Nanoparticles to kill cancer cells with heat

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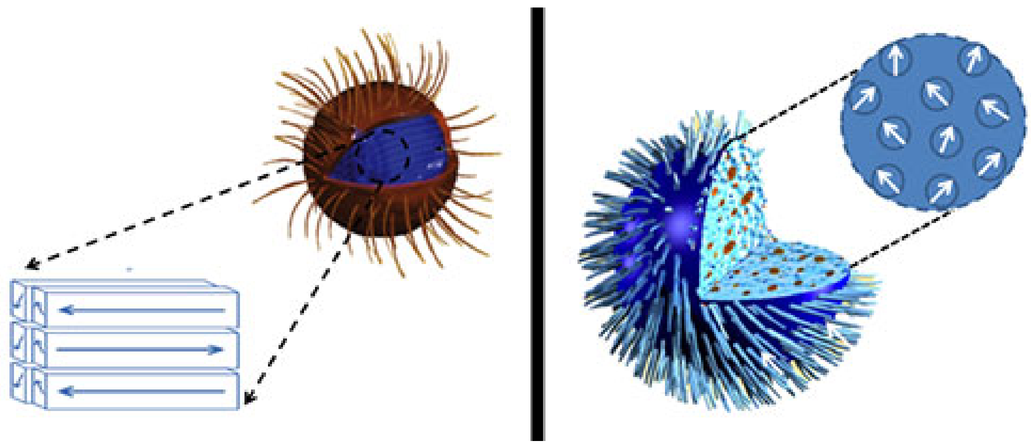

Iron oxide nanoparticles with a neatly-stacked internal structure (left) need a stronger magnetic field than expected to heat up, while those with a more haphazard arrangement heat up more quickly, even under a weak field. The findings, which run contrary to expectations, could affect which nanoparticles are chosen to treat certain types of cancer. Credit: NIST

Heat may be the key to killing certain types of cancer, and new research from a team including National Institute of Standards and Technology (NIST) scientists has yielded unexpected results that should help optimize the design of magnetic nanoparticles that can be used to deliver heat directly to cancerous tumors.

When combined with other treatments such as radiotherapy or chemotherapy, heat applied directly to tumors helps increase the effectiveness of those types of treatments, and it reduces the necessary dose of chemicals or radiation.

This is where magnetic nanoparticles come in. These balls of iron oxide, just a few tens of nanometers in diameter, heat up when exposed to a powerful magnetic field. Their purpose is to bring heat directly to the tumors. Materials research, performed in part at the NIST Center for Neutron Research (NCNR), revealed magnetic behavior that proved counterintuitive to the scientific team—a finding that will affect which particles are chosen for a particular treatment.

Choosing the right kind of particles is important because, depending on their structure, they deliver a different dose of heat to the cancer. Some heat up quickly at first, while others require a stronger magnetic field to get going but ultimately deliver more heat.

"You want to design your nanoparticles for the kind of cancer you're treating—whether it's localized or spread through the body," says NIST's Cindi Dennis. "The amount of electricity needed to create the field can be 100 kilowatts or more. That costs a lot of money, so we want to help engineer particles that will do the best job."

Although the magnetic field applied for hyperthermia is 100 to 1,000 times weaker that that typically used for MRI imaging, Dennis explains, it's an alternating field (the magnetic polarity switches rapidly), which requires a lot more power.

With colleagues at Johns Hopkins University School of Medicine, the University of Manitoba and in industry, the team studied two kinds of iron-oxide nanoparticles, each of which has a different internal structure. In one, iron-oxide crystals are stacked neatly, like bricks in a wall; in the other, the arrangement is more haphazard, like balls in a playpen. While subjecting both types to an alternating magnetic field, the team discovered that the neatly-stacked ones needed a stronger field than expected to heat up, while the haphazard particles got hot more quickly, even when the field was still weak.

It took a trip to the NCNR to figure out why these nanoparticles acted strangely. The neutron experiments showed regions of different sizes and shapes in the particles. Within each region, the so-called magnetic moments are uniform and point in the same direction. But the regions themselves did not align with each other. This unexpected behavior among regions, it turns out, profoundly affects the nanoparticles' response to a magnetic field."

Materials often behave unexpectedly on the nanoscale, and here we have another example of that," Dennis says. "We expect it will help design better cancer treatments. A localized cancer could be treated with nanoparticles that give out lots of heat right away because the field can be focused on a small region."

More information: "Internal magnetic structure of nanoparticles dominates time-dependent relaxation processes in a magnetic field." *Advanced Functional Materials*. Published online June 2, 2015. DOI: 10.1002/adfm.201500405

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