Research on the Source and Recovery Methods of Gallium

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Abstract

In recent years, gallium has been widely applied in high-tech industries, such as optoelectronics, microelectronics, high-quality semiconductors, LED lights, mobile devices, television, laptop displays, solar cells, and pharmaceuticals/radiopharmaceuticals. However, no single mineral deposit of gallium is found in nature. This article provides an overview of the sources of gallium and introduces the current recycling status of various sources, which is expected to provide potential routes for recycling and utilization of gallium in the future.

Keywords: Gallium, Source, Extraction

1. Introduction

Gallium is a shining, slightly white, rare metal with a low melting point and high boiling point. It is widely applied in semiconductors, alloys, optoelectronics, and other fields [1-2]. Gallium is particularly scarce because it is found in low-content ores, and it is only produced as a by-product of other metal production [3-4]. Different extraction methods are used to recover gallium from different sources, such as zinc ore, bauxite, fly coal ash, and other minerals. This paper briefly introduces the source and methods of recovering gallium, which is expected to provide new ideas for recovery and utilization of gallium in the future.

2. Sources of Gallium and Current Status of Gallium Recovery

2.1 Recovery from Zinc Ore

Resources of zinc ore with gallium content ranging from 0.01 % to 0.04 % can be obtained after flotation, roasting, leaching, and other processes.

In addition, zinc slag is also considered to be an important source of gallium. Qiu [5] extracted gallium and indium from zinc slag using P204 and TBP as extractants (the process flow is shown in Figure 1). By adjusting the acidity, gallium and indium were extracted, respectively, with the final extraction rates of both elements being above 99 %.

Luo Jinhua [6] showed that Cu, Zn, Fe, Cd, Ga, and other elements in zinc refinery residue were easy to leach through atmospheric pressure leaching experiments, and the leaching rate increased with the increase of sulfuric acid concentration, reaction temperature, liquid-solid ratio, and reaction time. Under optimal leaching conditions of 1.5 M sulfuric acid, a leaching temperature of 80 °C for 3 h, with a liquid-solid ratio of 7.5, the leaching rates of gallium and germanium were 97.74 % and 82.46 %, respectively. The effects of leaching agent (sulfuric acid), leaching temperature, leaching time, liquid-solid ratio, and agitation speed on the leaching rate of Ga and Ge were also examined through a two-stage hot-acid leaching.

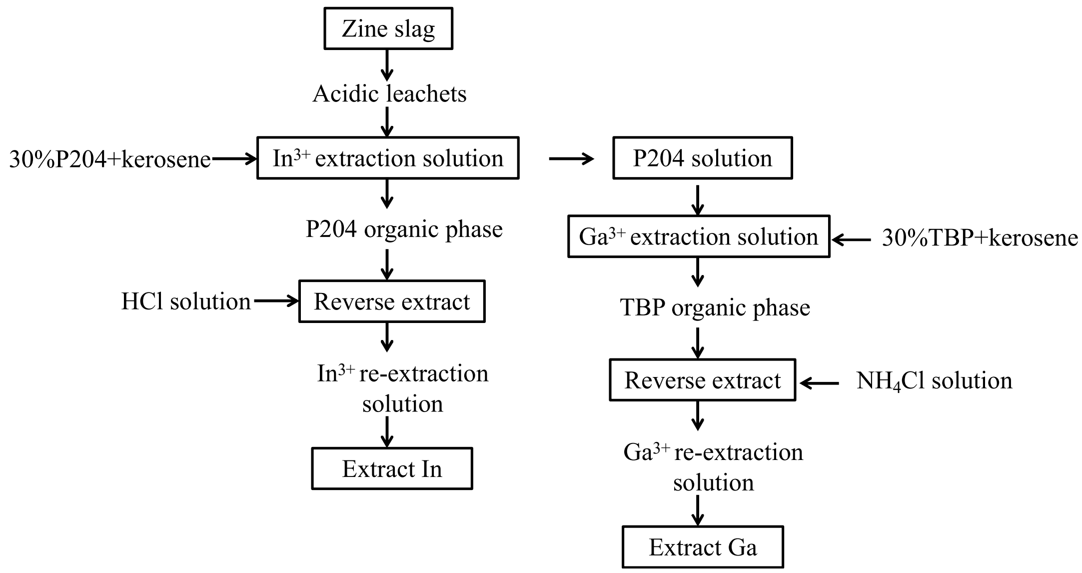

Figure 1. Flow sheet for extraction method from zinc slag [5].

Ma's [7] results showed that the optimal leaching conditions were as follows: an initial mass concentration of sulfuric acid of 188 g/L, a leaching temperature of 95 °C, a leaching time of 3 hours, an L/S ratio of 5:1, and a stirring speed of 300 r/min. Under these conditions, the leaching rates of Ga and Ge in the acid leaching solution from the multi-group comprehensive tests were improved from 72 % to 86 %.

Rao's [8] study of zinc, gallium, and germanium showed that they could be selectively leached from zinc refinery residue by controlling a suitable pH condition.

Wu Xuelan [9] extracted gallium with 10 % G315, 5 % P204 and 2.5 % isooctanol. After four stages of extraction, three stages of washing and three stages of reverse extraction, the extraction rate was higher than 96 % and the reverse extraction rate was higher than 97 %. In industrial production, the process of extracting gallium from zinc residue is widely adopted by combining hydrometallurgy and pyrometallurgy.

However, the gallium content in the leaching solution is extremely low compared with other metal ions such as zinc, copper, and iron, resulting in poor extraction efficiency of gallium. Moreover, high energy consumption, a long process and secondary pollution hinder the industrial expansion of production.

2.2 Recovery from Bauxite

Bauxite, a major raw material for alumina production, is estimated to contain more than one million tons of Ga, with an average concentration of approximately 50 ppm. Gallium is usually extracted from bauxite using the Bayer process. After leaching, adsorption, desorption, purification and electrolysis, 4N high-purity gallium can be produced. The process flowsheet is shown in Figure 2.

to separate alone without the influence of impurities. During leaching treatment, gases or a large amount of waste residue are produced, making it difficult to achieve recycling and utilization, which can pollute the environment.

In addition to the issues mentioned above regarding the separation and extraction of gallium from coal fly ash, different leaching methods should be selected according to the content of gallium in coal fly ash. For high-content fly ash, suitable conditions should be selected to leach gallium while minimizing the leaching of other impurities; for low-content fly ash, optimal conditions should be selected, and a simpler method should be studied to deal with impurities through process optimization.

2.4 Recovery from Other Ores

Not only zinc ore, bauxite, and coal fly ash, but some other ores also contain trace amounts of gallium, such as iron ore, copper ore, lead ore, cassite, tungsten and molybdenum ore. Generally, the gallium content in these minerals is too low to be exploited alone, but can be recycled as a by-product in other metal extraction processes, which is currently a potential source of gallium, accounting for less than 10 % of the world's gallium metal production. The boehmite co-exists in the aluminite claystone and coal seam was found in the No. 6 low-sulfur bituminous coal in Ordos, Neimeng province, which contains abnormally large amounts of gallium and rare earth elements. The average amount of Ga in Section 7 coal seam is 44.8 µg/g. The clay layer and bauxite layer of upper carboniferous Benxi, Liaoning province produced from the weathering denudation surface at the top of Middle Ordovician are also important sources of gallium. In addition, significant volcanic crystals and volcanic ash are found in clayey conglomerates, which can partially become sources of gallium [28].

3. Conclusion

In summary, the source of gallium mainly depends on the mining and utilization of zinc ore, bauxite and coal fly ash, while other minerals can only be used as potential sources. With the increasing demand for gallium and the change of resource conditions, new extraction methods and sources may develop in the future.

4. References

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