PONTIFÍCIA UNIVERSIDADE CATÓLICA
DO RIO DE JANEIRO

Leslie Yasmin López Olivares

Fundamental aspects of hematite flotation using the bacterial strain *Rhodococcus ruber*

Dissertação de Mestrado

Thesis presented to the Programa de Pós-graduação em Engenharia de Materiais e Processos Químicos e Metalúrgicos, PUC-Rio as partial fulfilment of the requirements for the degree of Mestre em Engenharia de Materiais e Processos Químicos e Metalúrgicos.

Advisor: Prof. Mauricio Leonardo Torem
Co-advisor: Dr. Antonio Gutierrez Merma

Rio de Janeiro
April 2014

PONTIFÍCIA UNIVERSIDADE CATÓLICA
DO RIO DE JANEIRO

Leslie Yasmin López Olivares

Fundamental aspects of hematite flotation using the bacterial strain *Rhodococcus ruber*

Thesis presented to the Programa de Pós-graduação em Engenharia de Materiais e Processos Químicos e Metalúrgicos do Centro Técnico Científico da PUC-Rio as partial fulfilment of the requirements for the degree of Mestre em Engenharia de Materiais e Processos Químicos e Metalúrgicos.

Prof. Mauricio Leonardo Torem
Advisor
Departamento de Engenharia de Materiais - PUC- Rio

Dr. Antonio G. Merma
Co-advisor
Departamento de Engenharia de Materiais - PUC - Rio

Dr. Gabriela A. H. Pino
Departamento de Engenharia de Materiais - PUC - Rio

Dr. Marissa B. M. Monte
Centro de Tecnologia Mineral - CETEM

Prof. José Eugenio Leal
Coordinator of the Centro Técnico Científico - PUC-Rio

Rio de Janeiro, april 7th, 2014

Leslie Yasmin López Olivares

Leslie Yasmin Lopez Olivares holds a BSc. in Chemical Engineering from Universidad Nacional Mayor de San Marcos (2011), and now a MSc. in Materials Engineering and Chemical and Metallurgical Processes from Pontifícia Universidade Católica do Rio de Janeiro. She has experience in Metallurgical Process Consulting in Peru, developing mainly in Mineral Processing and Geometallurgy. From 2012 to 2014, she worked as researcher in Mineral and Environmental technology.

Bibliographic data

López Olivares, Leslie Yasmin

Fundamental aspects of hematite flotation using the bacterial strain *Rhodococcus ruber* / Leslie Yasmin López Olivares; advisor: Mauricio Leonardo Torem; co-advisor: Antonio Gutierrez Merma. – 2014.

107 f.: il. (color.); 30 cm

Dissertação (mestrado) – Pontifícia Universidade Católica do Rio de Janeiro, Departamento de Engenharia de Materiais, 2014.

Inclui bibliografia

1. Engenharia de materiais – Teses. 2. Hematita. 3. Bioflotação. 4. *Rhodococcus ruber*. 5. Célula de flotação Partridge-Smith. I. Torem, Mauricio Leonardo. II. Gutierrez Merma, Antonio. III. Pontifícia Universidade Católica do Rio de Janeiro. Departamento de Engenharia de Materiais. IV. Título.

CDD: 620.11

My gratitude to Rosa, Daniel and Harold, for the same love as always, for your patience and comprehension in this time we were apart. I love you, God bless your ways. And to Him, for the strength and faith to accomplish this goal. Thanks.

Acknowledgments

Nothing happens by chance in our lives. I strongly believe we all came for a reason which is the purpose in our passage. Therefore, it is with great pleasure I would like to thank the people who influence in a positive way this work.

In first place, I would like to thank my dear professor and thesis advisor, Prof. Mauricio L. Torem, for not only the lessons I received from him, but also for the trust he gave me since we met; for his support and for believing in me. Thanks for everything, my dear mentor. God bless you.

I would also like to thank Dr. Antonio G. Merma, my co-advisor, for the support and for sharing with me his knowledge and experience to the successful development of this work. *Muchas gracias, Doctor.*

To Dr. Gabriela H. Pino, for her partnership and support in the laboratory, and for offering me her lovely friendship and guidance. *Muchas gracias Gaby!*

To the Mineral Technology Group from the Department of Materials Engineering (DEMa) at PUC-Rio, specially to Clarissa Fontelles, Elaynne Rohem, Flávia Miranda, Carlos Castañeda and Ronald Rojas.

To Vicente Alyta Filho, from Qualyta Lab Ltda., for contributing to the design and the manufacture of the modified Partridge-Smith flotation cell.

To Dr. Rogério Navarro Siqueira, Carlos A. R. Queiroz and Ronald Mejia from DEMa, for the aid and guidance given for the characterization of hematite sample and *Rhodococcus ruber* strain.

To the professors of the Department of Materials Engineering, especially to the professors of the Chemical and Metallurgical processes area.

I would also like to acknowledge the Coordenação de Aperfecionamento de Pessoal de Nível Superior (CAPES), Brazil for the financial support of my Master studies.

To my fellow colleagues from Post-graduation of DEMa, especially from Casa 21. I am really glad to have met you all and learn from each one of you.

I would like to thank my dear friends Ronal De la Cruz, Karen Garces, Pamela Velarde and Paul Juarez, for their constant help, support, and friendship. Thank you guys for always be there for me.

To Gloria and Alfred Norris, Maria Isabel Ramos, Ludy Cáceres, Eliana Marin, Lorena Chamorro and Mariella Cortez for offered me not also a valuable friendship but a comfort place to live in. Thank you for making me feel safe and loved, as I would be at home.

I also like to thank the people who partly made possible today I am here. To Fernando Zeballos and Belenia Medina, for the advices, friendship, lessons and help offered.

And how not to thank my beloved parents, Rosa and Daniel, for their cheers and love, and my fellow colleague, best friend and brother, Harold, for his daily support, constant jokes and guidance. Love you all, guys.

And finally, thanks to the city that so gently hosted me for the past two years. Thanks Rio, for the sunny and rainy days, for your joy and grace and for your kind people. And to Brazil, for the opportunity that was given to me in your land.

To all of you, my endless gratitude.

Abstract

López Olivares, Leslie Yasmin; Torem, Mauricio Leonardo (Advisor). **Fundamental aspects of hematite flotation using the bacterial strain *Rhodococcus ruber*.** Rio de Janeiro, 2014. 107p. Dissertação de Mestrado - Departamento de Engenharia de Materiais, Pontifícia Universidade Católica do Rio de Janeiro.

In the recent years, research has been developed in the application of microorganisms in mineral technology, acting as environmental friendly collectors, depressors and/or frothers and inducing hydrophobic properties, since they can be selectively adhere onto the surface of the mineral. This research work deals with the fundamental aspects of hematite flotation using the bacterial strain *Rhodococcus ruber*. The aim of this research was to study and evaluate the behavior of *Rhodococcus ruber* strain before and after interaction with hematite particles. The sample was conditioned with the biomass suspension by stirring under specific conditions such as particle size, biomass concentration, pH solution and conditioning time. Among the studies conducted are the microbial adhesion to the mineral surface, zeta potential measurements and analysis of infrared spectra before and after interaction of *Rhodococcus ruber* with hematite, as well as microflotation studies. The results showed a change in hematite zeta potential profile after interaction with *Rhodococcus ruber*, and its adhesion onto the mineral surface was higher at pH 3 and at concentration of 0.60 $g.L^{-1}$ (10^9 cells). Flotation studies were carried out in a 0.23L modified Partridge-Smith flotation cell, and the highest floatability (84%) was achieved at size fraction -53+38 μm. Also, floatability studies were performed using frother Flotanol D24 combined with the *Rhodococcus ruber* biomass, concluding with interesting results in function of the particle size range. This work aims to evaluate the efficiency of bioflotation of minerals, particularly hematite, and the potential use of *Rhodococcus ruber* as biocollector, projecting its future application in mineral flotation industry.

Keywords:

Hematite; *Rhodococcus ruber*; Flotanol D24; Partridge-Smith cell.

Resumo

López Olivares, Leslie Yasmin; Torem, Mauricio Leonardo. **Aspectos fundamentais da flotação de hematita empregando a cepa bacteriana *Rhodococcus ruber*.** Rio de Janeiro, 2014. 107p. Dissertação de Mestrado - Departamento de Engenharia de Materiais, Pontifícia Universidade Católica do Rio de Janeiro.

Nos últimos anos, vários estudos têm sido realizados na aplicação dos microrganismos na biotecnologia mineral, atuando como coletores, depressores ou espumantes amigáveis com o meio ambiente, e induzindo propriedades hidrofóbicas, uma vez que eles podem-se aderir seletivamente sobre a superfície do mineral. O objetivo deste trabalho é estudar e avaliar o comportamento da cepa *Rhodococcus ruber* com a hematita. Entre os estudos efetuados estão à adesão microbiana à superfície mineral, medida do potencial zeta e análise no infravermelho antes a após interação do biorreagente com a hematita, assim como o estudo dos ensaios de microflotação. A amostra foi condicionada com a suspensão de biomassa por meio de agitação sob condições específicas, tais como tamanho das partículas, concentração da biomassa, pH da solução e tempo de condicionamento. Os resultados mostraram uma mudança no perfil do potencial zeta da hematita após interação com a *R.ruber*, e sua adesão na superfície do mineral foi maior ao redor do pH 3, e na concentração de $0.60 g.L^{-1}$ (10^9 células). Estudos de flotação foram realizados na célula de flotação modificada Partridge-Smith de 0.23L, e a maior valor de flotabilidade (84%) foi atingido na fração -53+38 μm. Estudos complementários de flotabilidade foram realizados utilizando o espumante comercial Flotanol D24 combinado com a biomassa *R.ruber*, encontrando resultados interessantes em função do tamanho de partícula. Assim esta pesquisa visa avaliar a eficiência da bioflotação de minerais, particularmente da hematita, e do uso potencial do *Rhodococcus ruber* como biocoletor, projetando-se a uma futura aplicação na indústria da flotação mineral.

Palavras-chave:

Hematita; *Rhodococcus ruber*; Flotanol D24; célula Partridge-Smith.

Contents

List of figures

List of tables

"Gutta cavat lapidem non vi sed saepe cadendo."/ "A water drop hollows a stone not by force, but by falling often."

Latin proverb