ISSN 2689-0852

BIOTECHNOLOGY KIOSK

Volume 3, Issue 11
NOV 2021

www.biotechkiosk.com

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ISSN 2689-0852

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From the Publisher's Desk

Welcome to Biotechnology Kiosk!

The new issue of BK is now online for our readers with the regular features. This issue includes a perspective on the applications of superhydrophobic surfaces and coatings for advanced healthcare and editor picks.

We hope our readers will enjoy reading these news and views on the current cutting-edge topics that include latest research breakthroughs in different areas of medicine and biotechnology.

We look forward to receiving your feedback. We do hope that you will enjoy reading this issue of Biotechnology Kiosk. Please do write to us with your comments. Your suggestions are always appreciated.

Dr. Megha Agrawal & Dr. Shyamasri Biswas.

Editors-in-Chief, Biotechnology Kiosk

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Perspective

Superhydrophobic Materials for Advanced Healthcare

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DOI: https://doi.org/10.37756/bk.21.3.11.1

Article type: *Perspective*

Received: *October 2, 2021*

Revised: *October 15, 2021*

Accepted: *October 20, 2021*

To cite this article: Biswas A and Gupta R, Superhydrophobic Materials for Advanced Healthcare, Biotechnol. kiosk, Vol 3, Issue 11, PP: 3-10 (2021); DOI: https://doi.org/10.37756/bk.21.3.11.1.

Abstract

Superhydrophobic surfaces are known for a vast array of industrial applications. These surfaces and coatings are now increasingly finding applications in the biomedical sector. Such applications include substrates to control protein adsorption, cellular interaction, and bacterial growth and blood repellent actions. Superhydrophobic surfaces can be leveraged to develop advanced biotechnology platforms for drug delivery devices and also for diagnostic tools. In this short perspective, we have presented some of the most relevant recent research developments that have been reported on superhydrophobic biomedical surfaces and coatings and that have been considered significant in advanced healthcare.

Keywords: *Superhydrophobic; self-cleaning; medical implants; blood repellence; antimicrobial*

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To cite this article: Biswas A and Gupta R, Superhydrophobic Materials for Advanced Healthcare, Biotechnol. kiosk, Vol 3, Issue 11, PP: 3-10 (2021); DOI: https://doi.org/10.37756/bk.21.3.11.1.

INTRODUCTION

It is known that when surfaces of superhydrophobic materials come in contact with water, these surfaces maintain air at the solid-liquid interface and exhibit high contact angles exceeding 150°. The resulting high contact angle is due to the composite solid-air surface that is formed under a water droplet [1, 2]. Materials that are used to fabricate superhydrophobic surfaces have low surface energy. The low surface energy arises due to non-polar chemistries of CH2/CH3 or CF2/CF3 organic groups present in the materials. In addition, other features include close packed and stable atomic structures that result in high contact angles even without material surface roughening. Over the years, these favorable surface properties have prompted researchers to fabricate synthetic superhydrophobic surfaces with tailored surface chemistry and morphology in order to maintain air at the material-water interface for various applications including biomedical technologies [3].

Superhydrophobic surfaces have not only been considered to protect plants and animals, but they are also considered pivotal to safeguard human life and health. With respect to biomedical applications, superhydrophobic coatings have been considered especially due to their unique non-wetting properties and self–cleaning, corrosion-resistant, and resistant to bioadhesion, to name a few [4-6]. In a number of studies, it has been shown that superhydrophobic surfaces interact with tissues, cells, biological fluid, and biological molecules that can be leveraged for applications in healthcare. To this end, several biological applications of superhydrophobic surfaces have been demonstrated that include but not limited to medical devices and artificial blood vessels to improve their anticoagulation and blood compatibility. Another clinically-important area is superhydrophobic antibacterial coating. These coatings can be employed to inhibit the growth of bacteria on the surface or directly kill bacteria by surface modification. To this end, researchers have employed superhydrophobic and antibacterial coatings on the surfaces of medical devices and biological implants [7, 8]. For example, surgical instruments in the clinic can get contaminated by blood adhesion and bacterial adherence during surgery. These contaminated instruments can subsequently cause bacterial infections in patients. Blood contacting medical devices that are treated with superhydrophobic antibacterial coatings can overcome these challenges by preventing blood adhesion and bacterial adherence, thus, safeguarding the life and health of patients [9-14]. Figure 1 shows various biomedical applications employing superhydrophobic surfaces [3].

In this short perspective, we have presented some exciting applications of superhydrophobic materials in modern healthcare.

Antimicrobial and Self-Cleaning Surfaces in Modern Healthcare

In modern healthcare, it is critical to reduce morbidity and mortality that happen as a consequence of bacterial infections. To this end, antimicrobial and self-cleaning superhydrophobic materials are considered vital that can meet the requirements of medical devices and public health products for practical applications. It is believed that such antimicrobial coatings can induce surface functionality while maintaining the overall performance of the material. Therefore, the development of superhydrophobic coatings with antimicrobial and self-cleaning properties is currently a very active field of research in the healthcare industry that needs antimicrobial protection to medical devices and biological implants. Such strategies are believed helpful to counter or prevent growth of certain microorganisms that can survive on medical devices for more than 90 days. This can subsequently result in maintaining significant antimicrobial and antibacterial effects on pathogenic microorganisms for a longer period of time for medical grade antimicrobial materials. Additionally, studies have shown that such superhydrophobic antimicrobial material coatings can also impart excellent biocompatibility for medical bio-implants [15-17].

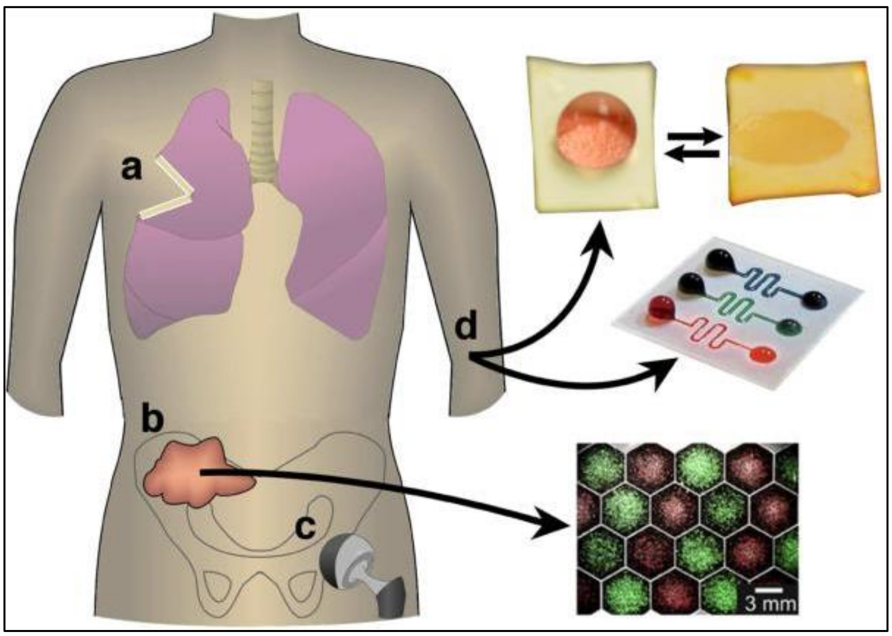

Figure 1: *Superhydrophobic materials for a number of medical applications that include (a) control of the local release of drugs after tumour resection (b) patterned cell growth that can be applied to study cellular communication (c) reduced bacterial adhesion on implants such as hip replacements can be achieved and (d) stabilization of droplets to drive flow using microfluidics and diagnostic assays [Source: Biomaterials (2016)].*

Need for Blood-Repellent Surfaces for Medical Devices

Medical devices that function in contact with blood are very common in today's clinical medicine and biotechnology. The use of implantable medical devices is considered a very important part of modern healthcare. There are several such devices that include vascular grafts, coronary stents, heart valves, catheters, hemodialysers, heart-lung bypass systems, just to name few [18]. However, there are challenges for the proper functioning of these devices. For example, when medical devices come into contact with blood, the interaction could result in undesired activation of blood cells including platelets and monocyte/macrophages of the immune system. This also includes some other bioactive blood components, for example the complement and coagulation cascades. These reactions generally lead to serious medical conditions including formation of blood clots or thrombi, inflammation, and also it could activate the immune system. To overcome these medical issues, there have been several advances and breakthroughs that have focused on developing new line of treatment. These efforts were primarily aimed to overcome the various levels of blood incompatibility of surfaces. However, some issues still remain to be addressed that include the tendency to adsorb proteins that triggers both enzyme cascade and blood-cell activations. Hence, there is an urgent need to develop materials that are thrombus-free indefinitely and in all situations including extracorporeally, in the venous circulation and also in the arterial circulation [19, 20].

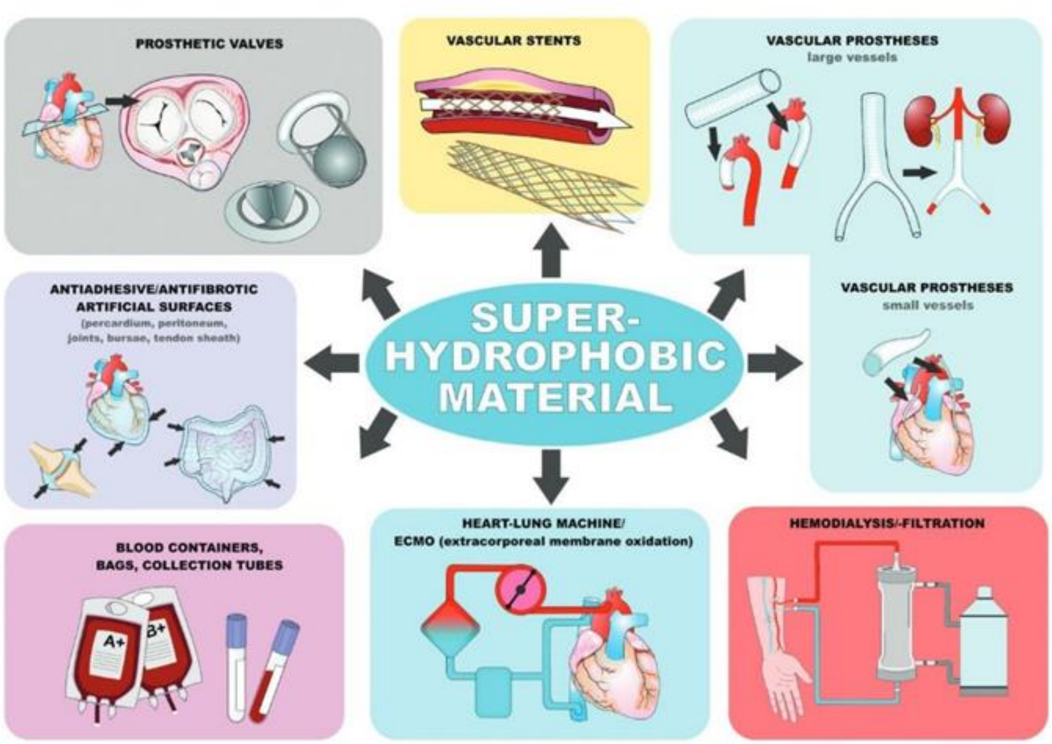

Figure 2: *Schematic conceptual depiction of employing superhydrophobic surfaces as blood-repellent coatings for advanced medical devices [Source: Adv. Mater. (2018)].*

Further, it has been observed that the biological environment in the body is conducive to the colonization of microorganisms on the surface that results in the formation of biofilms on the surface of catheters. This happens as a result of need for the devices for short-term or long-term existence in the body and frequent contact with the human body. This may lead to serious infection of medical materials that are implanted in the body that may cause thrombosis [21].

As we described before, biocompatibility should be considered along with antibacterial effects for all medical human implants. Superhydrophobic surfaces are very promising to address the issues related to blood contacts because such surfaces are known to be antibacterial as well as biocompatible properties that can be leveraged for biomedical implant applications. A major advantage of employing a superhydrophobic surface coating is that it can prevent the rejection of biomedical implants in the human body. To this end, in a study, researchers demonstrated a superhydrophobic material for dental implants. It was fabricated using commercial stainless steel, stearic acid, and chemical etching compounds. In another study, superhydrophobic titanium was fabricated by the anodizing method. Titanium structures were combined with fluorine coatings in valves and stents that resulted in reducing platelet adhesion and thrombosis [20, 22, 23]. Figure 2 shows various applications of superhydrophobic surfaces in preventing blood adhesion [20].

Concluding Remarks

There is a growing need for medical implants in today's healthcare to combat complex diseases and medical conditions. To this end, recent research activities have shown huge promise of employing superhydrophic materials and coatings for medical devices to mitigate the challenges of blood contact induced issues including serious infections and pathogens, to name a few. This field is still evolving and we anticipate more research activities to develop biocompatible, self-cleaning superhydrophobic materials in the future for all next generation applications of medical devices and implants.

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Biotechnology Advances around the World

Editor's Picks

Every issue of Biotechnology Kiosk presents select latest research news picked by the editors-in-chief on significant research breakthroughs in different areas of biotechnology around the world. The aim is to promote further R&D in all of these cutting-edge areas of biotechnology. The editors have compiled and included the following innovations and breakthroughs to highlight the latest biotechnology advances.

Dr. Megha Agrawal
Co Editor-in-Chief

Dr. Shyamasri Biswas
Co Editor-in-Chief

Sleep Research

Keeping the brain sharp

It is known that Alzheimer's is the main cause of cognitive decline in older adults. This has been shown to contribute to about 70% of dementia cases. Over the years, researchers have argued that lack of sleep or poor sleep is a common symptom of the disease that drives and accelerate the disease's progression. The general consensus is that poor sleep and Alzheimer's disease are both associated with cognitive decline. It has been proven to be challenging to separate out the effects of each, i.e. to determine how sleep and different stages of Alzheimer's disease are related. With respect to studies done on this subject, researchers have shown that self-reported short and long sleepers are both more likely to perform poorly on cognitive tests. However, such sleep studies typically have not included assessments of Alzheimer's disease.

In a new study, researchers in the US have addressed this issue and they studied older adults who sleep short or long. Their report showed that these adults experienced greater cognitive decline than those who sleep a moderate amount, even when the effects of early Alzheimer's disease were taken into account. The findings were published Oct. 20 in the journal Brain (Sleep and longitudinal cognitive performance in preclinical and early symptomatic Alzheimer's disease. Brain, 2021 DOI: https://doi.org/10.1093/brain/awab272).

In this multiyear study of older adults, researchers employed tracking cognitive function in a large group of older adults over several years and analyzed it against levels of Alzheimer's-related proteins and measures of brain activity during sleep. Subsequently, they generated crucial data that helped untangle the complicated relationship among sleep, Alzheimer's and cognitive function.

This study suggested a middle range, or sweet spot for total sleep time where cognitive performance was stable over time. Further, short and long sleep times were found to be associated with worse cognitive performance. It was attributed to the possible insufficient sleep or poor sleep quality. Ths research could open up new avenues to gain insights into possibility to intervene to improve sleep including increasing sleep time for short sleepers by an hour or so. This could potentially lead to positive effects on the cognitive performance with no decline further.

The findings could pave the way to new understanding and efforts to help keep people's minds sharp as they age.

Stem Cells

Gene regulation network in human brain development

It is known that the chimpanzee is our closest living relative in evolutionary terms. Studies have suggested that our kinship derives from a common ancestor. There is a strong evidence that our evolutionary paths separated about five to six million years ago that led to the chimpanzee of today, and Homo Sapiens, humankind in the 21st century. So, there is a general consensus that our DNA is very similar to that of the chimpanzee. This makes chimpanzee our closest living relative in evolutionary terms.

In a recent study, stem cell researchers at Lund University in Sweden have found a previously overlooked part of our DNA, so-called non-coded DNA. This DNA appears to contribute to a difference. This may explain despite all our similarities, why our brains work differently. The study by the researchers in Sweden was published in the journal Cell Stem Cell (A cis-acting structural variation at the ZNF558 locus controls a gene regulatory network in human brain development. Cell Stem Cell, 2021; DOI:https://doi.org/10.1016/j.stem.2021.09.008).

In this study, researchers used stem cells grown in a lab instead of studying living humans and chimpanzees. The stem cells were reprogrammed from skin cells by research partners in Germany, the USA and Japan. Subsequently, they examined the stem cells that they had developed into brain cells.

Using the stem cells, the researchers then specifically grew brain cells from humans and chimpanzees and then compared the two cell types. It was found that humans and chimpanzees use a part of their DNA in different ways. It appears to play a considerable role in the development of human brains.

The part of the DNA that was identified in this study as different was rather unexpected. It was found to be a so-called structural variant of DNA that were previously called junk DNA. This junk DNA has a long repetitive DNA string that has long been deemed to have no biological function and which constitutes the majority of our DNA. This study sheds new light because in previous studies, researchers studied the part of the DNA where the protein-producing genes were that only made up about two per cent of the entire junk DNA and they investigated the proteins themselves to find examples of differences.

This study is significant as it suggests that the basis for the human brain's evolution are genetic mechanisms that are probably a lot more complex that previously adopted hypotheses. These results pave the way to gain new insights into brain's development.

Compiled and Edited by Dr. Megha Agrawal and Dr. Shyamasri Biswas.


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