Advances in Natural Science
Vol.**4**, No.**1**, **2011**, pp. 58-63
www.cscanada.net

ISSN 1715-7862 [PRINT]
ISSN 1715-7870 [ONLINE]
www.cscanada.org

The Review of the Bionic Self-cleaning Technology and Its Prospect

ZHAO Guangsheng[1]
YANG Cheng[2]
LI Yinwu[3]
LI Kun[4]
LI Hui[5]
YANG Zhidong[6]

Abstract: By discussing the significance of the modern self-cleaning technology and the current changes in our lives, this paper reviewed several kinds of typical surface structures and their wettability of plants and animals. Then the bionic self-cleaning materials technology was proposed. List the developments and widely applications of the bionic self-cleaning technology in the various fields. Meanwhile, the bionic self-cleaning materials technology was also discussed. Furthermore, the potential applications and developments in these fields were prospected.

Key words: Bionic self-cleaning; Surface material; Wettability; Review

DOI: 10.3968/j.ans.1715787020110401008

INTRODUCTION

With the rapid development of global economy in the 21st century, people's material civilization is taking a revolutionary change. Meanwhile, the requirements of the spiritual civilization appear unprecedented high. So advocating environmental protection, clean, no pollution unconsciously becomes the important premise of era development. In view of these pressing needs, the self-clean technology has quietly interest-free into to our life, and it is playing an important even revolutionary role. Through the continuously exploring and research, finally, people discovered the surface wettability rule from the surface structure characteristics of the animals and plants in the nature. From then on, the bionic self-clean technology and theirs many related

[1] Corresponding Author, Key Laboratory of Engineering Bionics Jilin University, Ministry of Education, Changchun, China.
* Corresponding Author. E-mail: zgs007888@163.com
[2] Key Laboratory of Engineering Bionics, Jilin University, Ministry of Education, Changchun, China.
[3] Key Laboratory of Engineering Bionics, Jilin University, Ministry of Education, Changchun, China.
[4] Northeast Asian Studies Academy of Jilin University, Changchun, China.
[5] The Department of Mechanical and electrical engineering, Jiamusi Technician Institute, Jiamusi, China
[6] Jiamusi Environmental Protection Agency, Jiamusi, China
† Received March 9, 2011; accepted May 28, 2011.

bionic self-clean materials were developed; meanwhile, people apply the technology and materials in the machinery, construction, chemical industry and so many domains.

1. THE STRUCTURE AND SURFACE WETTABILITY OF PLANTS AND ANIMALS

After billions of years of evolution, the natural creature formed a special surface morphology structure with excellent characteristics. Therefore, it has the extremely vital significance that to do research on the new functional materials and special surface materials and its characteristics for the bionic design of surface morphology (Wang Liduo et al., 1996). Among them，many plants and animals have the self-clean characteristics in theirs surface, which has a very important enlightenment on the research on the bionic self-clean surface.

1.1 The Surface Structure of Plant Leaf and Its Wettability

Besides the roots, there is epidermis in the other parts of plants. Its microstructure likes trichome, skin lap and waxy crystal and so on. Most hydrophobic surfaces of the plants leaves are covered with waxy crystals with the thick of l ~ 5 microns. Meanwhile, there are trichomes, hypodermal cells with the convex bag shape, the sinking and bumps nerve tissue; these morphology structures enhance the surface roughness, so theirs surface have hydrophobic characteristics (Tong Jin et al., 2001).

The professor of Wilhelm Barthlott studied thousands of microscopic structure of plant leaves surface (Wilhelm B et al., 2001; Holloway P et al., 1994), and found the plant leaves with rough surface have certain hydrophobic role. These morphological structures of microscopic non-smooth dramatically increase the hydrophobic characteristics of the surface, which make them have the function of the self-clean. Wang sujie of the Ji Lin University (Wang Sujie et al., 2004) studied non-adherence function of non-smooth micro surface of the pollen wall of the vegetable plants, through observing the surface structure of the pollen wall of vegetable plants and choosing the typical non-smooth structure characteristics for descripting. This research not only enriches the theory of biological non-adherence but also provides some theoretical basises and useful information for developing bionic self-clean materials, so this non-smooth microstructure has important reference significance for preparation the self-clean bionic surface.

1.2 The Surface Structure of Animals and Its Wettability

Through the scanning electron microscope, we can clearly observe that it neatly arranges some micro thorns and micro bumps structure on the surface of animals. However, through many researches of scholars, it has also confirmed that many of the characteristics of these animals have a close relationship with these micro thorns or the bumps shape structure (Zhuo Xin, 2003). The typical example is that many insect wings are covered by wax crystals, and the crystal sizes are similar with plant wax crystals. This kind of surface has been proofed that it has the characteristics of not wet and self-cleaning effect in many experiments.

For example, the research on the butterfly wings (Gu Zhongze et al., 2003; Yang Xiaodong et al., 2002), when the contact angle is 137 degrees between the wings and water, we would find that many scales structure, and there are a lot of sub-micron micro slots and small particles covering in each scale surface structure. This time the self-cleaning phenomenon is that the wing will not be wetted by water. By analyzing, we can know the reason of self-cleaning is that the powder of wings are made of flat capsule with the size about 100 microns, and capsule is made of corneous layer composed with countless chitin and its surface is not bright and clean.

Through the above research on the microscopic structure of plants and animals, we can know that it would have important significance to imitate and prepare surface cleaning materials like the structure characteristics of plants and animals. So this kind of bionic research on microstructure surface plays a great important practical role on the self-cleaning technology.

2. BIONIC SELF-CLEAN TECHNOLOGY AND ITS PRESENT SITUATION

2.1 Bionic Self-clean Technology

Through the study and research on the surface morphology structure of animal and plant and the self-clean technology in advanced field, we can define the bionic self-clean technology as follow: the bionic self-clean technology is that using self-clean characteristics (wettability, self-clean of hydrophobicity etc.) of some surface morphology from the nature animals and plants and in conjunction with the relevant material characteristics develop the bionic self-clean materials with the characteristics of self-cleaning or auxiliary clean and having the same or similar structure with the plants and animals for different areas application.

2.2 The Present Situation of the Bionic Self-clean Technology

After the research on the surface of the animals and plants, scientists found the phenomenon of self-clean function because of forming the hydrophobicity surface is very common in nature, and one of the most typical is lotus leaf as a representative of the plant leaves (Barthlott W et al., 1997). Xu Jian of the bionic materials expert and other researchers of the institute of chemistry of the Chinese academy of sciences analyzed the surface minute structure of the lotus leaf, and found there are a lot of emulsion bumps in the surface. These small particles with the characteristics of invisible to the naked eyes are the causes of the self-clean effect of lotus, which can keep the lotus leaf from the dirt.

So Xu Jian and his partners developed an artificial bionic lotus leaf film which imitated the surface structure of lotus leaf. This kind of bionic lotus leaf film actually is a kind of man-made polymer film, which has the characteristics of not glue water and not sticky oil. Bionic lotus leaf also has “self-repair” function similar with lotus leaf. It can still keep the function of self-cleaning and not glue water, even though the outer of bionic surface is damaged in some conditions. The research can be used for the development of a new generation of bionic surface materials and coatings. The new "bionic lotus leaf film" can be used in the manufacturing some waterproof products like waterproof film. Meanwhile, metope will not touch dirt after painting with coatings of the bionic lotus leaf. The technology will be used in enduring dirty products like the production of architectural coatings, fabric, utensils panels of kitchen, so it should arouse widespread concern.

3. THE APPLICATION OF SELF-CLEAN TECHNOLOGY OF BIONIC MATERIALS

From the surface microstructure of plants and animals in nature to bionic engineering, provides a new design and morphology structure way for preparation the hydrophobicity self-clean materials, which will be widely used in a range of applications field. Meanwhile, because the appearance and orderly degree of microstructure is better than the all kinds of artificial preparation structure at present, so If people can make it as the natural templates to prepare the bionic materials which will create a new self-clean technology with the characteristics of lower cost and higher quality in the economic benefits for human beings. At present, the self-clean technology of bionic materials has been used in the application fields of machinery, construction, chemical, life daily and so on.

3.1 Self-clean Technology of Bionic Materials in Glass

Paint a layer of the bionic self-clean materials film with the characteristics of thin and hydrophobicity in the construction glass, automobile glass and so on, which will make this kind of glass self-cleaning and not leave any trace when it undergoes the rain effect. After processing, the glass surface is super hydrophilic, which can make water completely evenly unfold in the glass surface, at the same time; it also can fully wet the glass and the dirt. Finally through the gravity of water will carry off pollutants attach on the glass so that to realize the self-cleaning effect and maintain glass clean in the long-term. However, the common glass

will be formed drip on its surface and adhere to dust. According to the self-clean technology developing bionic product will own a broad market prospect. And we can use it to make the tables cover of family garden chairs so that the face of desk and chair still keep new vision and clean after long-term undergoing wind and rain and so on.

In the meantime, the self-clean glass of bionic materials can replace the traditional clean way of glass used in construction industries, and there are a lot of advantages in avoiding artificial cleaning and basket cleaning of building hanging. The first, save the cleaning expenses and make a clean glass once and for all. Second, reduce the corrosion and damage which cause by the cleaning agent to glass structure when artificial cleaning. Third, reduce the safety risk when in the high altitude cleaning so that lower person casualties. Further, solve the cleaning problem of not upright metope of the building, which will show the perfect art style of the modern architecture. The last but not the least, this kind of cleaning style really reflects the value of environmental protection and so on.

3.2 The Coating of the Bionic Self-clean

With the implementation of the housing industrialization and the building energy efficiency, the needs of self-clean coating is becoming more and more big in painting different kinds of wall. At the same time, when painting the outer wall, this kind of self-clean coating requires that it should have the following characteristics: not easy adherent pollution or contaminants can be removed by the outside natural conditions like rain, wind and so on. So it has become an important index to improve the ability of anti-contamination of the exterior walls for measuring quality of high performance coating.

The professor Barthlott W of botany of University of Bonn from Germany researched the lotus leaf structure with the characteristics of rejecting water and keeping clean, and revealed the principle of rejecting water and keeping clean of lotus leaf, that is Lotus-effect (Wagner P et al., 2003).

Through the two kinds of method can realize lotus-effect (Lin Xuanyi, 2000). One is to join super hydrophobic agent such as surfactants of the kinds of fluorine and silicon, which make the coating film surface has a lower surface energy so that dust is difficult to stick. The other is to simulate the concavo-convex microstructure of lotus leaf surface and to design coating film surface so that reduce the contact area between the pollutants and coating film.

Ashley Jones and his partners (Ashley J et al., 2003) used the reaction between the hydroxyl of the PDMS and the silanophilic of surface of the Silica nanoparticles and put the PDMS onto particles of the Silica nanoparticles so that prepared the hybrid coating of organic or inorganic. The morphology observation of AFM coating showed that when the Silicon oxide was added the surface roughness of the coating would have a greatly improvement, which would make the surface contact angle of the PDMS be up to the highest degree of 172; and we can control the surface hydrophobic through the mixed quantity of silicon oxide.

Kang (Kang X et al., 2007) dissolved the LDPE of low density into the solvent of xylene or cyclohexanone and heated the temperature up to 90℃, and then cooled the temperature of polymer solution down to room temperature so that could get the gel shape suspension body; finally, covered the gel on the substrate of glass and vacuum drying to get coating film of polymer which has the contact angle of 152.2 degrees with water. It indicates the three-dimensional structure of micron grade length and nanoscale thickness which the LDPE particles have will make the coating film get a good self-cleaning characteristic.

Based on the above principle and technology, finally, people developed the bionic coating which is suitable for cleaning the exterior surface of walls, which improves the ability of self-cleaning of the exterior walls of the building; so it greatly reduces the use of raw materials and reduces the economic cost.

3.3 Other Applications of the Bionic Self-clean Technology

The bionic self-clean technology also widely uses in textile (Du Wenqin et al., 2007), solar panel, traffic signs, and even tiles of the house. Moreover, according to the non-smooth microstructures of stoma of leaf surface, we can develop various kinds of bionic agricultural films with the characteristics of the

self-cleaning, better transmittance, no droplet, which will bring huge economic benefits and social benefit and so on (Wang Sujie et al., 2005).

5. SUMMARY AND PROSPECT

At present, there have had many reports about the study of the theory of the self-clean bionic hydrophobic surface in domestic and foreign. The products of hydrophobic self-cleaning bionic materials in real application are also more and more common. But there are still great research space in preparing a kind of self-clean bionic surface with the characteristics of self-cleaning and being mechanical performance, long servicing life, and stable state and it also can be applied in reality life (Zheng Lijun et al., 2004).

Through the macro and micro observation analysis and characteristic description on the surface morphology of animal and plant, find the characteristic parameters of microstructure and further make the classification to the existing typical microstructure, then discuss bionic function mechanism of the adaptive, self-mediation, self-assembly so that it will provide the theory basis for the advanced feedback bionic, micro mechanical design and so on (Wang Sujie et al., 2005).

After the analysis and research on the existing bionic self-clean technology, the authors think the bionic materials self-clean technology should be further and system research on the following several aspects in future.

(1) When looking for the suitable surface material, we should be tightly around the cost value and try our best to ensure the universality and circulating or reproducibility when selecting materials.

(2) Through the process optimization of the preparation and the choice of the preparation methods prepare bionic self-clean materials. At the same time, it will become the challenging task in this field.

(3) Quantitative analysis, description, and express on various kinds of the self-clean surface characteristics will become the urgent and difficult task for the present and future.

(4) Based on the behavior analysis of the adsorption and adhesion for the surface of animals and plants, look for the self-clean mechanism in different self-clean surface and the same environmental media, and the same self-clean surface and different medium.

(5) Try to study the bionic self-clean organic materials so that to reduce the pollution of the environment. At last, establish the environment-friendly society.

(6) Try to study the bionic self-clean materials with the characteristic that it can be recycled and for reusing. If that we will have an economical society.

(7) Try to study the multi-functional bionic self-clean materials. In that way, it will realize a kind of bionic material provides many kinds of practical value.

REFERENCES

[1] Ashley, J., Zhang, H. & Robert, L. (2003). *Nonfluorinated superhydrophobic coatings: Smart coatings for construction materials* (pp. 46-48). Brussels.

[2] Barthlott, W. Neinhuis, C. (1997). Purity of the sacred lotus or as—cape from contamination in biological surfaces. *Planta, 02*, 1

[3] Du, W.Q., (2001). Application of Lotus-Effect on self-cleaning and water repellency fabrics. *Dyeing and Finishing, 9*, 36

[4] Gu, Z.Z., Hiroshi, U., Kazuyuki, T., (2003). Structural color and the lotus effect. *Angewandte Chem Int Edition, 42*(8), 894

[5] Holloway, P. J., Plant, C., (1994). Physicochemical characteristics and biosynthesis. *Air Pollution and Leaf Cuticle*, (1) 1-13.

[6] Kang, X. Zi, W.W., Xu, Z.G., (2007). Controlling the micro/nanostructure of self-cleaning polymer coating. *Applied Surface Science, 22*(253), 8830-8834.

[7] Lin, X.Y., (2000). Water increase and keep clean the microstructure of the outer wall emulsioni paint and the application of bionics in architectural coatings. *Chemical Building Materia, 7*(5), 7-9.

[8] Tong, J., Ma, Y.H., Ren, L.Q., (2001). *Naturally biological materials and their tribology, Tribology, 21*(4), 316.

[9] Wang, S.J., Ren, L.Q., Han, Z.W., (2005). The effect of non-smooth of being creatures and its bionic applied research. *Journal of Agricultural Mechanization Research, 1*, 209.

[10] Wang, S.J., Zhou, C.H., (2004). the non-smooth surface structure and bionic desorption of the vegetables pollen wall. *Journal of Agricultural Mechanization Research, 9*(5), 123.

[11] Wagner, P., Furstner, R.F., Bartblottw, (2003). Quantitative assessment to the structural basis of water repellency in natural and technical surfaces. *Journal of Experimental Botany, 54*(385), 1295-1303.

[12] Wilhelm, B., Christoph, N., (2001). Surfaces autonettoyantes selon 1' exemple dela nature. *International Textile Bulletin*, (1), 8-12.

[13] Wang, L.D., Sun, W.Z., Liang, T.X. (1996). The research status of bionic materials. *Materials Engineering, 2*, 3-5.

[14] Yang, X.D., Ren, L.Q., (2002). Morphology structures and properties of animal hairs. *Transactions of the Chinese Society of Agricultural Engineering, 2*(18), 21.

[15] Zheng, L.J., Wu, X.D., Lou, Z., Wu, D., (2004), Surface preparation micro-structure hydrophobic membranes surface.*Chinese Science Bulletin, 49*(17), 169.

[16] Zhuo, X. (2003). Shape design of space steel structures based on bionics. *Steel Construction*, *1*(18), 9.