Rare Earth Metals

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Rare earth elements are the general named of 17 special elements, containing lanthanide element, scandium and yttrium. They are commonly represented by RE. They have been widely applied in functional materials, steel and nonferrous metals due to its special optical, electrical and magnetic properties.

Keywords: rare earth metals ; preparation ; purification

1. Introduction

Rare earth element (named as RE) is the general name of 17 special elements, containing lanthanide element, scandium, and yttrium. They have been widely applied in functional materials, steel, and nonferrous metals because of their special optical, electrical, and magnetic properties. In particular, RE functional materials and structure materials play an important role in the development of aerospace industry, military equipment [1], domestic appliances [2], new energy saving, and environmental technologies [3][4]. For example, neodymium and samarium are the main components of NdFeB permanent magnets and SmCo permanent magnets respectively. Furthermore, magnetic energy product of RE permanent magnet materials is much higher than that of ferrite and Al-Ni-Co permanent magnet materials [5][6].

Therefore, RE permanent magnet materials have been proverbially used in air conditioning, sound box, and permanent magnet motor. Terbium and dysprosium are the main ingredients of magnetostrictive materials, and the magnetostrictive coefficient is superior than that of Fe-Ni-Co alloy. In addition, RE magnetostrictive materials have been widely used in high-power emitting sonar, sensor, and communications. RE hydrogen storage alloy shows the advantages of high electric capacity, good stability, high hydrogen absorption efficiency, and no pollution, which makes it to be widely used in the fields of battery, brake, and refrigeration [7].

The addition of rare earth to steel can modify inclusions, refine grain, and strengthen microalloying, which can significantly improve the fatigue performance of bearing steel [8]. The purity of rare earth metals is the key factor affecting the performance of functional materials and structural material. For example, high oxygen concentration of rare earth metals could weaken the intrinsic coercivity of RE permanent magnet materials. Low purity rare earth metals may cause nozzle clogging and unstable performance in continuous casting process of RE steel. Specially, magnetostrictive materials and sputtering target materials require the purity of rare earth metals to be higher than 99.99% [9][10]. The purity of rare earth metals should exceed 99.95% in permanent magnetic materials [11]. In recent years, the preparation and purification of high-purity rare earth metals has attracted more attention from governments and experts. The relevant departments of the United States, Japan, and other countries have even listed RE products as the key strategic elements for the development of military technology and high technique industries. With the progress of science and technology, high purity rare earth metals play a critical role in national economic construction and daily life [12][13].

2. Progress in Preparation and Purification of Rare Earth Metals

2.1. Progress in Preparation of Rare Earth Metals

With the wide applications of rare earth metals, the increasing demand for high-purity rare earth metals has stimulated the rapid development of preparation technology. At present, molten salt electrolysis and metal thermal reduction are the common methods for preparing rare earth metals. In principle, these two methods can extract all kinds of rare earth elements. Light rare earth metals such as La, Ce, Pr, and Nd are produced by molten salt electrolysis for considering economic cost factors such as fixed asset investment, raw materials, and energy consumption [14]. Metal thermal reduction method is more suitable for preparing heavy rare earth metals such as Gd, Tb, and Y with high melting and boiling points.

2.2. Progress in Purification of Rare Earth Metals

Whether molten salt electrolysis or metal thermal reduction, the purity of rare earth metals is in a range of 95.5~99.5%, which cannot meet the requirements of high performance materials [15]. At present, the purification methods mainly include vacuum distillation, arc melting, zone melting, and solid state electromigration [16][17].

3. Summary and Prospect

In the past 60 years of development, remarkable achievements have been achieved in scientific research and industrial application of rare earth elements, forming a relatively well-developed rare earth industrial system. But at the same time, it should also be noted that there are issues in many areas that need to be solved.

(1) Molten salt electrolysis and metal thermal reduction possess high efficiency and yield, but low purity of rare earth metals and high energy consumption are generally non-negligible.

(2) The preparation process of rare earth metals is mainly a manual operation with low automation degree and severe environmental pollution issue.

(3) Deep purification ability of rare earth metals is insufficient, and the industrialization is limited to the use of vacuum distillation, which is difficult to meet the needs of high technology development.

Consequently, expensive price of high-purity rare earth metals appeared and limit their application. Therefore, the following directions are the focus of our attention in future:

(1) The impurity concentration of rare earth metal should be further reduced so as to provide high purity starting material for the purification process.

(2) A combination of various purification methods should be chosen to remove the impurities for considering the kinds and uses of rare earth metals.

(3) Purification methods suitable for mass production such as vacuum levitation melting and electron beam melting should be developed and researched.

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