Strontium Production from Strontium Oxide Using Vacuum Aluminothermic Process

Mehmet Buğdaycı¹,², Ahmet Turan², Y. Cucurachi¹, Onuralp Yücel¹
¹İstanbul Technical University, ²Yalova University - Türkiye

Abstract

In this present study production of strontium metal from its oxide was studied under the pressure of 1-5 mbar by metallothermic process. In the experiments SrO which has 99 % purity was used. Effects of Al powder addition (100, 200, 300 % of stoichiometric ratio) and time were investigated on recovering of metallic strontium. Effects of BaO addition (100 %, 200 %, 300 %) was also investigated. The final residues were examined for their chemical composition. XRD, AAS and Flame Photometer devices were used for chemical analysis. More than 90 % of strontium metal recovery was observed.

1. Introduction

Strontium is an element which is used in many advanced technology applications. Barium strontium titanat, strontium bismuth titanat, and strontium bismuth tantalat thin films are promising materials in ferroelectric and Schottky-based microelectronics technologies, especially for memory applications. Physical vapor deposition (PVD) techniques as magnetron sputtering, thermal evaporation and molecular beam epitaxy (MBE) are the most widely used methods for growth of these thin films [1-3]. In these techniques high-purity of Sr metal is used as evaporation sources and sputtering targets. Furthermore, metallic strontium is used as a “getter” in electron tubes, and as an alloying elements in aluminum alloys [4].

The most used Sr compound is SrCO₃ and widespread process used in production of SrCO₃ is the hydrometallurgical carbonation of celestite. Although there are considerable amount of Selestit reserves, SrCO₃ and strontinum metal are not being produced in Turkey, yet [5].

Concentrated celestite (SrSO₄) is converted to SrCO₃ in carbonate media. Black ash and direct conversion processes are currently used methods. There are many satisfactory studies about hydrometallurgical carbonation of celestite and decomposition of SrCO₃ [6, 7]. Since strontium metal is produced from it’s oxide (SrO), SrCO₃ is need to be decomposed to SrO.

Strontium is produced only by the thermal method for industrial use. Timminco Metals, Ontario, Canada used a method similar to the Pidgeon Process in the production of strontium. However complete details on the actual strontium production route is not determined clearly [8]. In this study, production of strontium metal from its oxide was studied. The present work aims to investigate the parameters effecting the aluminothermic reduction of SrO using aluminum metal. In the experiments, charge composition, amount of reducing metal and time were taken as variables in order to obtain high recovery efficiencies.

Theoretical investigations

ΔG°-T diagram for oxide formation indicates that SrO reduction with aluminum is only possible beyond 2000 °C. In order to obtain strontium metal at lower temperatures for Eq. 1, partial pressure of the strontium vapour and/or activity of Al should be lowered. For this aim, vacuum technique and additions of BaO for formation of a basic slag (BaO.Al₂O₃) are needed.

$$3 \text{SrO} + 2\text{Al} + \text{BaO} = 3\text{Sr} + \text{BaO.Al}_2\text{O}_3$$  (Eq. 1)

By using the FactSage 5.2 thermodynamic program the Figure 1 was simulated for aluminothermic reduction of SrO by Al powder at different temperatures under 1 bar and 1 mbar of vacuum atmosphere [9]. As can be seen in the figure reduction of strontium oxide starts at around 1050 °C and it totally reduced to metallic Sr under pressure of 1 mbar.
2. Experimental Procedure

Raw materials: In the experiments, synthetic SrO is used as strontium source. Al powder was used as reducing agent and BaO was used for slag formation.

Reduction technique: The schematic diagram of the experimental set up was illustrated in Fig. 2. The temperature was measured by 6RhPt-30RhPt (EL-18) thermocouple. The reduction process was carried out in a retort made from Incoloy 800H/HT alloy [10]. In order to pump the retort for vacuum, a two stage compact rotary vane pump was used.

The stoichiometric ratios of Al and BaO were together selected 100%, 200% and 300%. The desired weight ratios of SrO, BaO and Al metal powder were mixed throughly. The mixture was weighted and briquetted. Briquettes were put in an alumina boat. The charged boat was inserted into the retort at room temperature. After closing the retort cover, the inside pressure was decreased to 1-5 mbar. In order to condensate the strontium vapour formed during the reduction reactions, a cooling copper tube was mounted at the retort cover. After the furnace attained to the required temperature, the retort was inserted into the furnace. Since the furnace temperature decreases after inserting the retort, initial time was started when the furnace reached the desired temperature.

At the end of the reduction experiments, the retort was left in the furnace at the same vacuum values and was cooled to room temperature. Then, the cover was opened and the condensed strontium metal on the cooling section and the residue left in the boat were weighted and analyzed chemically. The degree of Sr metal recovery was calculated as

\[
\text{Sr Recovery, } \% = 100 - \left(\frac{W_1 \times \% \text{Sr}_1}{W_0 \times \% \text{Sr}_0}\right) \times 100
\]

where \(W_1\) the weight of the residue at time \(t\), \(\% \text{Sr}_1\) the weight percent of the strontium in the residue at time \(t\), \(W_0\) is the weight of the briquette, and \(\% \text{Sr}_0\) the weight percentage of the strontium of the briquette.

3. Results and Discussion

The effects of time and the stoichiometric ratio of reducing agent on recovery were investigated in this work. It’s observed that with increasing stoichiometric ratio of Al and BaO the recovery of strontium metal is increased. For example, 40.1% and 96.89% of recovery of strontium is observed while the stoichiometric ratios of Al powder and BaO were 100% and 300% respectively.

The experiments results which were carried out at 1250 °C for 60, 120, 180 and 240 minutes were shown in Fig. 4 and Fig 5. It is observed that with increasing time the recovery of strontium metal also increased. For example, recoveries of strontium were determined to be 40.1% after 60 min. and 96.89% after 240 minutes reduction time. Sr concentration in the residue decreased with increasing time. For example strontium concentration in residue were determined to be 69% after 60 min. and 2.25% after 240 minutes reduction time.
4. Conclusion

On the basis of the results of the present study of aluminothermic reduction of SrO by Al powder under 1-5 mbar pressure for different stoichiometric amount of reducing agent and time, following conclusions can be drawn:

Highest Sr recoveries were determined as: 1) 96.89% with addition of 300% stoichiometric Al and BaO for 240 min., 2) 96.87% with addition of 300% stoichiometric Al and BaO for 180 min., 3) 86.45% and 85.28% with addition of 200% stoichiometric Al and BaO for 240 min and 180 min respectively.

References

[10] ASTM B 409, B 408, B 407, B 564