真空技术与表面工程

——第九届真空冶金与表面工程学术会议论文集

Vacuum Technology and Surface Engineering

Proceedings of the 9th Vacuum Metallurgy and Surface Engineering Conference

主　编：巴德纯
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内 容 简 介

本书是2009年在中国沈阳举办的第9届真空冶金与表面工程学术会议的论文集，收录了来自国内外的102篇投稿论文，反映了近年来在真空冶金、表面工程和真空技术等领域的许多最新科研成果，内容主要包括真空冶金、真空热处理、真空冶金涂层、表面改性技术、生物材料表面工程、纳米表面工程和纳米摩擦学、超薄薄膜与功能薄膜、气相沉积技术、摩擦学、腐蚀与防护、纳米新材料的真空制备技术、表面工程基本问题、真空技术及应用、真空设备故障诊断、大型真空冶金设备的自动化等，可供从事真空工程、真空冶金、表面工程、真空应用等研究和应用领域的学者、技术人员和研究生参考。

This book gathers 102 pieces of papers from the 9th Vacuum Metallurgy and Surface Engineering Conference held in Shenyang China in 2009, which reflects many latest research achievements in such areas as vacuum metallurgy, surface engineering, vacuum science and technology in recent years. The papers mainly cover many subjects like refinement technique outside furnace, vapor deposition technology, vacuum melting technology, tribology, vacuum heat treatment, corrosion prevention, vacuum metallurgy coating, the vacuum fabrication technology of new nanometer material, surface modification technology, the basic problem of the surface engineering, the surface engineering of biological materials, vacuum science and technology, the nanometer surface engineering and nanometer tribology, fault diagnose to the vacuum equipments, superhard film and functional film, the automatization of large vacuum metallurgy equipments etc. As a good reference book, it is fir for scholars, technical personals and graduate students engaged in vacuum metallurgy, vacuum engineering, surface engineering, and vacuum applications.

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前　言

“真空冶金与表面工程学术会议”是由中国真空学会真空冶金专业委员会主办的学术年会，自 1978 年至今已举办了 8 届。2003 年起，改为每两年举办一次，该年会的目的是为真空冶金与表面工程领域的专家、学者、工程技术人员提供一个交流的平台，以推动我国该领域的科技发展和应用。

第 9 届中国真空冶金与表面工程学术会议于 2009 年 8 月 24～27 日，在辽宁沈阳东北大学举办。本次会议由东北大学真空与流体工程研究中心承办，邀请了国内外知名学者和专家将做十余场精彩的大会特邀报告。

截止到 2009 年 6 月 30 日，会务组共收到投稿论文 150 余篇。经大会学术委员会评审，论文集共收录 102 篇，论文作者包括来自中国、日本、韩国、澳大利亚等在内的多个国家和地区。

本次会议将开设真空冶金、表面工程和真空技术三个分会场的学术交流，还将组织参会代表赴相关进行企业考察，会议成为大学、研究部门和企业之间的桥梁。在举办过程中，会议得到了多家单位的支持和赞助，在此一并表示感谢。

感谢电子工业出版社的辛勤劳动和各位论文作者的出色工作，使得这本论文集得以付梓。论文集的出版与发行，将对我国真空冶金与表面工程领域的学术与技术交流的蓬勃发展起到重要的意义。

中国真空学会真空冶金专业委员会

2009 年 7 月 10 日

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Preface

Vacuum Metallurgy and Surface Engineering Conferences are sponsored by the Vacuum Metallurgy Committee of Chinese Vacuum Society (CVS-VMC), which have been already held seven times since 1978. Moreover, the next conference was held every two years since 2003, which is to provide a chance for experts, scholars, technical engineers and etc. in these areas to communicate with each other, then as a result science and technology in these area can be rapidly developed .

The 9th Vacuum Metallurgy and Surface Engineering Conference will be held in June 16th to June 19th of 2009 in Shenyang, Liaoning Province of China. This conference is sponsored by Vacuum and Fluid Engineering Research Center of Northeastern University. About 10 well-known scholars or professors will give wonderful invited speeches at the conference.

Close till May 10, 2009, we totally received more than 150 articles and papers. This book gathered 102 pieces of papers selected by the Academia Committee. The Authors comes from several countries include China, Japan, Koran, Australia and etc.

There are three grouped conference include Vacuum Metallurgy, Surface Engineering, Vacuum Science and Technology. We also organized visits to some related factories. We hope that the meeting could become the bridge of universities, research departments, factories and enterprises. We should appreciate the support and sponsor of several enterprises.

Thanks for the hard work of Electronics Industrial Publication House and the outstanding work of each author, which make it become true that this book can be printed and issued. We also hope that our work will be meaningful for the academic and technical development of vacuum metallurgy and surface engineering.

CVS-VMC

July 10, 2009

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第 1 部分　真空冶金

Part 1　Vacuum Metallurgy

Experimental Study on Extraction of Lithium by Vacuum Thermal Reduction with Ferro-silicon Alloy

DI Yue-zhong　DONG Wei-wei　WU Xiao-lei　WANG Zi-qian　FENG Nai-xiang

(School of Materials and Metallurgy, Northeastern University, Shenyang 110004, China)

Abstract: Extraction of lithium by vacuum thermal reduction may be used extensively in future. Influences of various technological parameters such as reaction temperature and time on thermal decomposition of lithium carbonate and Lithia reduction were investigated in the of extraction of lithium by vacuum thermal reduction with Ferro-silicon alloy. On the best condition obtained by $L_9(4^3)$ orthogonal test, the decomposition efficiency of lithium carbonate could be above 99%. With increasing reduction temperature, the reduction rate could be reach up to 95.85% at 1293K.The reduction rate increased gently when the reaction time excess 120min.

Keywords: vacuum; lithium; decomposition; reduction

硅铁真空热还原提取锂的实验研究

狄跃忠　董维维　武小雷　王紫千　冯乃祥

（东北大学材料与冶金学院，辽宁　沈阳　110004）

摘　要：真空热还原是目前较有前景的生产金属锂的方法。研究了以硅铁合金为还原剂制取金属锂的过程中，反应温度和时间对碳酸锂分解和氧化锂还原率的影响。通过 $L_9(4^3)$ 正交实验获得碳酸锂分解的最佳条件，分解率可达 99%以上。在研究范围内，随着温度升高金属锂还原率显著提高，1293K 时可达 95.85%；反应时间超过 120min，还原率增加趋于平缓。

关键词：真空；锂；分解；还原

1　Introduction

The lightest of all metals, lithium is used in a variety of applications, including petrochemical industry, lubricating material, synthetic rubber, glass ceramic. Nowadays it is called energetic metal of 21 century used extensively in the areas of aviation, nuclear-generated power and electric battery industry [1].

Nowadays, molten salt electrolysis and vacuum thermal reduction are main method of producing lithium. Over 90% of the world's primary lithium is produced by electrolyze LiCl-KCl molten salt system[2-3]. The technology of electrolysis is very sophisticated, but its development will be effected by some factors: high-purity LiCl as raw material is very expensive; chlorine from anode pollutes environment; natrium content of lithium produced by electrolysis is too high. Vacuum thermal reduction may be used extensively in future because of low-energy consumption, high-purity and short-cycle. In this experiment, metal lithium was extracted by vacuum thermal reduction with Ferro-silicon alloy [3-4].