Scientific Research Publishing

Journal of Materials Science and Chemical Engineering, 2025, 13(11), 39-47
https://www.scirp.org/journal/msce
ISSN Online: 2327-6053
ISSN Print: 2327-6045

Super Hydrophobic Biomimetic Preparation and Properties Research Based on Cherry Blossom Leaves Veins

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How to cite this paper: Liu, M.H., Tang, Z.Y. and Zeng, F.Y. (2025) Super Hydrophobic Biomimetic Preparation and Properties Research Based on Cherry Blossom Leaves Veins. *Journal of Materials Science and Chemical Engineering*, **13**, 39-47.
https://doi.org/10.4236/msce.2025.1311004

Received: September 24, 2025
Accepted: November 22, 2025
Published: November 25, 2025

Abstract

According to some scientific evidence, cherry blossom leaves have natural super hydrophobic properties, and there may be micron-sized stomata or nanoscale waxy protrusions on their surface, and such structures can trap air and form an air cushion (Cassie-Baxter state) to help improve hydrophobicity. The skin of cherry blossom leaves with a waxy layer is covered with hydrophobic wax (the main components are long-chain alkanes, fatty acid esters, etc.), which can reduce the surface energy and make the water's contact angle reach 100˚ - 140˚ (close to but not up to the super hydrophobic standard > 150˚). We adopted the method of coating the surface of cherry blossom leaves silica silicone model with a low-surface-energy fluorinated polymer, and their surface energy can be further reduced, and also increase the water contact angle. This fluorination treatment enhances hydrophobicity without damaging the original microstructure. Since water droplets form spherical shapes on the leaf surface and roll off easily, the model achieve a super hydrophobic effect. Additionally, using micro-nano fabrication techniques can create more micrometer or nano meter-scale structures on the leaf surface of Cherry blossom leaves, further enhancing hydrophobicity and achieving a super hydrophobic surface. Inspired by this property, this essay will use cherry blossom leaves to make a super hydrophobic structure and fluorinate it to satisfy the super hydrophobic standard.

Keywords

Cherry Blossom Leaves, Super Hydrophobic, Micro Nano Structure, Fluorination, Silica Gel, Sliding Contact Angle

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[*]The contributions of the authors in this paper are equal, and the order is based on alphabetical sequence.

1. Introduction

The development of modern materials science has often drawn inspiration from the intricate designs found in nature, particularly from plants and animals that have evolved over millions of years to develop specialized structures enabling them to thrive in their environments [1]. Many classical theoretical concepts in material science are directly inspired by these biological adaptations [2]. Through the process of natural selection, organisms have developed unique morphological and chemical features that allow them to adapt to specific environmental conditions, such as extreme temperatures, moisture levels, or mechanical stresses [2] [3]. In recent decades, the field of bionics has gained significant traction, leading to the development, production, and widespread application of numerous bio-inspired materials in everyday life [4] [5]. The study of bionic materials has emerged as a groundbreaking direction in material innovation, offering novel solutions to overcome technological bottlenecks and push the boundaries of material performance [1] [3].

Superhydrophobicity represents one of the most remarkable and widely studied properties in material science. A superhydrophobic surface exhibits extreme water repellency, characterized by a water contact angle exceeding 150˚ [6], which allows water droplets to bead up and roll off effortlessly [7]. This phenomenon has found diverse applications across various industries, significantly enhancing the functionality and durability of everyday products. For instance, raincoats and umbrellas leverage superhydrophobic coatings to provide superior waterproofing, ensuring comfort during rainy weather [8]. Solar panels incorporate superhydrophobic surfaces to achieve self-cleaning capabilities, as water droplets efficiently remove dust and debris [7], thereby maintaining optimal light absorption and improving energy conversion efficiency. Similarly, drones equipped with superhydrophobic coatings can maintain stability and operational efficiency even in wet conditions, as water droplets slide off without leaving residues [9]. Beyond these examples, superhydrophobic materials are also utilized in the formulation of self-cleaning exterior paints, which reduce the need for frequent maintenance and lower the long-term costs of building upkeep. Additionally, the textile industry has adopted superhydrophobic treatments to create waterproof fabrics, offering innovative solutions for outdoor sports gear and protective clothing [8]. The potential applications extend to the electronics sector, where superhydrophobic coatings are applied to smartphone screens and other devices to enhance their resistance to moisture, thereby improving reliability in humid or wet environments [10].

The foundation of superhydrophobic research can be traced back to the observation of natural biological surfaces that exhibit unique wetting behaviors, most notably the "lotus leaf effect." This phenomenon was first systematically studied in the 1970s by the German botanist Wilhelm Barthlott, who investigated the surface properties of lotus leaves [11]. Barthlott discovered that water droplets on lotus leaves form nearly perfect spheres and readily roll off [11], carrying away dust particles in the process a mechanism now known as the self-cleaning effect [7]. Through electron microscopy, he revealed that the lotus leaf surface is composed of micron-scale papillae structures, each further adorned with nano-sized waxy crystals. This hierarchical micro-nano roughness drastically minimizes the contact area between water and the leaf surface, resulting in exceptional water repellency.

While the lotus leaf remains the most iconic example of natural superhydrophobicity, many other plants also exhibit similar hydrophobic properties, albeit with variations in structure and composition [12]. For instance, cherry blossom leaves display distinct surface morphologies that differ from those of lotus leaves, potentially influencing the stability and durability of their superhydrophobic characteristics. Currently, most superhydrophobic materials are fabricated by replicating the microstructure of lotus leaves, but the raw materials for such replications are often limited [13]. To diversify the range of available templates, we propose exploring cherry blossom leaves as an alternative source. Notably, cherry blossom trees shed their leaves in large quantities after the blooming season, presenting an abundant and renewable resource. By collecting and repurposing these fallen leaves, we can not only reduce the costs associated with material production but also contribute to the sustainable management of biomass waste [14].

When evaluating the potential of cherry blossom leaves for superhydrophobic applications, it is essential to consider not only their seasonal availability and ease of collection but also their underlying microstructure. Preliminary observations suggest that cherry blossom leaves possess a rough micro-nano surface architecture similar to that of lotus leaves, providing a promising foundation for achieving superhydrophobicity. In summary, cherry blossom leaves represent a cost-effective and environmentally friendly alternative for the development of superhydrophobic materials. Therefore, this study aims to utilize cherry blossom leaves as a primary resource in the fabrication of advanced superhydrophobic surfaces, exploring their structural properties and potential applications in material science.

2. Experiment Section (Figure 1)

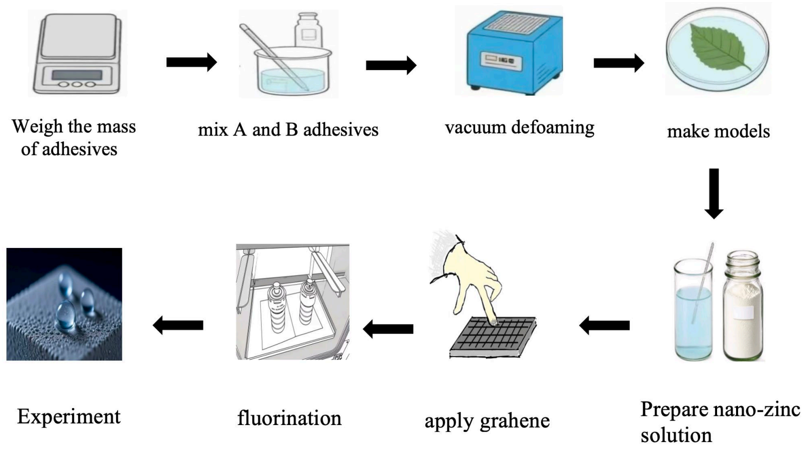

Figure 1. The process of the experiment.

2.1. Preparation of Silica Model of Leaf Structure (Food Grade Platinum Silica)

Equipment and materials used: Beaker, clean cherry blossom leaves, food grade platinum silicone, petri dishes, glass rods, vacuum drying ovens, heating tables, heating boxes, reactors.

Select cherry blossom leaves, choose fresh leaves with rough surfaces, consistent in size with culture dish, and clear vein patterns, ensure that the surface is clean and not broken. As shown in **Figure 2**.

Figure 2. Cherry blossom leaves (front).

AB silicone mixture shown in **Figure 3**, First, peel the scale to zero, and then use the electronic scale to weigh 20 g of "food grade platinum silicone A". Then put it in a clean beaker. Peel the scale again and weigh 20 g of "food grade platinum silicone B". After this, mix silicone B with silicone A and stir slowly clockwise using a glass rod for 10 - 15 minutes to ensure a good mix.

Figure 3. Food grade platinum silicone.

Pour the beaker mixed with food-grade platinum silicone AB into a larger container (about 1/3 of the space to prevent spillage). Then put it into the vacuum drying oven and close the door tightly, open the vacuum valve and start the vacuum pump, and rotate the balance port until no gas flows out. Observe the process closely; if silicone overflow occurs during vacuuming, immediately stop the vacuum pump. If no liquid spills during vacuuming, continue vacuuming until the bubbles completely disappear (about 5 - 10 minutes).

Prepare a new and clean culture dish, spread the collected cherry blossom leaves, glue them to the bottom of the dish, prime on top with mixed food-grade platinum silicone AB, and completely cover the leaves. After that, put the prepared culture dish into a vacuum drying oven and vacuum until the bubbles between the silicone and the leaves completely disappear.

Remove the culture dish and place it on a heating table for about 1 hour until the silicone is fully cured. Then take out the cured leaf structure silicone model and place it at room temperature for cooling. After that, the leaves were slowly separated from the silica gel, and finally the leaf vein inverse structure model was obtained. As shown in **Figure 4**.

Figure 4. Cured leaf structure silicone model.

2.2. Prepare Nano-Zinc with Structures

Prepare Electronic scales, beaker, measuring cylinder, glass rod, Medicine spoon, Reactor, blank paper, etc.; Ensure that the work surface is clean and dry to avoid contamination.

Prepare a clean and tidy piece of white paper and place it on the scale and peel it to zero. Weigh 0.35 g of ammonium salt (NH_4Cl) with a spoon and place it in a clean beaker. Use a measuring cylinder to measure 100 mL of distilled water and pour it into a beaker and stir until it is completely dissolved. make the molarity of ammonium salt in the solution reach 0.0654 mol/L. Clean the medicine spoon, weigh 0.74 g of zinc nitrate and put it in a beaker and continue stirring until the solution is uniform and transparent.

The reverse structure model of the leaf veins of the cherry tree leaves was placed in a reactor (structurally side down) and the prepared solution was poured into the prepared solution to completely submerge the model. Tighten the reactor lid and check the tightness. The reactor is placed in a constant temperature environment or in a static place for hydrothermal reactions (95˚C heating and reaction for 10 hours).

Ammonium salt can provide an appropriate pH reaction condition for the hydrothermal reaction of ZnO, and secondly, it can control the magnitude and dispersion of crystals. At the same time, ammonium salts can form easily volatile or soluble substances with impurity ions in the reactants, which can effectively improve product purity.

2.3. Fluorination

After the hydrothermal reaction of fluoridation, the nanostructured silica gel model will be generated from the leaf vein inverse structure model of cherry tree leaves. Then fluoridate it.

First, prepare a glass dryer, 1H,1H,2H,2H-perfluorodecyltriethoxysilane, syringe tube, and heating box. Drop two or three drops of 1H,1H,2H,2H-perfluorodecyltriethoxysilane in a glass dryer. Then put the silicone model with the nano structure into the glass dryer. Finally, seal the glass dryer and put it in the heating oven. Heating box' temperature setting always at 85˚C, to ensure that 1H,1H,2H,2H-perfluorodecyltriethoxysilane can evenly cover the surface of the silicone model. During the process of heating, the silane molecules will react with the hydroxyl groups on the surface of the silica gel and form a stable fluorinated silane layer. This process will maintain about 6 hours to ensure that the fluorination reaction can be react in the everywhere on the surface.

After fluorination reaction, take the silicone model out of the heat oven and the rinse with deionized water to remove unreacted silane molecules the surface. Then, fuming cupboard put model into fuming cupboard to drying at room tmperature. The dried model surface will have extremely low surface energy, which makes it have the good hydrophobicity and the anti-pollution ability.

To further test the characteristics of fluorinated silica models, contact angle measurements and adhesion resistance tests can be performed. Contact angle measurements can evaluate the hydrophobicity of the model surface, and through these tests, it can be verified that fluorination has successfully enhanced the performance of the silicone model. If the test results are as expected, then this fluorinated silicone model can be used for further research or practical applications.

3. Result and Discussion

Test for Hydrophobicity

Drop water droplets on the fluorinated model surface to observe whether water droplets remain on the surface.

To further test the characteristics of fluorinated silica models [15], contact angle measurements and adhesion resistance tests can be performed. Contact angle measurements can evaluate the hydrophobicity of the model surface, and through these tests, it can be verified that fluorination has successfully enhanced the performance of the silicone model [16]. If the test results are as expected, then this fluorinated silicone model can be used for further research or practical applications.

We added a set of non-fluorinated models to compare them to show the effect of fluorination. Fluorine atoms are extremely electronegative atoms, and their properties make it very difficult to act with water molecules, which means their repulsion to water is much greater than other hydrophobic groups [17]. so the most important function of fluorination is to reduce the surface of the material, increase the size of its contact angle, and thus make it easier to meet the super hydrophobic standard [6]. The hydrophobicity of a material is essentially determined by the surface energy: the lower the surface energy, the weaker the interaction of water molecules with the surface of the material, and the easier it is to form "spherical" contact and roll off. And also the surface polarity of silicon model after fluorination is low, which make it difficult for water molecules to penetrate into the micro nano structure, thus avoiding the air layer being replaced by water and achieving long-term hydrophobic characteristics [18].

As shown in **Figure 5**, 1 ml of water was dropped on the leaf vein inverse structure model of cherry blossom . As can be seen from the figure, the water droplets are spherical on the surface of the model, indicating that the surface of the model has super hydrophobic properties. The static contact angle test results show that the water droplet (1 ml) has a contact angle of 169˚ on the surface of the model, thus demonstrating super hydrophobicity [6] [18], At the same time, we added a set of non-fluorinated silicon model silicon model for static testing, and their contact angle test results were 124˚, which does not meet the standard of superhydrophobicity. The two sets of data indicate that through this fluorination treatment, the surface of cherry blossom leaves achieves super hydrophobicity.

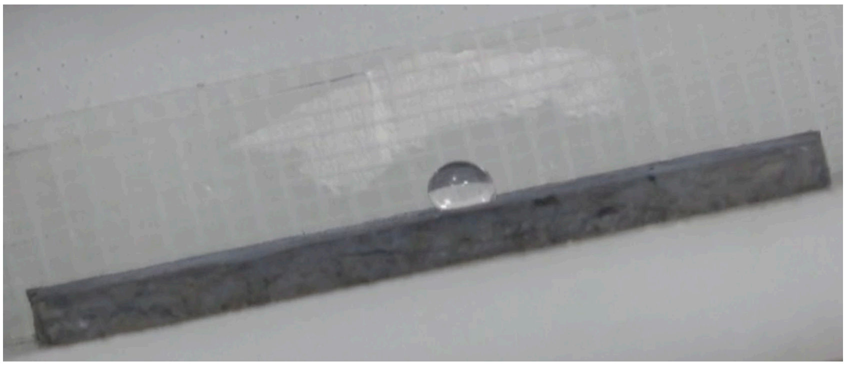

Figure 5. Rolling angle of the superhydrophobic model of cherry blossom leaf veins. *When the rolling angle is less than or equal to 10 degrees, the super hydrophobic standard is reached, and the sliding contact angle of this experiment is 10 degrees, so it meets the super hydrophobic standard.

We tested the contact angle of the fluorinated silica model again after 14 days, and it remained at 169 degrees, indicating that the fluorinated silica model has a certain degree of durability.

Contact-angle protocol:

Goniometer model: Dataphysics OCA 20 system;

Droplet volume: 0.12 - 0.18 Ml;

Ambient conditions: Indoor chemical materials laboratory, room temperature, standard atomsphere.

Number of measurements: 16 times;

Mean ± SD: 169 ± 1 degrees.

4. Conclusion

According to the experimental data, the cherry blossom leaf vein model has been superhydrophobic after fluorination, and the micro nano structure on its surface can greatly reduce the contact area with water droplets, so that the contact angle of the model is greater than 150 degrees, which meets the standard of super hydrophobicity [6] [11]. Through this fluorination treatment, the surface of the leaves of cherry blossom trees not only achieves super hydrophobicity, but also enhances its durability and anti-pollution ability. For example, when water droplets roll on a treated leaf vein model, dust and dirt can be taken away from the surface, thus keeping the leaves clean [7]. This characteristic has important ecological significance in nature, such as reducing the attachment of pathogens and improving the self-protection ability of plants [7].

Authorship Contribution

Fanyi Zeng: Background investigation and preparation, writing of result and discussion, experiment participate, search of references, editing of pictures. **Minghao Liu:** Recording and writing of the experimental section, writing of the conclusion part, experiment participate. **Ziyuan Tang:** experiment participate and discussion of concepts.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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