EVALUATION OF WETTING TRANSITIONS ON INJECTED MOLDED HIERARCHICAL MOSS STRUCTURES

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Abstract

Bio-inspired hierarchical surfaces demonstrate a potential for a variety of green technologies. The design of those surfaces remains a challenging scientific and technological task. The diversity of plant surface structures, evolved over 460 million years, has led to a large variety of highly adapted functional structures. The plant cuticle provides structural, chemical and physical modifications for surface wetting, ranging from superhydrophilic to superhydrophobic. Understanding the physical mechanism of wetting transitions is crucial for the design of those biomimetic surfaces. In this paper is investigated hydrophilic surface structure of moss. Enlarged structures is replicated on cavity insert in a mold base of standard two plates tooling core. Using different types of polar and non-polar termoplastic polymers were injected testing specimens than were evaluated wetting transitions by different types of liquids.

Keywords: *biomimetic, wetting transitions, termoplastic polymers, injection molding*

1. Introduction

Driven through millions and millions of years has evolved structural diversity and properties of bilogical surfaces by long-lasting game of mutaion a natural selection. Different environments led to huge variety adaptations and development of multifunctional, protective interfaces. The diversity is based on the variability of cell shapes, micro and nanostructures on the cell surfaces and by the formation of multicellular structures [1]. Those hierarchical structures with dimensions of features ranging from the macro to nanoscale provide interesting properties. Superhydrophobicity, self-cleaning, drag reduction in fluid flow, molecular-scale devices, energy conversion and conservation, high adhesion and reversible adhesion, aerodynamic lift, fibres and materials with high mechanical strength, biological self-assembly, antireflection, thermal insulation, structural coloration, self-healing and sensory-aid mechanisms are some of the examples found in nature that are major objects of scientific interest [2].

Properties related to the structure of plant surfaces include the formation of low-adhesive surfaces (sliding of insects), and an increase in the reflection of visible light or absorption of harmful UV radiation. Hierarchical micro and nanostructures of plant surfaces are also relevant for surface wettability. During the last years has been given a lot of attention to the superhydrophobic and self-cleaning properties of plant surfaces, but in plants also water-spreading (superhydrophilic) surfaces. Wetting of surfaces is related to surface structuring and surface chemistry.

Wetting is process of liquid interaction at solid–gas interfaces. It describes how a liquid comes in contact with a solid surface [1]. The main method for the characterization of the wettability of surfaces is contact angle (CA) measurement.

Contact angle is the unit for the surface wettability. A high CA describes surfaces on which a water droplet forms a spherical shape, and the real contact between the adhering droplet and the surface is very small. Wettable surfaces, on which an applied drop of water tends to spread, have a low CA. The CA of a liquid on a surface depends on the surface tension (molecular forces) of involved liquid, solid surface and surrounding vapour. Thus, wetting depends on the ratio between the energy necessary for the enlargement of the surface and the gain of energy due to adsorption [1].

The wetting behaviour of solid surfaces can be divided into four classes, defined by their static CA (Fig. 1).

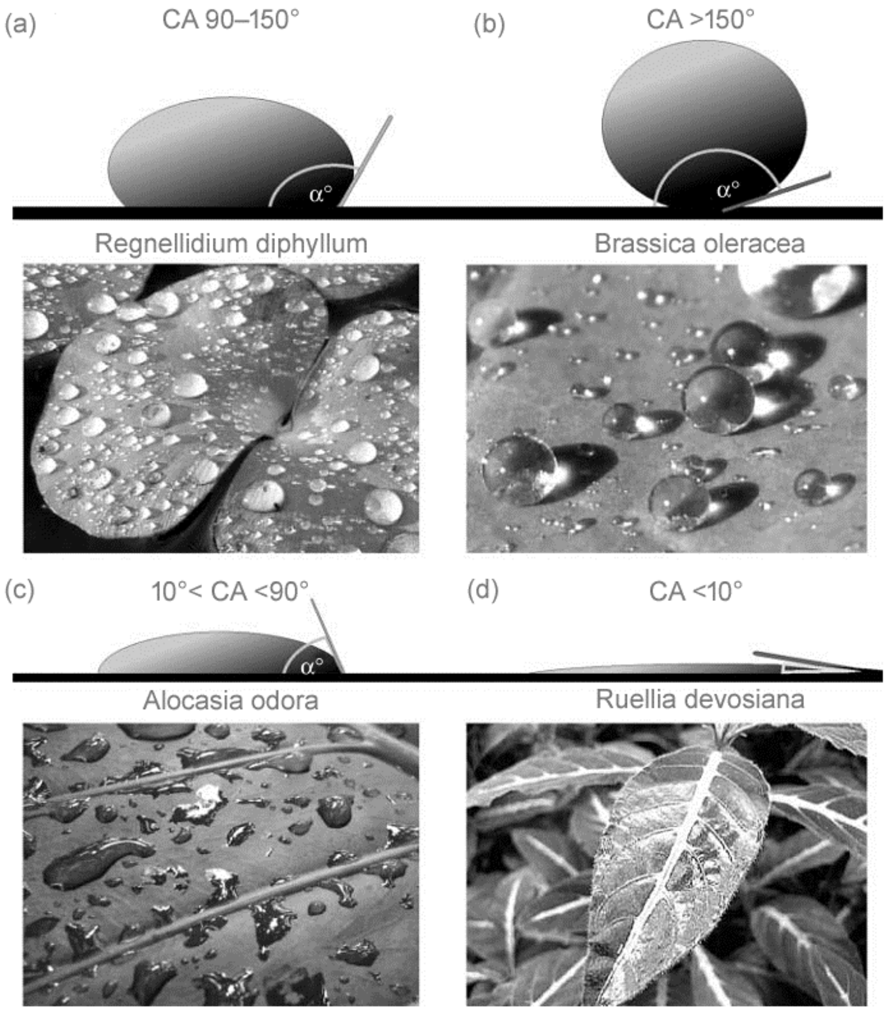

Fig. 1: *Four classes of surface wettability and representative leaves examples: a) hydrophobic,b) superhydrophobic , c) hydrophilic , d) superhydrophilic [1]*

Based on lessons from nature, one of the ways to increase the hydrophobicity is to increase surface roughness. So roughness-induced hydrophobicity has become a major object of scientific interest.¨

Superhydrophilic surfaces are if the contact angle is below 10°. Plant surfaces can either absorb water or let water spread over its surface. Surface roughness on a hydrophilic or hydrophobic surface decreases or increases the contact angle, respectively, based on the so-called Wenzel effect. Air pocket formation in the valleys can increase the contact angle for both hydrophilic and hydrophobic surfaces based on the so-called Cassie–Baxter effect. Formation of air pockets, leading to a composite interface, is the key to very high contact angle and low contact angle hysteresis [2].

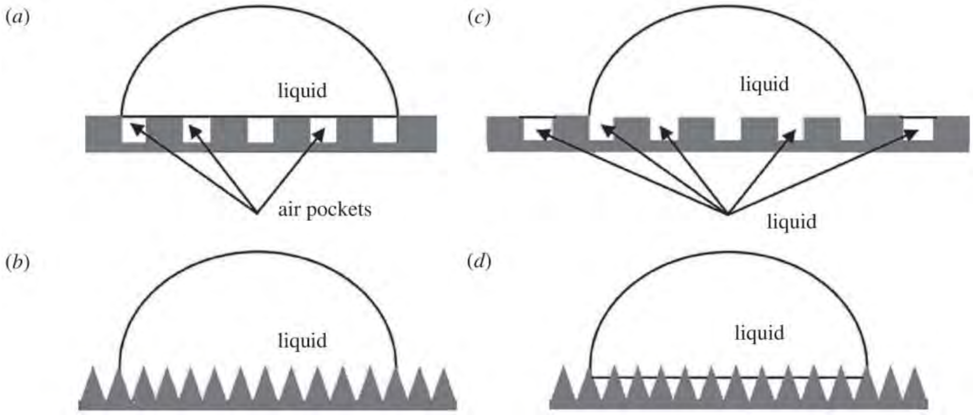

Fig. 2: *Various wetting states occurring on rough surfaces: (a) Cassie air-trapping state,(b) Wenzel state, (c) Cassie impregnating wetting state and (d) mixed wetting state [3]*

2. Method

Firstly has been captured micrographs using scanning electron microscope (SEM) (Fig. 3) on representative moss specimen.

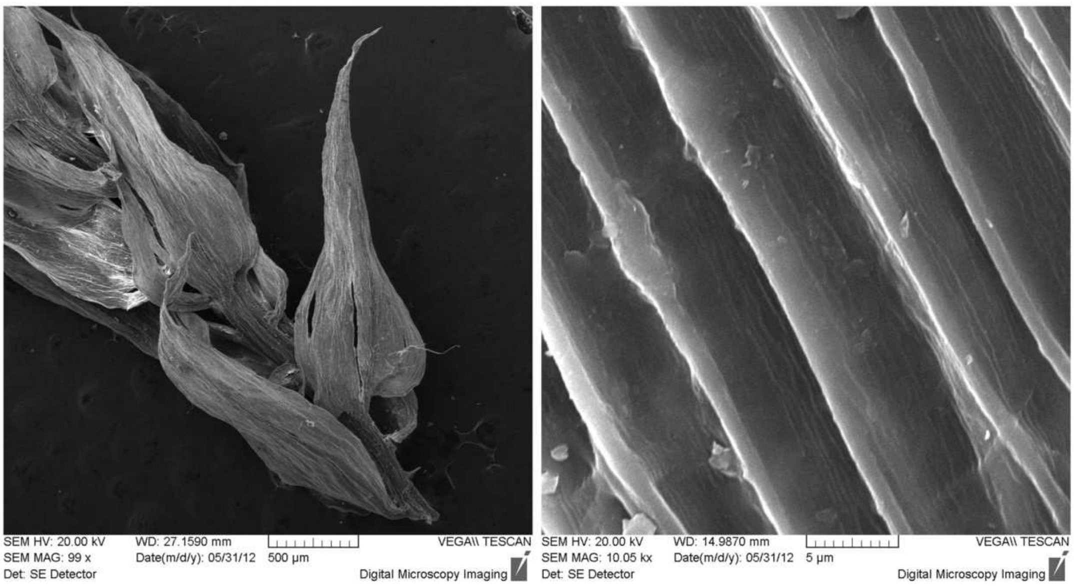

Fig. 3: *SEM micrographs of moss hydrophilic surface structure*

By investigation of natural pattern has been suggested hierarchical structure for replication. This structure has been consequently transferred by the laser beam machining to the cavity insert in a mold base of standard two plates tooling core. Using the laser beam machining is still that smallest possible manufacturable surface 40x enlarged compared to real natural structure. Due to this were suggested two types of 40x and 100x enlarged hierarchical structures for replication.

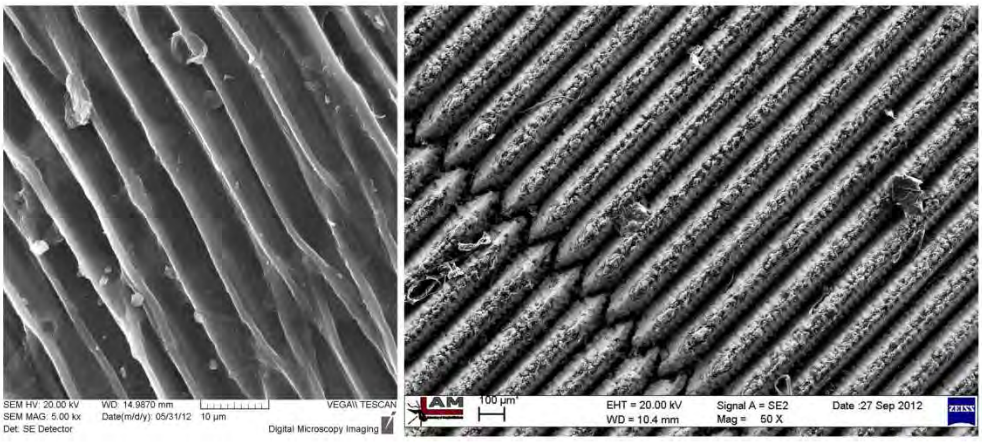

Fig. 4: *SEM micrographs of natural and laser beam machined replicated structure.*

Consequently were injected on injection molding machine (Fig. 5) termoplastic testing specimens from PP, ABS, PA. Chemically speaking, PA with its amide bonds is a polar polymer, resulting in its typical water absorption. ABS, on the other hand, is a non-polar polymer like PP. Because non - polar character of PP and ABS paid for years as unvarnished plastics.

Fig. 5: *Injection moulding machine ARBURG 270S 400-100*

As a measuring liquids for assesment of contact angle measurement were used three types of liquids: a) Redestilated water (H_2O), b) Glycerine ($C_3H_8O_3$), and c) Eethyleneglycol ($C_2H_6O_2$). Exhibits measuring liquids were to be spreading by micro-pipette on testing surface in the form of drops about bulksize 4µl. This small bulk drops ensure, that drops has not been deformated owing to gravitation. The contact angle has been measured using three - point method by Surface Energy Evalution System 6.3 (SEE System).

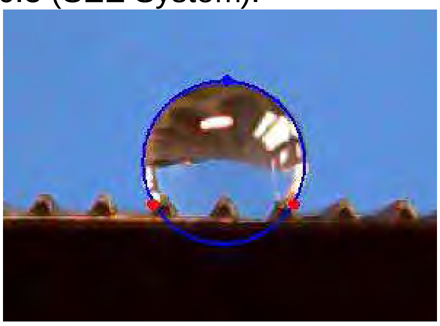

Fig. 6: *Example of tree – point metod on PA replicated structure measured on crosswise side.*

3. Results and discussion

Observed contact angle measurements are shown in following figures. Most of the observed surfaces are hydrophilic, some of them even hydrophobic. There is no superhydrophilic surfaces with contact angle below 10°.

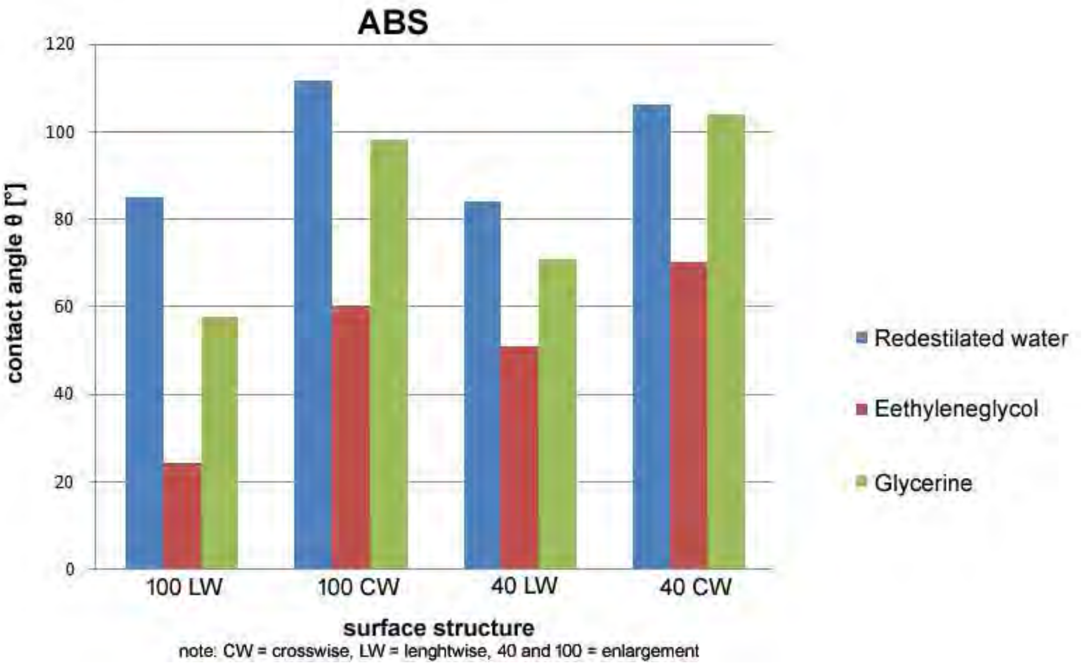

Fig. 7: *Summarized CA measurements for ABS*

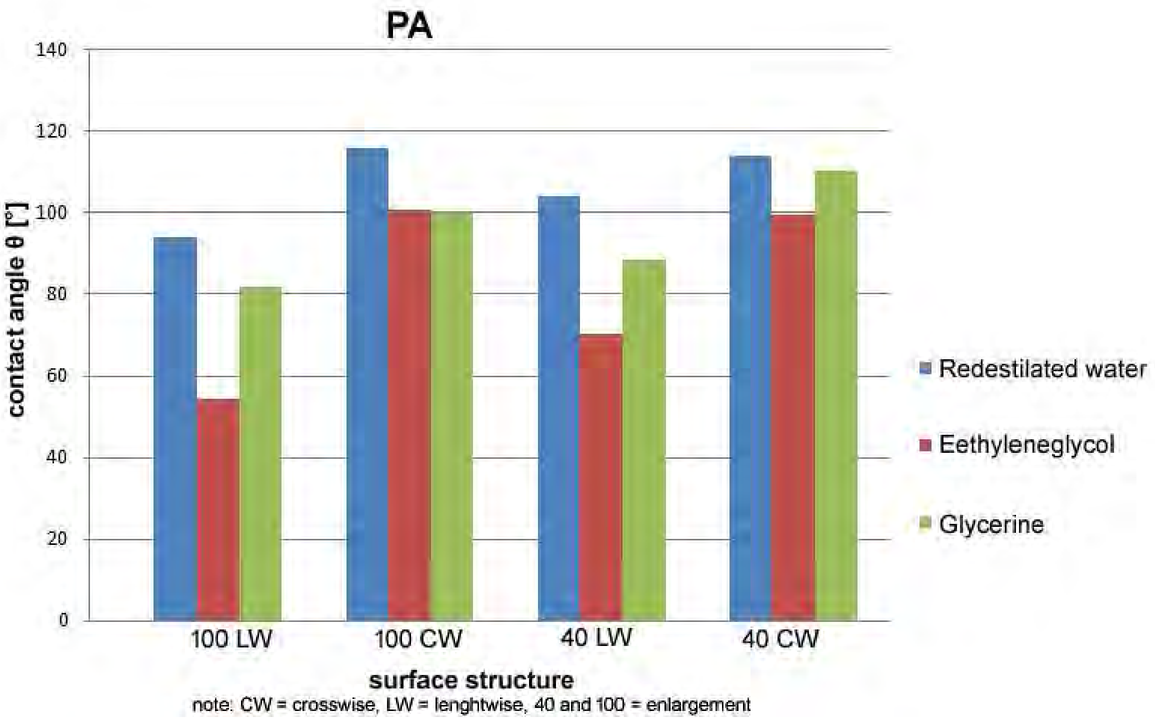

Fig. 8: *Summarized CA measurements for PA*

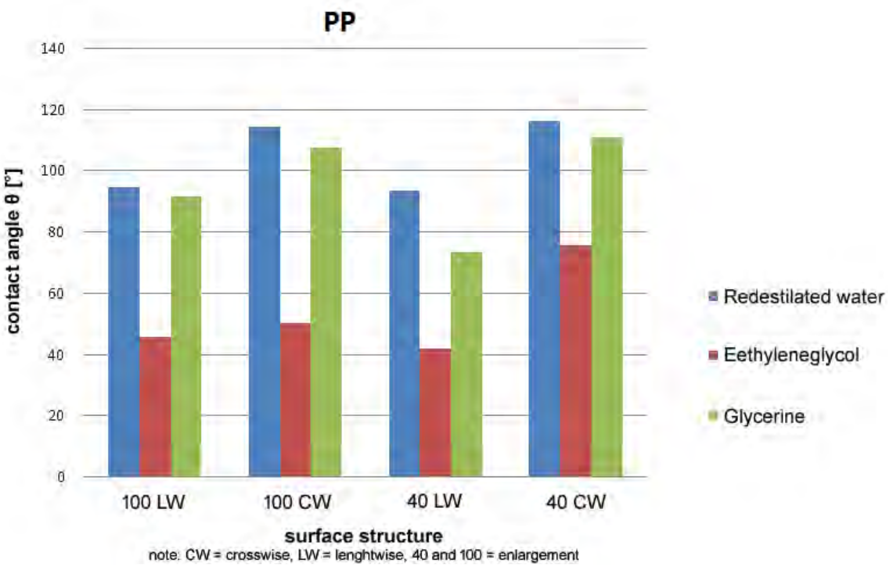

Fig. 8: *Summarized CA measurements for PP*

4. Conclusion

Bio-inspired special wettability is a promising field in materials science and surface science. Most of the measured surfaces are hydrophilic, some of them even hydrophobic. There is no superhydrophilic surfaces with contact angle below 10°. Overall, the results presented in this study confirm that there must be used more progressive technology to replicate the structure in exactly same size like natural pattern. The laser beam machining can be used just for creation microstructure paterrns, but for creation sucesfully replicated natural pattern we need to go deeper to the nano - scale structures on microstructured surface. For example techniques like soft and nano lithography. Wetting of surfaces is related not just to surface structuring but also to surface chemistry and on the surface tension. In further studies should by investigated hydrophobic properties of polymers related to the water spreding on their surfaces.

5. Acknowledgement

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