

PRODUCTION AND CHARACTERIZATION OF BACTERIAL NANOMAGNETS

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PRODUCTION AND CHARACTERIZATION OF BACTERIAL NANOMAGNETS

by

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Submitted

**in fulfillment of the requirements of the degree of
Doctor of Philosophy**

to the



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Dedicated to

My Family

And

My beloved Parents

CERTIFICATE

This is to certify that the thesis entitled “**Production and characterization of bacterial nano-magnets**”, being submitted by **Mr. Naresh Mohit V S** to the Indian Institute of Technology, Delhi, for the award of degree of **Doctor of Philosophy**, is a record of bonafide research work carried out by him, which has been prepared under our supervision and guidance in conformity with the rules and regulations of “Indian Institute of Technology, Delhi”. The research reports and the results presented in this thesis have not been submitted in part or full to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

In this work, *M. gryphiswaldense* cultures have been successfully grown on agar plates, test tubes, flasks and finally in 3 L bioreactors.

Using the classical biochemical engineering approach for understanding the consumption of carbon, nitrogen, oxygen and iron by magnetotactic bacteria in bioreactors, this work reports the first ever experimentally derived stoichiometric formula for a magnetotactic bacterial cell. By balancing the carbon sources, oxygen feeding rates and soluble iron concentrations, this work has provided 40% higher productivity (compared to published literature) for cultures of *M. gryphiswaldense*.

Subsequent to the above, the obvious energetic impact of sophisticated eukaryotic-like membrane-bound organelle assembly on a presumably simpler prokaryotic system is not addressed in literature. This work reports the first of its kind experimental evidence for the presumed energy consumption during assembly of naturally occurring sub-100 nm intra-cellular organelles. This study provides the first experimentally derived estimate of energy for organelle synthesis by *Magnetospirillum gryphiswaldense* as ~ 5 nJoules per magnetosome.

Besides the chemical formula for a magnetotactic bacterial cell and energetics of organelle synthesis, detailed structural characterization work has been carried out for the biologically synthesized nanomagnets. This work includes results on the first of their kind measurements on the intracellular distributions of bacterial nano-magnets using TEM and HRTEM with rigorous data analysis. These results include the intracellular size and crystal density distributions for bacterial nanomagnets with very specific structural features. This work has explicitly discussed various fundamental implications of the

results obtained, while highlighting the relevance of the findings in the context of understanding the mechanism of biological synthesis of nanomagnets.

Apart from detailed structural characterizations, this work reports the first ever magnetic measurements on bacterial nanomagnets inside intact bacterial cells. Rigorous AFM/NSOM experimentation coupled with data analysis on several single cells has provided fascinating insights into the magnetic behavior of the intracellular nanomagnets.

One of the very promising applications of nanomagnets is the possible ability to control and direct motion of small entities using external magnetic fields. By using dead (but intact) and living bacterial cells as representatives of 3-4 micron long entities containing nanomagnets, this work shows magnetic control of motion in absence and presence of other (biological) forces such as natural propulsion.

CONTENTS

Title	Page No.
List of Figures	i-ii
List of Tables	iii
List of Abbreviations	iv-v
Chapter 1: Introduction and Objectives	1-3
1.1 Introduction	1
1.2 Objectives	2
Chapter 2: Review of Literature	4-19
2.1 Biological synthesis of (inorganic) crystalline nanostructures	6
2.1.1 Iron- Rich Magnetic Nanostructures	7
2.1.2 Silver and Gold Nanostructures	9
2.1.3 Cadmium- and Zinc- Based Nanostructures	10
2.1.4 Other Inorganic–Metallic Crystalline Nanostructures	11
2.2 Biological Synthesis of Nanostructures - Magnetotactic Bacteria: The Example of Nanomagnets	13
2.3 Controlled Positioning of Biological “Factories” Synthesizing Nanostructures	16
2.3.1 Controlling Orientation: The Case of Magnetotactic Bacteria	18
Chapter 3: Materials and Methods	20-33
3.1 Chemicals and special equipments	20
3.1.1 Chemicals	20
3.1.2 Special equipments	23
3.2 Microbial cell culture	24
3.2.1 Growth of <i>M. gryphiswaldense</i> on Activated Charcoal Agar (ACA)	24
3.2.2 Culture maintenance and inoculum preparation of <i>M. gryphiswaldense</i>	25
3.3 Growth of <i>M. gryphiswaldense</i> on different cultivation media	25

Title	Page No.
3.3.1 Preparation of DSM 380 medium	26
3.3.2 Preparation of DSM 512 medium	27
3.3.3 Preparation of HS medium	27
3.3.4 Production medium for growth of <i>M. gryphiswaldense</i> in Bioreactor	28
3.3.5 Addition of exogenous siderophores	29
3.4 Magnetosome Purification	29
3.5 Analytical methods	29
3.5.1 Estimation of Lactate concentration	29
3.5.2 Estimation of nitrate concentration	29
3.5.3 Estimation of total nitrogen concentration	30
3.5.4 Estimation of Iron	30
3.5.5 Estimation of cell growth	30
3.5.6 Estimation of wet cell weight	30
3.5.7 Estimation of dry cell weight	31
3.5.8 Estimation of cell count	31
3.5.9 Estimation of magnetite (Fe ₃ O ₄)	31
3.5.10 Measurement of growth rate (k), specific growth rate (μ) and Yield	31
3.5.11 Estimation of carbon dioxide (CO ₂)	32
3.6 Specimen Preparation for TEM and HRTEM	32
3.7 Specimen Preparation for NSOM	32
3.8 Design of electromagnet and sample preparation for digital video microscopy	33
Chapter 4: Results and Discussion	34-118
4.1 Culturing of magnetotactic bacteria and production of magnetosomes:	35
From tubes to shake flasks to bioreactors	
4.1.1 Energetics of organelle formation in magnetotactic bacteria	35
4.1.1.1 Introduction	35
4.1.1.2 Results and Discussion	37
4.1.1.2.1 <i>M. gryphiswaldense</i> cell cultures show two	37

Title	Page No.
phenotypes, with magnetosomal synthesis leading to heavier cell pellets	
4.1.1.2.2 Energetics of cell growth and organelle synthesis	41
4.1.1.2.3 Energy calculations for cell growth and organelle synthesis	43
4.1.1.2.4 Iron uptake leading to magnetosomal synthesis stunts bacterial growth	47
4.1.1.2.5 Exogenous siderophores assist in reducing the metabolic load for synthesizing magnetosomes	50
4.1.1.2.6 Carbon is the “limiting reactant” during iron uptake leading to organelle synthesis	51
4.1.1.2.7 Energetics for organelle synthesis of <i>M. gryphiswaldense</i>	54
4.1.2 The chemical formula of a magnetotactic bacterium	58
4.1.2.1 Introduction	58
4.1.2.2 Results and Discussion	61
4.1.2.2.1 Growth of <i>M. gryphiswaldense</i>	61
4.1.2.2.2 Determination of chemical formula for <i>M. gryphiswaldense</i>	63
4.1.2.2.3 Nutrient consumption of <i>M. gryphiswaldense</i>	75
4.1.2.2.4 Role of water for magnetosome formation	80
4.2 Structural Characterization of magnetosomes	82
4.2.1 Introduction	82
4.2.2 Results and Discussion	83
4.2.2.1 Structural characterization of magnetosomes by HRTEM	83
4.2.2.2 NSOM imaging of magnetosomes	89

Title	Page No.
4.3 <i>In vivo</i> magnetic properties of bacterial nanomagnets	91
4.3.1 Introduction	91
4.3.2 Results and Discussion	93
4.3.2.1 Magnetosomal size depends on intracellular position	93
4.3.2.2 <i>In vivo</i> measurements of magnetosomal magnetic fields	100
4.3.2.3 Magnetization of magnetosomes depend on their intracellular positions and magnetosomal size	104
4.4 Control of motion of micron-scale entities using biological nanomagnets	109
4.4.1 Introduction	109
4.4.2 Results and Discussion	110
4.4.2.1 Design of microscope bench to control motility of magnetotactic bacteria	110
4.4.2.2. Controlling Orientation of magnetotactic bacterial cells	113
Chapter 5: Summary and Conclusions	119-122
References	123-155
Appendix	156-161
Resume of author	162-166