Journal of Biotechnology & Biomaterials
ISSN: 2155-952X
2020
Vol.10 No.5

Destructive electron extraction from bacterial membrane respiration chain for advanced infection

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Abstract

The rise of multidrug-resistant bacteria and the dearth of novel antibiotic development urgently need breakthrough strategies that go beyond classical antibiotic mechanism to fight this approaching human health cataclysm. There is an increasing demand for successful infection treatment through innovative therapy solutions. Inspired by the metabolism cascade of bacteria, a new antibacterial concept i.e. “bacteria starvation therapy” is developed to enable the drainage of extracellular electrons from the electron transfer chain in membrane respiration and thereby interrupt the energy metabolism. This thought has been realized by several elaborately designed material systems including: (i) graphene film on conductor Cu, semiconductor Ge and insulator SiO2 substrates, (ii) Ag, Au or Co doped TiO2 coatings, and (iii) W doped VO2 thin films. We first design system (i) and show that the antibacterial ability has a strong dependence on substrate electrical conductivity (band structure) in the order of Cu > Ge > SiO2. To testify our thought, we further use system (ii) to display that the antibacterial activity can be significantly enhanced along with narrowing TiO2 bandgap and tailoring energy band structure to make its conduction band bottom lower than the biological redox potentials (−4.12 ~ −4.84 eV) generated from the sequential redox couples in extracellular electron transfer chain of bacteria. To expand the universality of our hypothesis, we select system (iii) and reveal that W doping is able to tailor the semiconductor-tometal phase change of VO2 thin film, narrow its bandgap and increase electrical conductivity, thereby boosting the antibacterial property. In conclusion, band-structure-tunable semiconductor materials can serve as extracellular electron acceptors and interfere with electron transfer and energy metabolism to effectively inhibit bacteria growth (“bacteria starvation therapy”). Through the infection starvation therapy, the number of bacteria on biomaterial implants and infected tissues can be significantly decreased. This starvation therapy concept can also apply to cancer therapy because mitochondria are similar to bacteria on the basis of endosymbiotic theory. The “bacteria starvation therapy” provides new insights into the nano–bio interactions and paves the way for the design of novel antibacterial and anticancer nanomaterials.

Biography:

Dr. Jinhua Li received his Ph.D. in Materials Science from University of Chinese Academy of Sciences in 2016. He then worked as postdoc researcher from 2016 to 2018 at University of Hong Kong. He is currently Alexander von Humboldt Fellow at Technische Universität Dresden.

Speaker Publications:

1. Advanced antibacterial activity of biocompatible tantalum nanofilm via enhanced local innate immunity
2. Destructive electron extraction from bacterial membrane respiration chain for advanced infection

5th Annual Conference and Expo on Biomaterials; Webinar - August 31- September 01, 2020

Abstract Citation:

Jinhua Li, Destructive electron extraction from bacterial membrane respiration chain for advanced infection, Biomaterials 2020, 5th Annual Conference and Expo on Biomaterials; August 31-September 01, 2020

(https://biomaterials.insightconferences.com/abstract/2020/destructive-electron-extraction-from-bacterial-membrane-respiration-chain-for-advanced-infection)