

The Powder Metallurgy Processing of Refractory Metals and Alloys

Ricardo Morales, Ragnhild E. Aune, Olle Gröndler, and Seshadri Seetharaman

Molybdenum and tungsten are refractory metals in the elemental form with the largest production volume in the world. The fabrication of these refractory metals, as well as their alloys and intermetallics, using high-temperature powder metallurgy (PM) is reviewed in this article. The primary focus is on the role of traditional high-temperature PM in producing alloys with tailor-made properties. An insight into the bulk production of molybdenum and tungsten alloys with nano-grains is highlighted.

INTRODUCTION

Refractory metals, widely agreed to be those with a melting point greater than 2,273 K, comprise the following elements in the order of their melting point: W, Re, Ta, Os, Mo, Ru, Ir, Nb, Hf, and Ti. However, only four of these metals have major commercial applications in elemental form: Mo, W, Ta, and Nb. The other metals are too rare and have limited use.

Powder metallurgy (PM) processes play an important role in the fabrication of refractory metals. Since the turn of the 20th century, PM use has steadily grown and now almost any material can be produced via these processes. This is especially useful when alloys are difficult or impossible to produce using conventional ingot metallurgy. For example, refractory alloys are best produced via PM when the components have greatly differing melting temperatures, limited mutual solubility, and different densities.

The economic advantage of PM processing over ingot melting relies on the greater recovery of products. Further, the finer grain size of the powder products facilitates hot working operations. It must, however, be borne in

mind that PM is never likely to replace ingot metallurgy.

The PM process applied to the fabrication of refractory metals consists of several steps. The most common steps are:

- Production and treatment of metal powders
- Cold compaction
- Sintering under hydrogen or vacuum
- Forming (metal working or machining)

This article presents an overview of the high-temperature PM of refractory metals in their elemental or alloyed form, with an emphasis on the production of metal powders. The article will focus on tungsten and molybdenum, which offer the most commercial applications of all refractory metals because their production worldwide is the greatest of all refractory metals.

PRODUCTION

Refractory materials usually fall into one of the following three categories: solid-solution alloys, oxide or carbide

dispersion-strengthened materials, or materials with doped qualities.

All of the tungsten-based products and most of the molybdenum products are processed via PM. Due to the high melting point of these metals, they cannot be produced using atomization. Thus, chemical reduction processes and electrolysis are the only practical methods. Powders produced electrolytically from aqueous electrolytes or in the molten state are of high purity and active during sintering. They have, however, the following shortcomings:

- Purification is required to remove residual impurities from the electrolyte, especially salt residues after electrolysis of molten salts.
- The process is often costly, consuming much electrical energy due to low current efficiencies.
- The process is limited to the production of pure metal powders since it is not possible to produce alloy powders by this method.

The reduction of metal compounds with solid or gaseous reducing agents at high temperature is important in

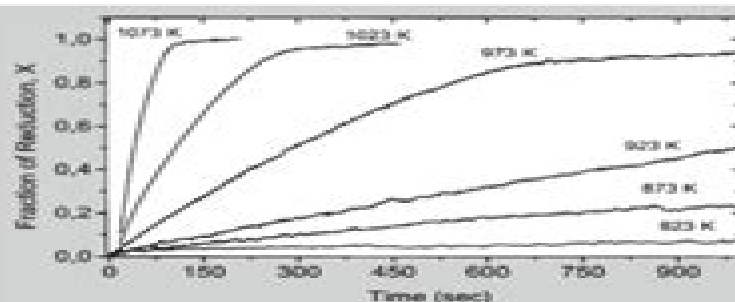


Figure 1. The isothermal reduction curves of $\text{Fe}_3\text{MoO}_{12}$.

Refractory Metals Alloys 2 Volume 17

Jessica J Manson



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Table of Contents Refractory Metals Alloys 2 Volume 17

1. Understanding the eBook Refractory Metals Alloys 2 Volume 17
 - The Rise of Digital Reading Refractory Metals Alloys 2 Volume 17
 - Advantages of eBooks Over Traditional Books
2. Identifying Refractory Metals Alloys 2 Volume 17
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Refractory Metals Alloys 2 Volume 17
 - User-Friendly Interface
4. Exploring eBook Recommendations from Refractory Metals Alloys 2 Volume 17
 - Personalized Recommendations
 - Refractory Metals Alloys 2 Volume 17 User Reviews and Ratings
 - Refractory Metals Alloys 2 Volume 17 and Bestseller Lists
5. Accessing Refractory Metals Alloys 2 Volume 17 Free and Paid eBooks
 - Refractory Metals Alloys 2 Volume 17 Public Domain eBooks
 - Refractory Metals Alloys 2 Volume 17 eBook Subscription Services
 - Refractory Metals Alloys 2 Volume 17 Budget-Friendly Options
6. Navigating Refractory Metals Alloys 2 Volume 17 eBook Formats

- ePub, PDF, MOBI, and More
- Refractory Metals Alloys 2 Volume 17 Compatibility with Devices
- Refractory Metals Alloys 2 Volume 17 Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Refractory Metals Alloys 2 Volume 17
 - Highlighting and Note-Taking Refractory Metals Alloys 2 Volume 17
 - Interactive Elements Refractory Metals Alloys 2 Volume 17
- 8. Staying Engaged with Refractory Metals Alloys 2 Volume 17
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Refractory Metals Alloys 2 Volume 17
- 9. Balancing eBooks and Physical Books Refractory Metals Alloys 2 Volume 17
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Refractory Metals Alloys 2 Volume 17
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Refractory Metals Alloys 2 Volume 17
 - Setting Reading Goals Refractory Metals Alloys 2 Volume 17
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Refractory Metals Alloys 2 Volume 17
 - Fact-Checking eBook Content of Refractory Metals Alloys 2 Volume 17
 - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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