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Lotus Effect Toy

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This is a short article about Aqua Drop, a toy that employs a superhydrophobic surface. After defining superhydrophobic surface, its occurrence in nature, and its importance in science and technology, I describe the toy, followed by several student activities that can be performed with the toy and easily found natural objects.

Background

Several plants and insects exhibit remarkable surfaces (e.g., leaves and wings) that combine chemical and physical attributes that cause water falling on them to effectively bead up and roll off. This ability serves for cleaning and survival purposes. These surfaces are waxy, making them hydrophobic ("water hater"). They also have nanometer-scale roughness elements that make them superhydrophobic. The difference between hydrophobic and superhydrophobic is characterized by the contact angle shown in Fig. 1.[1] If this angle is between 90° to 150°, the surface is called hydrophobic; for angles higher than 150°, the surface is classified as superhydrophobic. (Between about 5° to 90°, the surface is hydrophilic ["water lover"] and below 5° is considered superhydrophilic.)

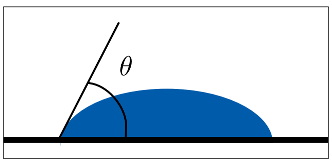

Fig. 1. Water drop on a surface (θ is the contact angle).

Wilhelm Barthlott, a professor of botany in Germany, discovered the mechanism of superhydrophobicity by observing the leaves of a lotus plant under a scanning electron microscope.[2] The term "lotus effect" was coined to exemplify superhydrophobicity of the plant. That discovery opened up new research and development in search of self-cleaning surfaces, low-drag coatings, and innovative fluid handling devices.[3] Currently, outdoor paints are marketed that make the façade of a building self-cleaning. That is, during a rain shower the accumulated dust particles on the surface are washed off by being collected on the rain drops as they bead up and roll off the surface, similar to what happens in nature on the lotus leaf. Furthermore, there are now fabrics available that allow ketchup, coffee, or wine spills to easily roll off of them. Several research teams around the world are investigating the creation of switchable surfaces to make them superhydrophobic or superhydrophilic depending on the application. This is of interest to designers of micro-sized fluidic devices.[4,5] A recent review of superhydrophobic and superhydrophilic plant surfaces as applied to biomimetic materials is available.[6]

Toy and student activities

Aqua Drop is a relatively new toy that vividly exhibits the lotus effect.[7] Shown in Fig. 2, the toy is made of a shallow plastic box containing a maze whose surface is superhydrophobic. Although the surface looks smooth, it has roughness elements on the order of nanometers, and a special polymer gives it a waxy shine. The maze includes several hemispherical depressions. An eye dropper is supplied with the toy and a small hole on the top of the box allows insertion of drops onto the maze with the eye dropper. An outlet hole is at the lower side of the box to drain water after using the toy. The objective is to bring to and park a water drop in each of the depressions. This is not easy! Even a tilt of a few degrees causes the water drops to roll on the surface. A similar toy that used an enclosed drop of mercury was available in the 1990s (see Fig. 3).

Besides playing with the maze to place a drop in each of the depressions, one can create a very large drop of water on the surface and then observe its movement around the maze by slightly tilting the toy back and forth and sideways. If the toy is shaken, the large drop breaks down into small drops, which then can be recombined by tilting the toy toward a corner and observing the coalescence of smaller drops into a large one. Another neat activity is to release two drops, one dyed with food coloring, into the toy and then observe their coalescence and the subsequent color dilution. Also, students can gather

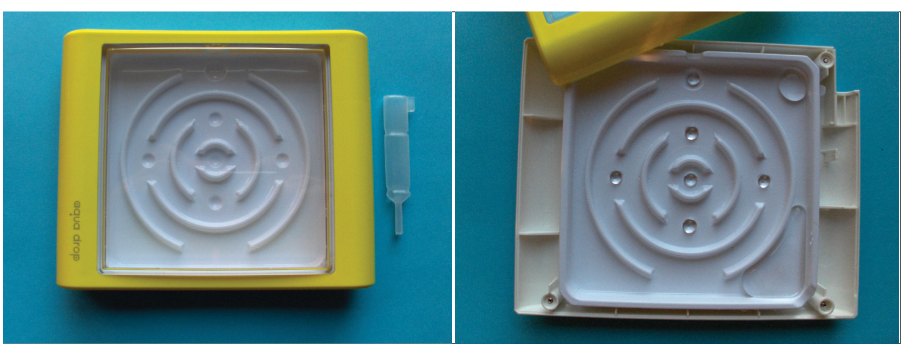

Fig. 2. Left, Aqua Drop with the included eye dropper. Right, small water drops are seen in depressions and large drops in the right corners. (Cover retracted for clarity.)

Fig. 3. Maze toy with the mercury drop at the bottom. (Photo courtesy of Christian Ucke.)

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natural materials such as bird feathers, plant leaves, flower petals, and fuzzy fruits such as peaches, and observe the differences in contact angles by placing a water drop on each.

The toy and activities described above allow students to gain an appreciation for superhydrophobic phenomenon, a topic of current interest in scientific and engineering fields.

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7. Aqua Drop, available in four maze patterns, can be found online.

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