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A critical review on secondary lead recycling technology and its prospect

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ABSTRACT

This article reviews recent studies on the recycling of spent lead paste and describes novel technologies. Although the pyrometallurgical process has been dominant in the secondary lead recycling processes, there has been growing pressure to achieve sustainable greener recycling methods to address the environmental pollution issues caused by emissions of lead particulates and sulfur oxides in the traditional smelting route. The electrowinning process has been studied for many years, but high energy-consumption and emissions of toxic components such as fluoride compounds have caused concerns and hindered rapid growth in industrial application. In last 10 years, many sustainable and environmental friendly processes, such as paste-to-paste recycling and hydrogen-lead oxide fuel cell method have been proposed for recycling spent lead paste from discarded lead acid batteries. Ultrafine leady oxide could be prepared from spent lead pastes via newly developed novel hydrometallurgical routes, and then applied as active materials in the cathode and the anode for making high-performance lead acid batteries. It is a green alternative for recycling of spent lead acid battery and other secondary lead.

Contents

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1. Introduction

Lead is a versatile and strategically important metal resource for the industrial development and global economy as it is intrinsically associated with automotive, back-up power and energy storage for renewables [1]. Due to its toxicity, industry related with lead production, recycling, application and consumption must deal with public health and environmental concerns from lead emissions, especially in lead smelting, lead-acid battery production and recycling [2].

The secondary lead produced by recycling process has gradually become the major source of lead in many areas of the world, which will continue to dominate the global lead market [3]. The secondary lead output in developed countries vastly exceed that of primary lead and globally recycled lead accounts for just over 2/3rd of the world output of refined lead [4]. Generally, discarded lead acid batteries (LABs) are the main resource of secondary lead, more than 85% in the total amount of secondary lead [5]. As disposing spent lead is not an option, recycling of spent lead-acid batteries has already proved its value [6]. Nowadays, most of the secondary lead recovery plants are based on pyrometallurgical methods [4]. The emission of sulfur oxides, nitrogen oxides and lead-containing particulate matters from the pyrometallurgical route constitute a serious consequence for the local environment and human lives. Furthermore, major lead poisoning incidents and high lead contamination near the lead factory have already been of great concern to the public. Several electrowinning technique [34–63] have been investigated for the clean treatment of spent battery. Any low temperature process is considered important way forward for eliminating excessive $PM_{2.5}$ (fine particulates less than 2.5 μm measured as aerodynamic diameter) particulates and sulfur dioxide and trioxide. Several studies have reviewed the recycling of lead-acid battery paste using electrowinning techniques, offering favorable comparison with the traditional pyrometallurgy method with respect to direct emissions [7]. However, the electrochemical route is highly energy-intensive and in the medium to long run may not be economically viable for commercial application on account of costs and also from the indirect emissions associated with purchased electricity if the source is based upon fossil fuels.

Recently, several novel methods for treating of the spent battery have been explored with most of these aiming to offer environmental benefits, lower energy consumption and improved reaction efficiencies. The concept of direct conversion of spent lead battery into a new high-performance battery with minimum number of steps is also worth reporting as such methods have been also considered.

This review introduces the quantity and importance of secondary lead, compared with the primary lead resources. The issues of pyrometallurgy and electrowinning methods for secondary lead recycle are critically analyzed, followed by the summary of the latest progress of novel methods developed in recent years.

2. Lead resources

2.1. Trends in lead production and consumption

In general, there are mainly two basic types of lead resources: primary lead resources and the secondary lead [8]. The quantity of the known lead ore is nearly 85 million tons. Most of the primary lead resources are in the form of minerals, such as, galena (PbS), cerussite ($PbCO_3$) and sulfuric acid galena ($PbSO_4$) [8]. Whereas, the secondary lead is mainly produced through the recycling of spent lead-acid batteries [3].

The global lead consumption from 1902 to 2012 is shown in Fig. 1 [9]. The global lead consumption in 2012 has already increased up to more than 10 million tons, nearly twice of the amount only a decade ago.

As shown in Fig. 2 [9], for the post 2000–2001 period, the global secondary lead production is increasing by a large margin, compared to the amount of primary lead production. However, the amount of primary lead production was almost constant from 1970 to 2012, indicating that the industrial demand for primary lead is relatively more stable than that of secondary lead worldwide.

It is important to notice that the secondary lead production in developed countries has exceeded the amount of primary lead

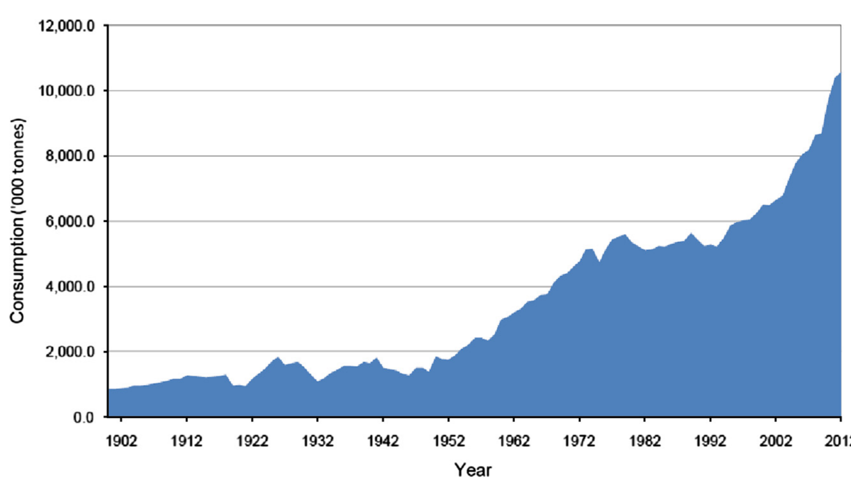

Fig. 1. The global lead consumption from 1902 to 2012 [9].