Discovering the universal relationship between physical properties and fractal dimensions

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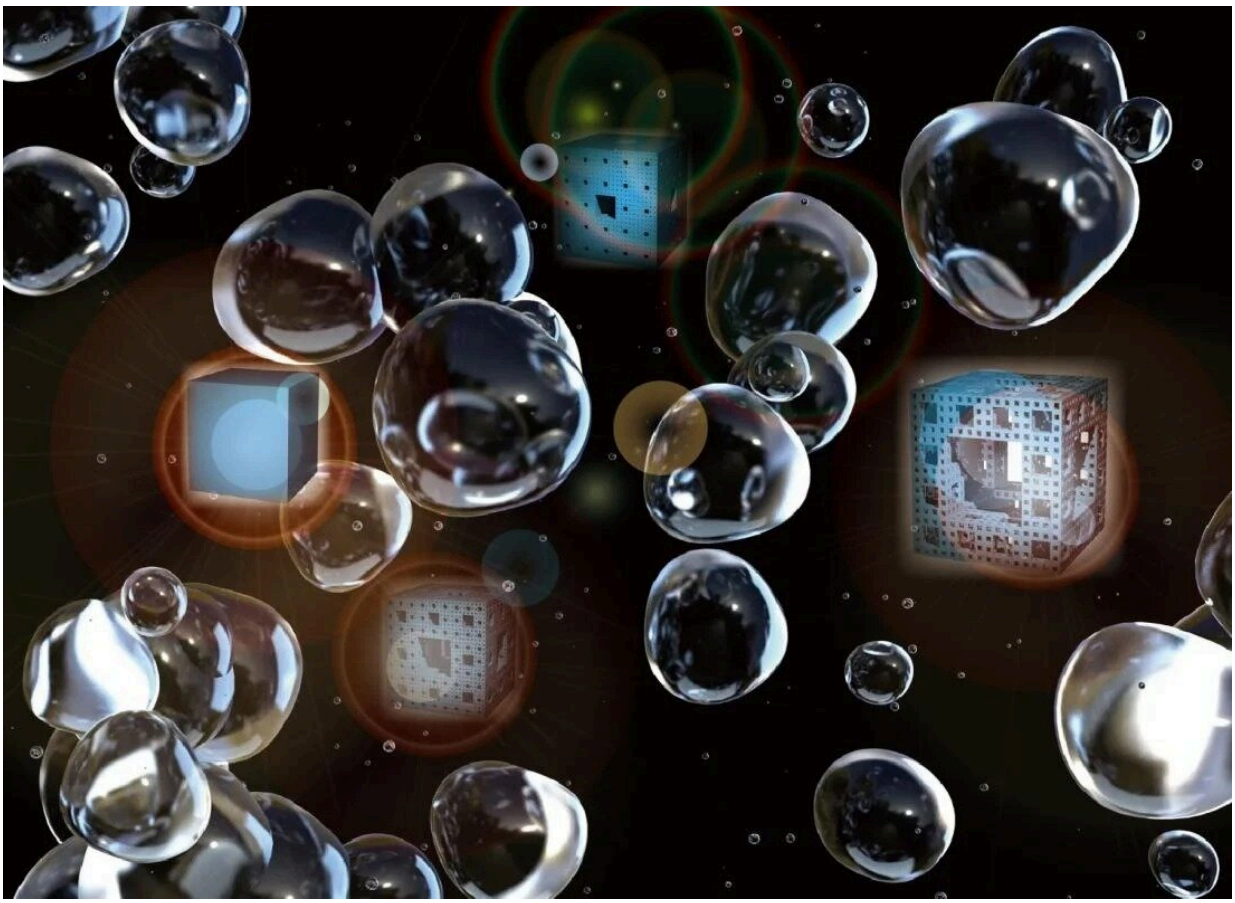


Fractal bodies in bubbles / The word “fractal” originates from “fractional”. Few could imagine fractal bodies with non-integer dimensions between two-dimensional (a plane) and three-dimensional (a cube, for example) figures. However, there are many fractal bodies around us such as clouds and coastlines, indicating fractal shapes are the most natural and fundamental forms of

existence in nature. Our finding of the universal relationship between physical properties and sample dimensions indicates that the dimensions also govern all kinds of physical and mechanical properties as a principle of nature. Credit: Toshio Naito, Ehime University

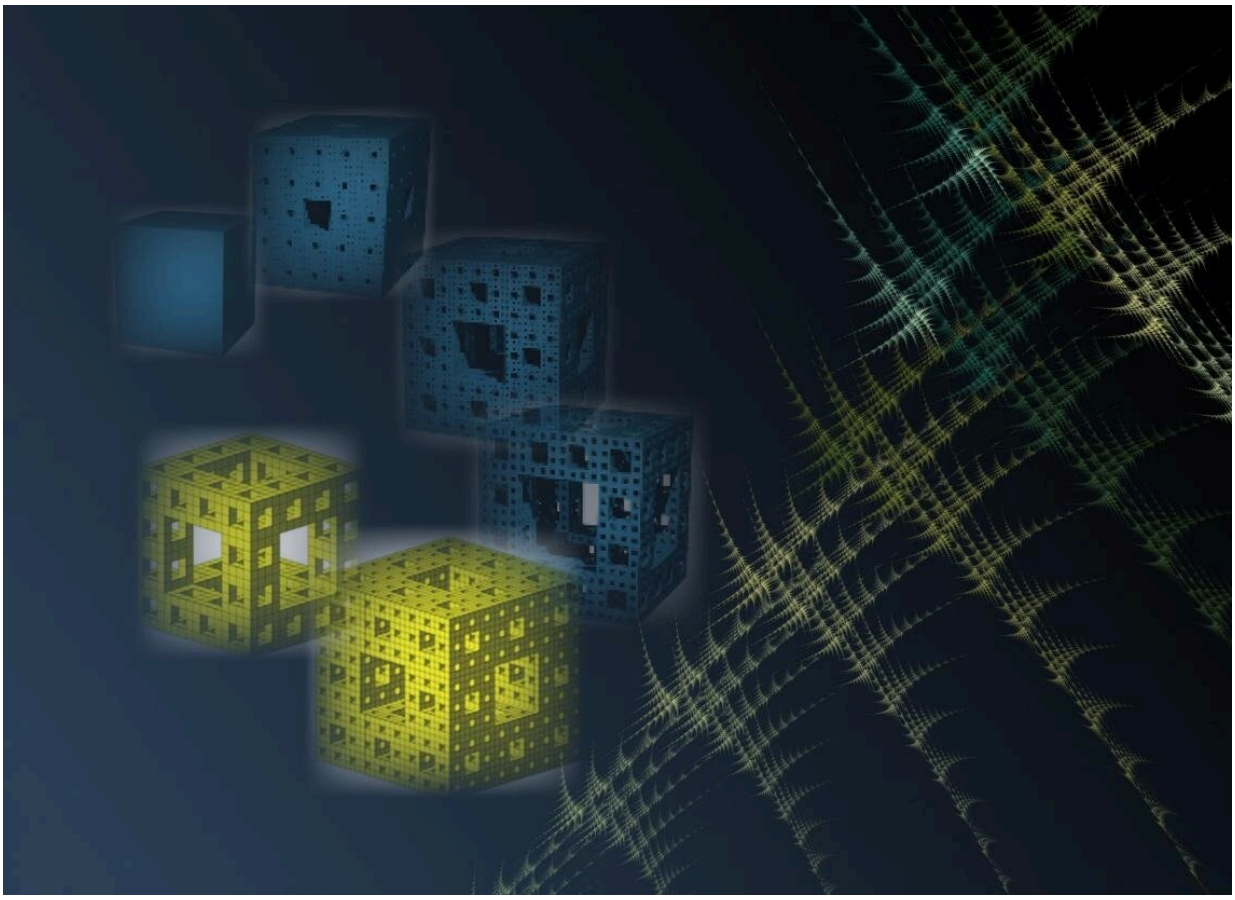
It has been known that nanoparticles, for example, exhibit quite different properties from the bulk samples of the same materials. Yet nobody knows why. Ehime University researchers discovered a control method of the fractal dimensions of any solid sample, enabling systematic and detailed examination of various physical properties of samples with different dimensions. As a result, they discovered the universal relationship between physical properties and fractal dimensions.

From heavenly bodies to human cells, everything in this universe possesses finite dimensions in three directions in space; everything in the real world is three-dimensional, according to Euclidean geometry. However thin or small a nanoscale object is, the dimensions can not be altered. Accordingly, it has been firmly believed that nobody could change or control the dimensions of real matter. However, by instead paying attention to fractal dimensions, dimension control is possible in a facile way.

The researchers prepared a series of mixed powder samples with the same material but with different fractal dimensions, corresponding to a different mixed ratio between the substance of interest and wax. Using these samples, they examined their structures and physical properties in detail. They also examined materials with different properties to confirm the universality of the results. With the aid of theoretical calculation based on original models and methods, they discovered that there is a universal relationship between the sample fractal dimensions and their

physical properties, such as electrical conduction and magnetism. This could be a newly unveiled principle of nature, in which the dimension of matter governs all its physical and mechanical properties.

The stereoscopically arranged cubes are fractal bodies with different dimensions. The largest yellow body belongs to 2.5-dimensional bodies, while the smallest blue body belongs to three-dimensional bodies. The reduction in the fractal dimension corresponds to an increase of the void spaces in the bodies. In our study, the void spaces are filled with special wax which plays no role in the physical properties. Credit: Toshio Naito, Ehime University



The series of blue and yellow fractal bodies possess slightly different fractal dimensions from each other. The largest yellow body belongs to 2.5-dimensional bodies, while the smallest blue body belongs to three-dimensional bodies. The reduction in the fractal dimension corresponds to an increase of the void spaces in the bodies. In our study, the void spaces are filled with special wax which plays no role in the physical properties. Credit: Toshio Naito, Ehime University

More information: Toshio Naito et al, The universal relationship between sample dimensions and cooperative phenomena: effects of fractal dimension on the electronic properties of high-TC cuprate observed using electron spin resonance, *Physical Chemistry Chemical Physics* (2021). DOI: 10.1039/D1CP04709D

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