).

Provided by Northwestern University

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