# How does the 'super hydrophobic' effect enable self cleaning surfaces?

The 'super-hydrophobic' effect is a principle extracted from natural phenomenon observed on the leaves of lotus plants. These leaves have exceptional self cleaning surfaces where all foreign matter like mud, dirt, dust, vegetable or animal waste, fungi, algae and pollens are washed off by a mild flow of water or a gentle dip. Not only are these leaves thus cleaned easily but the cleaning agent i.e. water itself also does not remain on the surface. The water even does not wet the leaves. The most amazing feature of the lotus leaves is their ability to release both the hydrophilic as well as the hydrophobic dirt upon rinsing by water. Hence the term lotus effect is associated with the self cleaning ability. This phenomenon is quite non-intuitive and has generated a great deal of research interest over the last decade. Biomimitic self cleaning materials based on the lotus effect principle have begun to appear on the market. These products include:

- Façade coatings
- Super hydrophobic coatings for aeroplanes
- Stain resistant low contact textiles
- Self cleaning cloth for tents and other outdoor enclosures
- Self cleaning glass for buildings
- Self cleaning roof tiles

The principle underlying 'Lotus effect' can be understood in terms of physico-chemical factors as follows: (Figure 1)

- Chemistry of the substrate: The surface should be inherently made of a hydrophobic material. The contact angle of water on its flat surface should be minimum100~120 deg. Many of the organic surfaces possessing non-polar character are hydrophobic. The wax present on the lotus leaves imparts such hydrophobicity to the surface. While this level of hydrophobicity may be adequate to prevent wetting of the substrate by water, it cannot quite provide self-cleaning effect by mere rinsing with water droplets. The contact angle of water with the lotus leaves is of the order of 170 deg. This enhancement of its hydrophobicity is brought about by the morphological modification of the surface as explained below.

- Microstructure of the surface: The surface is covered with tiny microscopic convex 'buds' or 'bumps' which in turn are covered with miniature bumps at micron and sub micron level. This forms a hierarchical fractal structure which reduces the number of contact points of water with the surface. The convex curvature of the buds at the contact points further increases the contact angle of water, thereby enhancing the hydrophobicity of the surface. This phenomenon is mathematically expressed by Cassie- Baxter equation. This equation also takes into account the complementary effect of the air entrapped between the droplets and the base substrate due to the textured topography. The classical Wenzel equation is based on the supposition of penetration of water right down to the base substrate filling up all the voids. Hence it is inappropriate for explaining the super hydrophobic surfaces.
- Air in the surface microvoids: When the surface is flat, there is no room for air between the substrate and the water. However, the fractal nature of surface makes the underside of water droplet 'bi-phasic' i.e. comprising of two phases – solid substrate in the form of buds and the gaseous air. These tiny air pockets contribute to the repulsion of oncoming water droplets.

The synergistic effect of all the above three factors results in a very high contact angle of the order of ~170 deg. Therefore, the impinging water droplets assume almost spherical shape and easily glide down the surface. Various types of foreign particles, commonly called 'dirt', delicately reside on the surface, atop the tiny buds with very few contact points for adhesion. The round water droplets roll down the surface, mop up the dirt particles on the way and drip off. This cleans up the surface without leaving any water behind. Due to the unavailability of water on such surfaces, the growth of bacteria, fungus and algae is significantly reduced.

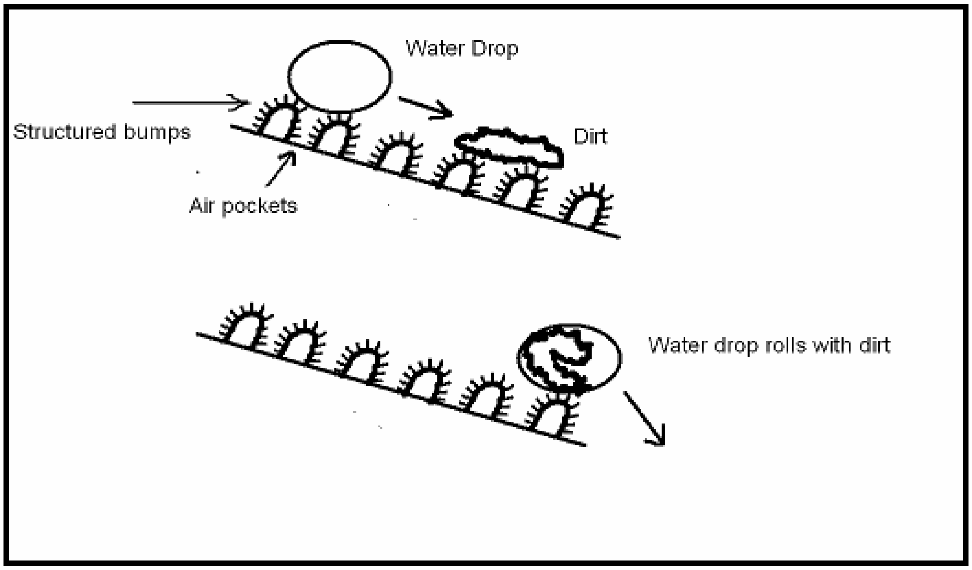


Figure 1: Super hydrophobicity or 'Lotus Effect'

Scientists in this field have developed various approaches for fabricating super hydrophobic surfaces modeled on the lines of the lotus leaf. These surfaces do contain hierarchical fractal structure of finer nanoscopic dimensions. Following are some of the methods employed for surface patterning:

- Layer-by-layer deposition of polymer by dipping and solvent evaporation
- So-gel technique to generate aerogel film on the surface with controlled porosity
- Deposition of nanoparticles of hydrophobic silica
- Vapor phase deposition

Commercial products for use in the coatings have also started appearing on the market in the form of additives e.g. Aeroxide L3 from Evonik.

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