PRODUCTION AND CHARACTERIZATION OF BACTERIAL NANOMAGNETS

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by

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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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(Naresh Mohit V S)

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.

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