



LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

Bacteria-Mineral Interactions on the Surfaces of Metal-Resistant Bacteria

A. J. Malkin

March 25, 2010

Disclaimer

This document was prepared as an account of work sponsored by an agency of the United States government. Neither the United States government nor Lawrence Livermore National Security, LLC, nor any of their employees makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States government or Lawrence Livermore National Security, LLC. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or Lawrence Livermore National Security, LLC, and shall not be used for advertising or product endorsement purposes.

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

FY09 LDRD Final Report

Bacteria-Mineral Interactions on the Surfaces of Metal-Resistant Bacteria

LDRD Project Tracking Code: 08-LW-027

Alexander J. Malkin, Principal Investigator

The extraordinary ability of indigenous microorganisms, like metal-resistant bacteria, for biotransformation of toxic compounds is of considerable interest for the emerging area of environmental bioremediation. However, the underlying mechanisms by which metal-resistant bacteria transform toxic compounds are currently unknown and await elucidation. The project's objective was to study stress-induced responses of metal-resistant bacteria to environmental changes and chemical stimulants.

This project involved a multi-institutional collaboration of our LLNL group with the group of Dr. H.-Y. Holman (Lawrence Berkeley National Laboratory). In this project, we have utilized metal-resistant bacteria *Arthrobacter oxydans* as a model bacterial system. We have utilized atomic force microscopy (AFM) to visualize for *the first time* at the nanometer scale formation of stress-induced structures on bacterial surfaces in response to Cr (VI) exposure. We have demonstrated that structure, assembly, and composition of these stress-induced structures are dependent on Cr (VI) concentrations. Our AFM observations of the appearance and development of stress-induced layers on the surfaces of *Arthrobacter oxydans* bacteria exposed to Cr (VI) were confirmed by Dr. Holman's biochemical, electron microscopy, and synchrotron infrared spectromicroscopy studies. In general, in vitro imaging of live microbial and cellular systems represents one of the most challenging issues in application of AFM. Various approaches for immobilization of bacteria on the substrate for in vitro imaging were tested in this project. Imaging of live bacteria was achieved, however further optimization of experimental methods are needed for high-resolution visualization of the cellular environmental structural dynamics by AFM

This project enhanced the current insight into molecular architecture, structural and environmental variability of bacterial systems. The project partially funded research for two book chapters (1,2), and we anticipate one more publication (3). The publications describe development of methods and results of studies of structural dynamics of metal-resistant bacteria that contribute to more comprehensive understanding of the architecture, function, and environmental dynamics of bacterial and cellular systems.

The results of this LDRD were presented in invited talks and contributed presentations at five national and international conferences and five seminar presentations at the external institutions. These included invited talks at the conferences of Gordon Research, Materials Research and American Chemical Societies.

Our scientific results and methodologies developed in this project enabled us to receive new funding for the multiyear project “Chromium transformation pathways in metal-reducing bacteria” funded by the University of California Lab Fees Program (\$500,000, 5/1/09 – 4/30/2012), with our proposal being ranked 1st from a total of 138 in the Earth, Energy, Environmental & Space Sciences panel.

REFERENCES

Publications in press:

1. A.J. Malkin (2010). Resolving the high-resolution architecture, assembly and functional repertoire of bacterial systems by *in vitro* atomic force microscopy. In: *Life at the Nanoscale: Atomic Force Microscopy of Live Cells*. (Ed. Y.Dufrene). To be published by Pan Stanford Publishing.
2. A.J. Malkin and M.Plomp (2010). High-resolution architecture and structural dynamics of microbial and cellular system: Insights from high-resolution *in vitro* atomic force microscopy. In: *Scanning Probe Microscopy of Functional Materials: Nanoscale Imaging and Spectroscopy*. (Eds. S.V. Kalinin and A. Gruverman). To be published by Springer.

In preparation:

3. M. Plomp, S. Elhadj, H.-Y. Holman, and A.J. Malkin, Structural dynamics of metal resistant bacteria: *Arthrobacter oxydans* stress responses to chromium exposure, *in preparation*.

PRESENTATIONS

Invited conference presentations:

Gordon Research Conference on Thin Film and Crystal Growth Mechanisms, Colby-Sawyer College, NH, July 2009

American Chemical Society Meeting, Salt Lake City, March 2009

American Chemical Society Northeast Regional Meeting), Burlington, VA, June 2008.

Materials Research Society Fall Meeting, Boston, MA, November 2007

Contributed conference presentation:

Physics of Cells: From the Edge to the Heart, Primošten, Croatia, September 2009

INVITED SEMINAR PRESENTATIONS:

Joint Bioenergy Institute, Emeryville, CA, April 2009

Molecular Foundry, Lawrence Berkeley National Laboratory, Berkeley, CA, February 2009

Novozymes Inc, Davis, CA, January 2009

University of California at Davis, Biophysical Program Davis, CA, October 2008

University of California at Riverside, Bioengineering Department, Riverside, CA, April 2008