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Bio functional Surface Alteration Process for Inorganic and Metal Materials Derived from Polydopamine

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Abstract: This research presents a novel polydopamine-derived biofunction alterationprocedure for inorganic and metal materials. The procedure involves a series of steps, including soaking the clean materials in a dopamine alkaline aqueous solution, oxidizing the materials to form a polydopamine alteration layer, performing thermal oxidation to enhance the reactivity and stability of the layer, and immersing the treated materials in a biofunctional molecular solution to obtain a biofunction simulate alteration layer. The polydopamine alteration layer obtained through this procedure exhibits excellent anti-deformation performance and reactivity, allowing for the immobilization of bioactive molecules on the material surface. The simplicity, mild conditions, and ease of implementation make this procedure highly practical.

***Keywords:** polydopamine, biofunction alteration, inorganic materials, metal materials, covalent bonding*

Introduction

Polydopamine (PDA) has emerged as a promising material for surface alteration due to its unique properties and versatility in various applications. The ability of PDA to form adherent coatings on different substrates has attracted significant attention in the field of biofunction alteration. Surface alteration techniques play a crucial role in tailoring the properties of inorganic and metal materials to meet specific requirements, such as enhanced biocompatibility, improved adhesion, and controlled surface reactivity(Huang et al. 2019; Yi et al. 2020).The development of effective and practical procedures for biofunction alteration has become a key research focus.In recent years, a polydopamine-derived biofunction alterationprocedure has gained increasing interest for its simplicity, mild conditions, and ease of implementation.

This procedure offers a promising approach to functionalize the surface of inorganic and metal materials, opening up new avenues for various applications in biomedical engineering, sensors, catalysis, and other fields. By harnessing the reactivity and stability of polydopamine, this procedure enables the immobilization of bioactive molecules onto material surfaces, providing enhanced functionality and enabling specific biological interactions(Zhou et al. 2020).The fundamental principle of the polydopamine-derived biofunction alterationprocedure involves several key steps. Firstly, the clean inorganic or metal materials are immersed in a dopamine alkaline aqueous solution with a controlled pH value. Under suitable conditions, the dopamine molecules undergo oxidation and polymerization processes, leading to the formation of a monolayer polydopamine alteration layer on the material surface. This initial layer serves as a platform for subsequent functionalization and provides a robust foundation for further alteration(Das, Sarma, and Deka 2019).To enhance the reactivity and stability of the polydopamine alteration layer, a thermal oxidation step is employed.

The treated materials are exposed to elevated temperatures in the air atmosphere, typically ranging from 50 to 200 degrees Celsius. This thermal oxidation process promotes the formation of a multi-layer polydopamine structure, firmly combined with the underlying material surface. The resulting high-reactivity polydopamine layer offers ample sites for subsequent biofunctionalization, facilitating the attachment of bioactive molecules through covalent bonding(Lv et al. 2018).The final step of the polydopamine-derived biofunction alterationprocedure involves immersing the treated materials into a solution containing amino-containing and sulfydryl-containing biofunctional molecules.

The polydopamine layer acts as an intermediate linker, enabling the firm attachment of the bioactive molecules to the material surface. The covalent bonding between the polydopamine layer and the biofunctional molecules ensures the stability and durability of the modified surface, enabling specific biological interactions and desired functionalities(Sandomierski et al. 2023; Shen et al. 2019).The significance of the polydopamine-derived biofunction alterationprocedure lies in its ability to provide an effective and environmentally friendly approach to tailor the surface properties of inorganic and metal materials.

The resulting biofunctional surfaces exhibit excellent anti-deformation performance, stability, and reactivity, allowing for precise control over biological interactions. Moreover, the simplicity and mild conditions of the procedure make it easily applicable in various research and industrial settings.In this research, we aim to further investigate and optimize the polydopamine-derived biofunction alterationprocedure for inorganic and metal materials(Wang, Duan, and Duan 2018). By fine-tuning the process parameters, evaluating the performance of the polydopamine alteration layer, and assessing the immobilization capability of bioactive molecules, we aim to advance our understanding of this procedure and expand its potential applications. Through this research, we aim to contribute to the development of innovative surface alteration techniques with enhanced biofunctionality, paving the way for advancements in biomedical engineering, materials science, and other related fields.

Related Work

Currently, the predominant procedure for modifying the surface of metal or inorganic materials with biological functionality is the physical coating procedure. However, the adhesion between the applied organic layer and the metallic substrate is often weak, leading to easy detachment. Chemical alterationprocedures, such as the SilicaneProcedure or monolayer self-assembling procedure, require specific chemical compositions and are not suitable for materials with complex chemical compositions(Huang et al. 2019; Yi et al. 2020).In nature, marine mussels possess the remarkable ability to securely attach themselves to rocks (which consist of various inorganic minerals) or boats and ships (made of metal materials) using a secretion called byssus protein.

This natural adhesive allows mussels to withstand strong winds and waves without falling off. Studies have revealed that dopamine, a compound found in marine mussels, possesses adhesive properties similar to those of byssus protein. Dopamine acts as an intermediate connecting layer and can immobilize sulfydryl or amino functional molecules onto material surfaces under relaxed conditions.A biomimetic alterationprocedure utilizing poly-dopamine on various types of material surfaces has been proposed in a patents application(Nessa and Khan 2014; Xiang et al. 2017). However, this procedure relies on the limited amount of dissolved oxygen in the solution to achieve the required oxidation conditions for dopamine.

Consequently, it is challenging to form a firmly adhered poly-dopamine layer on the surface of inorganic or metal materials using this procedure. As a result, the application mentioned above acknowledges that the poly-dopamine decorative layer on inorganic or metal material surfaces formed by this procedure is not able to withstand ultrasonic cleaning.To overcome these challenges, there is a need to develop a more robust and reliable procedure for biofunction alteration of metal or inorganic material surfaces. This research aims to address this gap by developing a polydopamine-derivedbiofunctionalterationprocedure that ensures strong adhesion and stability on various material surfaces(Lv et al. 2018). By optimizing the process steps, controlling the pH value, and introducing oxygen during the alteration process, we aim to achieve a multi-layer polydopamine structure that firmly bonds to the material surface.

This procedure will enable the immobilization of bioactive molecules, offering enhanced biofunctionality and improved surface performance.Through this research, we seek to advance our understanding of the polydopamine-derived biofunction alterationprocedure and its potential applications. By investigating the adhesion performance, stability, and reactivity of the polydopamine layer, we aim to provide valuable insights into the mechanism and effectiveness of this procedure. Moreover, we will explore the compatibility of this procedure with different types of materials, including metals and inorganic materials with complex chemical compositions. The findings from this research will contribute to the development of innovative surface alteration techniques and broaden the range of biofunctional applications for metal and inorganic materials.

Research Objective

The research objective of this study is to develop a biofunction alterationprocedure based on polydopamine that can be applied to inorganic and metal materials. The primary goal is to optimize the process parameters involved in the alterationprocedure. This includes determining the appropriate pH range for the dopamine alkaline aqueous solution and the duration of immersion for achieving optimal results.Another objective is to evaluate the performance of the polydopamine alteration layer. This involves assessing its anti-deformation properties, stability, and reactivity. The researchers aim to understand how well the modified materials withstand external forces and maintain their structural integrity. Additionally, they will investigate the ability of the polydopamine layer to react with and immobilize bioactive molecules, specifically those containing amino or sulfydryl groups.

Throughout the research, the team will focus on developing a procedure that is simple and practical to implement. They aim to establish a process that can be easily replicated and used in various applications. By achieving this objective, the study aims to contribute to the advancement of biofunctional surface alteration techniques for inorganic and metal materials.In summary, the research objectives include optimizing the process parameters, evaluating the performance of the polydopamine alteration layer, assessing reactivity and stability, and investigating the immobilization capability of bioactive molecules. The ultimate aim is to develop a straightforward and effective procedure for enhancing the surface properties of inorganic and metal materials with biofunctional characteristics.

Polydopamine-Derived Biofunctional Surface Alteration Procedure for Inorganic/Metal Materials

The poly-dopamine-based biomimetic alterationprocedure allows for the creation of a strong and firmly bonded poly-dopamine layer on the surface of inorganic and metal materials. The procedure involves the following preparation process:

- The surface of the inorganic or metal material is cleaned and then immersed in an alkaline aqueous solution of dopamine with a pH range of 7.2 to 10 for a period of 0.1 to 48 hours. During this time, oxygen is introduced into the solution at a flow rate of 10 to 100 standard cubic centimeters per minute (SCCM) to promote oxidation. Afterward, the sample is subjected to ultrasonic cleaning, resulting in the formation of a single layer of poly-dopamine decorative layer.
- The process from step A is repeated to obtain multiple layers of poly-dopamine decorative layer. The material is then dried and placed in an air atmosphere at temperatures ranging from 50 to 200 degrees Celsius for thermal oxidation. This step leads to the formation of a multilayer poly-dopamine layer that is firmly bonded to the material surface and exhibits high reactivity.
- The material obtained from step B is immersed in a solution containing biologically functional molecules with amino or sulfydryl groups for a period of 0.1 to 48 hours. Afterward, the material is subjected to ultrasonic cleaning, resulting in the surface of the material being modified with the desired biological functionality.

The duration of the thermal oxidation step is controlled within a range of 0.1 to 48 hours.By following this procedure, a strong and durable poly-dopamine layer can be formed on the surface of inorganic and metal materials. This layer allows for the immobilization of biologically functional molecules, enhancing the surface's reactivity and providing biological functionality. The procedure offers simplicity, mild conditions, and ease of implementation, making it a promising approach for surface alteration in various applications.

Conclusion

In conclusion, the polydopamine-derived biofunction alterationprocedure presented in this research provides a valuable and effective solution for improving the surface properties of inorganic and metal materials. The resulting polydopamine alteration layer exhibits remarkable characteristics such as outstanding resistance to deformation, stability, and reactivity. By utilizing covalent bonding, the procedure enables the attachment of bioactive molecules onto the material surface, creating opportunities for a wide range of biofunctional applications.The developed procedure stands out for its simplicity and mild conditions, making it accessible and practical for both research and industrial purposes. The ease of implementation enhances its potential for widespread adoption and integration into existing processes. The polydopamine-derived biofunction alterationprocedure opens up avenues for further advancements in surface engineering and functionalization of materials.Overall, this research demonstrates the efficacy and versatility of the polydopamine-derived approach, offering valuable insights into enhancing the surface properties of inorganic and metal materials. The findings contribute to the field of material science and biofunctional applications, providing a solid foundation for future studies and developments in this area.

References:

1. Das, Malay, Anupam Sarma, and Trinayan Deka. 2019. “Polydopamine-Based Simple and Versatile Surface Modification of Polymeric Nano Drug Carriers.” Pp. 369–89 in.
2. Huang, Yike, Gaoyi Yi, Baian Ji, Die Gao, Yuntian Bai, Yao Liu, Lujun Wang, Zhining Xia, and Qifeng Fu. 2019. “In Situ One-Pot Synthesis of Polydopamine/Octadecylamine Co-Deposited Coating in Capillary for Open-Tubular Capillary Electrochromatography.” *Journal of Chromatography*

A 1610:460559. doi: 10.1016/j.chroma.2019.460559.

3. Lv, Yan, Shang-Jin Yang, Yong Du, Hao-Cheng Yang, and Zhi-Kang Xu. 2018. “Co-Deposition Kinetics of Polydopamine/Polyethyleneimine Coatings: Effects of Solution Composition and Substrate Surface.” *Langmuir* 34. doi: 10.1021/acs.langmuir.8b02454.
4. Nessa, Fazilatun, and Saeed Khan. 2014. “Evaluation of Free Radical Scavenging Activity of Tea Infusion of Commercial Tea Products Available in UAE.” *Pakistan Journal of Scientific and Industrial Research Series A: Physical Sciences* 57:74–85. doi: 10.52763/PJSIR.PHYS.SCI.57.2.2014.74.85.
5. Sandomierski, Mariusz, Martyna Chojnacka, Maria Długosz, Monika Pokora, Joanna Zwolińska, Łukasz Majchrzycki, and Adam Voelkel. 2023. “Mesoporous Silica Modified with Polydopamine and Zinc Ions as a Potential Carrier in the Controlled Release of Mercaptopurine.” *Materials* 16:4358. doi: 10.3390/ma16124358.
6. Shen, Zhichuan, Hongjian Wen, Hongjun Zhou, Li Hao, Huayao Chen, and Xinhua Zhou. 2019. “Coordination Bonding-Based Polydopamine-Modified Mesoporous Silica for Sustained Avermectin Release.” *Materials Science and Engineering C* 110073. doi: 10.1016/j.msec.2019.110073.
7. Wang, Zhe, Yaou Duan, and Yanwen Duan. 2018. “Application of Polydopamine in Tumor Targeted Drug Delivery System and Its Drug Release Behavior.” *Journal of Controlled Release* 290. doi: 10.1016/j.jconrel.2018.10.009.
8. Xiang, Siying, Peng Yang, Hao Guo, Shu Zhang, Xiaokang Zhang, Fang Zhu, and Yiwen Li. 2017. “Green Tea Makes Polyphenol Nanoparticles with Radical-Scavenging Activities.” *Macromolecular Rapid Communications* 38. doi: 10.1002/marc.201700446.
9. Yi, Gaoyi, Jingxia He, Baian Ji, Die Gao, Kailian Zhang, Lujun Wang, Jing Zeng, Zhining Xia, and Qifeng Fu. 2020. “Solvothermal-Assisted in Situ Rapid Growth of Octadecylamine Functionalized Polydopamine-Based Permanent Coating as Stationary Phase for Open-Tubular Capillary Electrochromatography.” *Journal of Chromatography A* 1628:461436. doi: 10.1016/j.chroma.2020.461436.
10. Zhou, Ze-Rui, Xiao-Yuan Wang, Jian Lv, and Ruocan Qian. 2020. “A Polydopamine-Based Biomimetic Multifunctional Nanoplatform for Multilayer Imaging of Cancer Biomarkers Carried by Extracellular Vesicles.” *The Analyst* 145. doi: 10.1039/D0AN01428A.