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Formation of ROS-Generating Nitrogen-Species in Bacteria-Derived Carbon Quantum Dots

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Extended Abstract

Bacteria are rapidly emerging as an intriguing, natural carbon source for the synthesis of carbon quantum dots (CQDs) [1,2]. Bacteria-derived CQDs have been proposed for microbial live/dead differentiation, environmental pollutant detection and infectious biofilm control. Anti-biofilm properties of bacteria-derived CQDs are due to the generation of reactive-oxygen-species (ROS) [3], but the specific nitrogen-species responsible for ROS-generation by bacteria-derived CQDs are unknown. Equally, the chemical components of source-bacteria yielding optimal ROS-generation by bacteria-derived CQDs are unknown. To address these open questions, CQDs were prepared by hydrothermal-carbonization of different strains of bacteria. Formation of low-yield CQDs (diameter 2-3 nm) was confirmed using UV-vis absorption and fluorescence emission spectroscopy. Amide bands characteristic of proteins in Fourier Transform InfraRed (FTIR) spectra of source-bacteria remained visible upon hydrothermal-carbonization in bacteria-derived CQDs as minor bands. X-ray Photoelectron Spectroscopy (XPS) indicated an N1s photo-electron binding energy peak at 399.5 eV in source-bacteria due to amines that were converted upon carbonization into pyrrolic (400.5 eV) and graphitic (401.8 eV) nitrogen in bacteria-derived CQDs. Considering the occurrence of amines in proteinaceous amide bonds, the combination of FTIR and XPS results demonstrates that bacterial proteins are converted into pyrrolic and graphitic nitrogen-species upon hydrothermal-carbonization, as confirmed by relations between the occurrence of amine nitrogen in source-bacteria with pyrrolic and graphitic nitrogen in CQDs. Relations between ROS-generation with the occurrence of pyrrolic and graphitic nitrogen-species, identified these nitrogen-species in bacteria-derived CQDs as being responsible for enhanced ROS-generation and accompanying anti-biofilm activity. These findings enable selection of source-bacteria with optimized ROS-generation and anti-biofilm activity upon carbonization based on their protein content.

References

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