Fractal Structures and Their Functional Properties

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1 Introduction

Fractal is mathematical (geometrical) concept[1], and has been used for long time as a measure of complexity in the fields of physics, chemistry, industrial technologies, and so on[2]. But the fractal concept has been found by the present author and his coworkers to be also a powerful tool to develop some functional materials. Fractal surfaces, for example, have very large surface area (infinitely large in pure mathematical sense), and this property can be applied to some useful functions. A fractal body having a smaller fractal dimension than 3 ($2 < D < 3$) should be the material of zero volume and infinitely large surface area (again in pure mathematical sense). Two topics concerning fractal surfaces and body will be discussed in this presentation.

2 Super water- and oil- repellent fractal surfaces

A super water-repellent surface has been obtained by utilizing the very large surface area of the fractal structure[3,4]. Fig.1 (a) shows a water droplet on a super water-repellent fractal surface made of alkylketene (AKD; a kind of wax). The contact angle of this droplet is 174° . However, the contact angle of water on a flat surface of the same material is 109° as shown in Fig.1 (b). One can see great effect of the surface roughness of fractal structure. Quite interestingly, the fractal structure of the AKD wax is formed spontaneously by crystallization from molten liquid by self-organization manner.

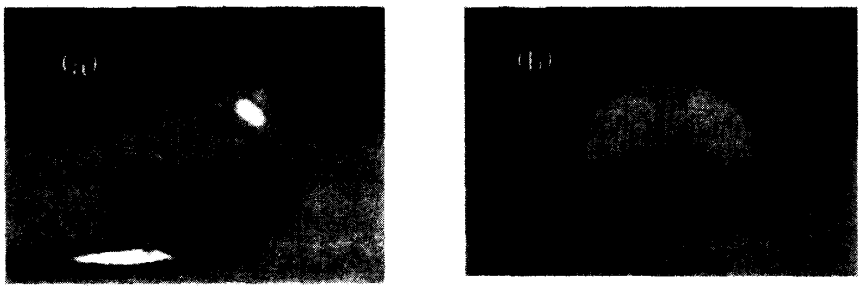

Fig.1 : A water droplet on a super-repellent AKD surface (a) and on a flat one (b).

Even super oil-repellent surfaces can be synthesized by making the surface fractal[5,6]. A droplet of rape seed oil shows the contact angle of 150° , and rolls around without attachment on this super oil-repellent surface. The oil-repellent surface is made of

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anode-oxidized aluminum treated with a fluorinated surfactant, and the fractal surface is again formed automatically by electrochemical reaction at the electrode.

Durability is the most serious problem when the super water- and/or oil-repellent surfaces are practically applied. Recently, environmentally stable (durable) super water-repellent surfaces were synthesized employing poly(alkylpyrrole) films[7,8], and they were converted to highly oil-repellent surfaces by coating a fluorinated silane coupling agent[9]. They are confirmed to be stable in thermal treatment at high temperatures and in the treatments with several organic solvents.

3 Creation of a fractal body

We have recently succeeded in making a fractal body utilizing the fine particles of AKD with fractal surface structure as templates. The densely packed fractal AKD particles were molded with a tetramethylorthosilicate solution, and the solution was solidified by sol-gel reaction followed by calcinations process. The cross-sectional fractal dimension of the fractal body was determined to be 1.87 ± 0.03 in ca. three decades (50 nm-30 μ m) of pore size distribution and volume fraction is 0.15. The fractal dimension and the volume fraction of this fractal body are interestingly in quite good agreement with those of the Menger's sponge of a mathematical model of typical fractal body. This unique novel material may hopefully show some unique functional properties in future.

References

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