Fighting cancer: Scientists develop a theory of 'collective behavior' of nanoparticles

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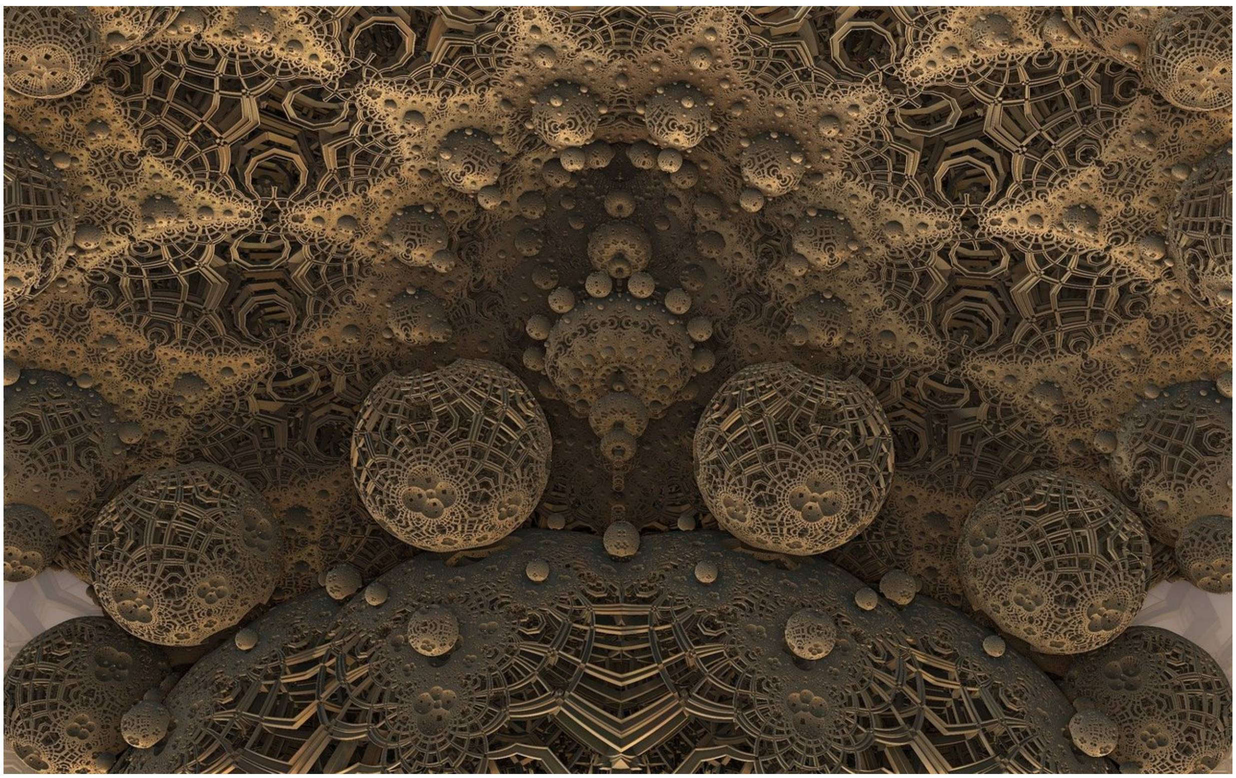

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A computer experiment conducted by the scientists of Ural Federal University together with colleagues from Edinburgh showed that it is incorrect to describe the behavior of magnetic nanoparticles that provide cell heating by the sum of reactions with each of them: particles constantly interact, and their "collective behavior" produces a unique effect. The scientists have published the research output in the *Physical Review E* journal.

"The computer simulation technique is cheaper than laboratory research, and we know all the parameters of each particle and all the influencing factors," Alexei Ivanov, UrFU professor, says.

In the framework of the study, the magnetic particles (magnetic materials' particles that are one hundred times smaller than the thinnest human hair) were considered as an essential element in the cancer treatment process, when a tumor is locally exposed to heat while at the same time a patient is undergoing chemotherapy.

"By exposing the particles to an external magnetic field, one can "transport" medications precisely to a specific part of the body," Ivanov explains. "If you put such particles in a special substance absorbed selectively by cancer cells, an X-ray will give a contrasting picture of the tissue affected by the tumor."

An alternating magnetic field formed by a source of alternating electrical current absorbs energy and causes particles to rotate faster and thereby provide heating. The intensity of the particles' response depends on various factors: the power of the magnetic field radiator, the frequency of its rotation, the size of the nanoparticles, how they stick to each other, etc.

UrFU professor and his colleague Philip Camp, a professor at the University of Edinburgh, predict the reaction of a whole "team" of magnetic nanoparticles to an external source of magnetic field of a particular power and frequency, using computer modeling. The Russian scientist was responsible for the theoretical underpinning of the experiment, and his colleague from Scotland for its practical execution

on a supercomputer. This research was supported by the Russian Science Foundation grant.

According to the classical Debye theory from 1923, the "collective behavior" of particles is described by the sum of the reactions of each of the particles put together in an "ensemble." Computer experiments led Ivanov and Camp to the assumption that this is a misconception: particles constantly interact, influence each other and their "collective behavior" produces a unique effect and does not boil down to the sum of "individual" reactions.

"At a certain frequency of an alternating magnetic field, resonance occurs: the maximum response of nanoparticles, the maximum absorption of energy by them and, consequently, the maximum heating," Ivanov adds. "As a result of a computer experiment, we identified two such maxima, for large and small particles, for media with a predominance of the former and the latter. If we applied the Debye formulas in calculating the period and intensity of local heating of the tumor, we would give the opposite prediction and would not get the best necessary effect. Our model shows that, in comparison with the classical Debye formula, the heating maxima should be an order of magnitude smaller, and the effect obtained should be twice as large."

Now Alexey Ivanov and his colleagues from the German Technical University of Braunschweig are planning to do a series of laboratory experiments to confirm the theory.

More information: Alexey O. Ivanov et al, Theory of the dynamic magnetic susceptibility of ferrofluids, *Physical Review E* (2018). DOI: 10.1103/PhysRevE.98.050602

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