Synthesis of Silver Powder for Zinc Silver Oxide Batteries

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ABSTRACT
Silver powder has been specifically synthesized for zinc silver oxide batteries by decomposition of its oxide at higher temperature. The particle size, surface area, density, porosity and purity level of silver powder are such that, it is suitable in using zinc silver oxide batteries. The electrochemical behavior/capacity of silver powder is also found quite satisfactory, while charging and discharging silver electrodes for three cycles. The synthesis method is simple and economical.

Keywords: Porosity, Decomposition, Electrochemical behavior.

1. INTRODUCTION
Having very strong Antiviral [1] antibacterial [2] antifungal [3] effects, silver has many applications in medical science. Because of best electrical and thermal conductivity characteristics, important applications for silver particles can be found in the catalyst and electronic industry [4-7], particularly for making conducting inks and paste for thin/thick films. To meet those and many other requirements silver powder is prepared through various processes ranging from chemical, physical (atomization and milling), and electrochemical to thermal decomposition. Silver nitrate is frequently used as silver precursor in chemical methods, being preferred to other compounds due to its high solubility in water and organic polar solvents. Agents like sodium borohydride, hydrazine or ethylene glycol are frequently used for silver nitrate reduction. Silver powder can be synthesized from sacrificial solid template [8] or by using an excess of a soft template with reducing power [9]. A prolonged heating of a silver nitrate solution in ethylene glycol [10, 11], or reduction with glycerol [12], also yield silver powder. Silver powder has huge applications in batteries’ technology. Among those batteries, zinc silver oxide is an important reserved battery, particularly useful for missile and aerospace application, as it has good high rate capability and high energy density [13]. The cells of these batteries are designed for thin plates and large surface area electrodes, which augments its high rate and low temperature capability and provide a flat discharge characteristic. Silver powder for these batteries should have specific characteristics e.g. Porosity, purity, particle size, surface area, density and discharge capacity of silver electrodes greater than the recommended value for silver powder. Silver powder is pressed on a metallic grid of silver [14, 15] to prepare positive electrodes, followed by electro-formation in alkaline solution. The procedure for synthesis of silver powder described in this paper is through thermal decomposition of its oxides while the process contains many specific steps which critically effect on the quality of silver powder. The detailed procedure given ahead is the ideal and economical route to yield silver powder of good quality for use in zinc silver oxide batteries.

2. EXPERIMENTAL

2.1 Chemical (s) Used
- Potassium Carbonate: (Purity > 98.5%, Merck)
- Silver Nitrate: (Purity >99%, Merck)
- Solvent: Deionized water (Conductivity < 4 µS/cm)

2.2 Synthesis Procedure
The synthesis of silver carbonate was carried out according to equation (1) given below, by taking silver nitrate as limiting reactant. One liter solution of silver nitrate was taken in the flask while an equal volume of potassium carbonate solution was added into, by drops, at rate of 5mL/minute. Further stirring 60 RPM (Round per Minutes) was ensured after completion of reaction, and then the flow chart given (Figure 1) was followed accordingly, to synthesize silver powder.

\[
2\text{AgNO}_3 + \text{K}_2\text{CO}_3 \rightarrow \text{Ag}_2\text{CO}_3 + 2\text{KNO}_3 \quad \text{Eq (1)}
\]
3. RESULTS AND DISCUSSIONS

Bulk density of powder was measured by density cup method [16]. Purity, volumetrically by EDTA (Ethylene Diammine Tetra Acetic acid) titration, particle size by LASER particle sizer Analystte22 FRITCH GMBH. The surface area of powder is measured by using Quanta chrome Autosorb-1, (Modle. ASIC-LP) and Trace metal impurities by Atomic Absorption Spectrometer, Perkin Elmers, Analyst 300. The porosity of silver powder is measured by density of silver powder and that of pure silver metal, with following formulae.

\[
\text{Porosity (\%)} = \left[1 - \frac{\text{Density of silver powder}}{\text{Density of silver metal}}\right] \times 100\%
\]

While density of silver metal is 10.49 g/cm³

The characteristics of synthesized silver powder are tabulated below;

<table>
<thead>
<tr>
<th>S#</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Density</td>
<td>0.99 g/cm³</td>
</tr>
<tr>
<td>2</td>
<td>Purity</td>
<td>98.4 %</td>
</tr>
<tr>
<td>3</td>
<td>Particle size</td>
<td>64.68 µm</td>
</tr>
<tr>
<td>4</td>
<td>Surface area (BET)</td>
<td>3.69 m²/g</td>
</tr>
<tr>
<td>5</td>
<td>Porosity</td>
<td>90.56 %</td>
</tr>
<tr>
<td>6</td>
<td>Cu,Fe,Zn,Pb</td>
<td>4.37 ppm</td>
</tr>
<tr>
<td>7</td>
<td>Average discharge capacity of silver electrodes for three cycles.</td>
<td>2.91+2.70+2.50/3=2.70 Ah</td>
</tr>
</tbody>
</table>

3.1 Scanning Electron Microscopy Analysis

Morphology of the synthesized powders was studied with the help of scanning electron microscopy. The porosity of agglomerated particles is clear in the images with much consonance among the particles with respect to shape and overall morphology.

3.2 XRD and EDX Analysis

Structural characterization of silver powder is determined by XRD analysis, which shows the distinct peaks of silver with cubical structure of individual particles, while impurities are non-existent. Energy Dispersive X-ray analysis also shows silver powder containing no impurities.
3.3 Electrochemical Activity Test

For electrochemical activity of silver, nine electrodes (7.4 g powder with area 18 cm² for each) are pressed on rectangular silver wire (2 mm thickness) loop and then a power pack is formed by attaching three electrodes parallel to each other (the centered electrode as test electrode and other two as auxiliary electrodes on each side). This constitutes a powder pack. Three such packs are formed, wrapped in separator for zinc silver oxide batteries, attached in series with each other’s and charging (through external power supply) and discharging (at 2.5 A load) of these powder packs is been carried out, three times, using potassium hydroxide electrolyte of density: 1.3 g/cm³. The average discharge capacity for the first cycle of three power packs was 2.91 Ah, while it was 2.70 Ah and 2.50 Ah for the second and third cycles respectively. The average capacity of all cycles is found 2.70 Ah, which is more than the required value for zinc silver oxide batteries (2.50 Ah). The discharge capacity (2.70 Ah/7.4 g) is also more than the capacity of silver powder based on weight (3.53 g/Ah, which means 2.09 g/Ah/7.4 g) [18], for battery usage.

The synthesized silver powder has the advantage of having relatively smaller particle size (64.68 µm) and large surface area (3.69 m²/g), with greater harmony among the morphology and size of particles distribution. During this research work, it is found that the spray of potassium hydroxide solution on silver oxide is critical during synthesis process, for decreasing the density of final silver powder up to 10%, which causes the porosity and surface area to increase with same extent. It is evident from the results that silver powder is been synthesized of good quality with characteristics suitable for its use in zinc silver oxide batteries.

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REFERENCES


