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Biomimetic Channels Providing Easier Access of Liquid Water Flow toward the Dry-Out Spots

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Abstract

A novel biomimetic aerodynamic thrust bearing is developed and investigated. The surface structure of the bearing is evolved from the micro-grids of dragonfly wings, which presumably aid flying and maneuver ability of dragonflies. The topography of the micro-grids of dragonfly wings was studied and five most representative geometries were extracted before being put on thrust bearings for performance examination. A theoretical model, solved with finite different and finite volume method, is developed to compare the static load capacity of the bearings under various velocities and flow angles, and the best geometry and velocity angle were selected and manufactured on the bearing surface for experimental tests. The dragonfly wing biomimetic bearing is found to increase load capacity by up to 46.11% in comparison with an optimized conventional spiral grooved bearing by experiments.

Keywords; n: Biomaterials; Heat transfer coefficient; Nano medicine; Nanotechnology; Tissue engineering

Introduction

Novel biomimetic structures are designed and synthesized to enable liquid water flowing from the periphery to the center of a heating surface, and promote local liquid wicking and active nucleation site density, which enhance the critical heat flux (CHF) and heat transfer coefficient (HTC) of pool boiling heat transfer. The biomimetic structures are designed by mimicking leaf vein growth from an initial point of petiole to an architecture that supplies water and nutrition to the whole leaf lamina. The in-plane flow channels are developed to distribute liquid toward bubble nucleation sites on a heating surface. The in-plane flow channels are then fabricated by: 1) machining a solid biomimetic groove structure at 250 µm height on plain copper surfaces, 2) depositing ~70 nm diameter copper nanowires (CuNWs) of height 25 µm on the solid biomimetic groove structure, and 3) sintering ~25 µm diameter copper powder to create porous biomimetic structures at various heights.

Discussion

The experimental pool boiling results on different structures show that the sintered porous biomimetic structure at 1.0 mm height yields the highest CHF of 343.1 W/cm2, an increase of 206% over that on a polished plain copper surface, which is due to the biomimetic channels providing easier access of liquid water flow toward the dry-out spots as indicated by a liquid inflow factor. The biomimetic structure of CuNWs has dramatically increased CHF and heat transfer coefficient (HTC) than that of a plain surface and a solid biomimetic structure. A theoretical analysis of the liquid thin film beneath hovering bubbles reveals that the population density of vapor stems in the liquid thin film increases with a decrease of the vapor stem diameter as heat flux increases. Moreover, the porous biomimetic structures take advantage of active nucleation sites and their wicking effect to delay the hydrodynamic instability of the liquid thin film, thus increasing the pool boiling heat transfer. Biomimetic catalysts have drawn broad research interest owing to both high specificity and excellent catalytic activity. Herein, we report a series of biomimetic catalysts by the integration of biomolecules (hemin or ferrous phthalocyanine) onto well-defined Au/CeO2, which leads to the high-performance CO oxidation catalysts. Strong electronic interactions among the biomolecule, Au, and CeO2 were confirmed, and the CO uptake over hemin-Au/CeO2 was roughly about 8 times greater than Au/CeO2. Based on the Au/CeO2(111) and hemin-Au/CeO2 (111) models, the density functional theory calculations reveal the mechanisms of the biomolecules-assisted catalysis process. The theoretical prediction suggests that CO and O2 molecules preferentially bind to the surface of noncontacting Au atoms (low-coordinated sites) rather than the biomolecule sites, and the accelerating oxidation of Au-bound CO occurs via either the Langmuir-Hinshelwood mechanism or the Mars-van Krevelen mechanism [1-4].

Accordingly, the findings provide useful insights into developing biomimetic catalysts with low cost and high activity. Smart surfaces that can manipulate droplets or fluids have attracted intense attention because of their essential application prospects. However, it is still a challenge to obtain multifunctional integrated metal platforms that can simultaneously manipulate water/oil droplets and water/oil fluids. Here, inspired by the structure and wettability of natural reed leaves and lotus leaves, dual biomimetic platforms with switchable and anisotropic/isotropic wettability were prepared on copper by laser processing, chemical etching, and mixed thiol modification. The wettability of the integrated platforms can respond to the change of external pH value and reversibly switch between superhydrophobicity and underwater superoleophobicity. The areas of "reed leaf" structure and "lotus leaf" structure on the biomimetic platform have anisotropic and isotropic wettability, respectively. Significantly, by rationally designing the distribution of bionic structures, the dual biomimetic platforms can simultaneously manipulate water/oil droplets and water/oil fluids. This work not only provides advanced integrated biomimetic platforms and interesting design strategies, but also has important reference value in the development of new metal microfluidic devices. Here we present a biomimetic strategy towards an influenza vaccine design based on hepatitis B virus core virus-like particles (HBc VLP).

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To this end, a temperature-shift based encapsulation process based on analysis of the unique thermal-associated structural flexibility of HBc VLP nanocages was proposed and proved efficient for encapsulation of antigen inside the VLP. By displaying a matrix protein 2 ectodomain (M2e) antigen on the exterior of HBc VLP through genetic fusion, and encapsulate a conserved internal nucleoprotein (NP) antigen peptide inside the VLP, a biomimetic dual-antigen influenza vaccine with interior NP/exterior M2e was constructed. For comparison, another non-biomimetic dual-antigen vaccine with interior M2e/exterior NP, and other four VLP-based single-antigen vaccines with NP or M2e either being encapsulated inside or genetically displayed outside the VLP were also constructed. Upon intraperitoneal immunization in mice, the dual-antigen VLP influenza vaccine elicited both NP and M2e-specific antibodies, which were stronger than those elicited by the single-antigen vaccines. Most importantly, after a lethal challenge of H1N1 virus, the biomimetic dual-antigen vaccine conferred the mice 100% protection without noticeable body weight loss in the absence of any adjuvant. While the protective efficacy conferred by the non-biomimetic one was only 62.5%, accompanying 12.5% body weight loss in the immunized mice. Besides the high level of antigen-specific antibodies, more efficient formation of total germinal center (GC) B cells and a higher level of effector memory CD8+ T cell population were observed in the biomimetic vaccine group, as compared with the non-biomimetic one. All these results demonstrate that VLP assembly and display of antigens in a biomimetic manner were making this a promising strategy for the production of efficient universal vaccines to influenza and other rapidly emerging pathogens [5-7].

Elastin-like polypeptides (ELPs), usually as a purification-tag, can be easily expressed and rapidly purified. We found ELPs[V9F-40], which did not contain hydroxyl or charged residues with the pI of 5.52, could biomimetic ally form silica when they were in ordered structure. The specific activity of ELPs [V9F-40] was 70.89 ± 9.53. Besides, the time needed for the completion of biomimetic silicification was about 138 s, which was only 1/3 of that for other reported peptides. The ELPs@silica is mainly spherical and the sizes of them were around 900 nm. However, currently presented mechanisms for peptide-triggered silica biomimetic mineralization could not explain such unique phenomenon. It would pave a new way for mining or designing peptides with such function, which provide a potential green method for the preparation of biomimetic silica particles. It would endow ELPs more functions and expand the application fields of ELPs such as the bioinspired synthesis of peptide biotemplated metal or nonmetal oxide nanoparticles. Construction of biomimetic catalytic systems is recognized as one of the most prospective, but is challenging approaches to achieve efficient aerobic oxidative transformations. Herein, a green aerobic oxidative desulfurization (AODS) biomimetic system was designed, which combined an Anderson polyoxometalate (POM) -based ionic liquid (IL) with deep eutectic solvent (DES). The 3-(pyridine-1-ium-1-yl) propane-1-sulfonate] 3 Co(OH) 6Mo6O18 {abbreviate as [PyPS]3Co(OH)6Mo6O18} combined high catalytic activity and stability with perfect synthetic availability on the desulfurization of diesel. Also, excellent recoverability showing little decrease in activity after 5 cycles has aroused the great interest. Cyclic voltammogram measurement shows conclusive evidence of oxygen activation with a 17-fold current density increase, further confirming the reduction of the aerobic oxidation reaction barrier. It revealed the biomimetic oxygen activation and synergistic electron transfers mechanism for ODS, which may provide a new insight into the construction of biomimetic system in the future. Protein-based bioadhesives are found in diverse marine invertebrates that developed attachment devices to adhere to various substrates. These adhesives are of interest to materials science to create bioinspired-adhesives that can perform in water or wet conditions and can be applied in a broad variety of biotechnological and industrial fields. Due to the high variety of invertebrates that inhabit the marine environment, an enormous diversity of structures and principles used in biological adhesives remains unexplored and a very limited number of model systems have inspired novel biomimetic adhesives, the most notable being the mussel byssus adhesive. In this review we give an overview of other marine invertebrates studied for their bioadhesive properties in view of their interest for the development of new biomimetic adhesives for application in the biomedical field but also for antifouling coatings. The molecular features are described, highlighting relevant structures, and examples of biomimetic materials are discussed and explored, opening an avenue for a new set of medical products. Biomimetic gold nanoparticles of biological origin have created a significant impact on the field of biomedicine due to the great expectations of its applications. Because of this, the influences of biomimetic gold nanoparticles have been immensely studied, targeting various cancer cells. However, the impact of biomimetic gold nanoparticles against normal non-cancerous cells is scanty, which impose several limitations in their utility. Taking this as a challenge, we in this study report the biomimetic based assays in cultured cells [8-10].

Conclusion

The gold nanoparticles obtained in the study were spherical shaped with a mean diameter of 12 ± 4.2 nm. The seaweed extract plays a crucial role in stabilizing the gold nanoparticles to avoid aggregation and coalescence. At an IC50 concentration of 43.09 ± 1.6 μgmL−1, the biomimetic gold nanoparticles were found to be toxic to cancerous cells (MDA-MB-231). Whereas, biomimetic gold nanoparticles exhibit significant biocompatibility with human embryonic kidney cells even at a higher concentration of 150 μgmL−1. The morphological based fluorescence assays confirmed the ability of biomimetic gold nanoparticles in inducing apoptosis and thereby kills cancer cells. Altogether, the gold nanoparticles were safe to normal cells and did not show a significant impact. Hence, the novel biomimetic gold nanoparticles hold potential as multifaceted agent and can further be taken up to various biomedical applications.

Acknowledgment

None

Conflict of Interest

None

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