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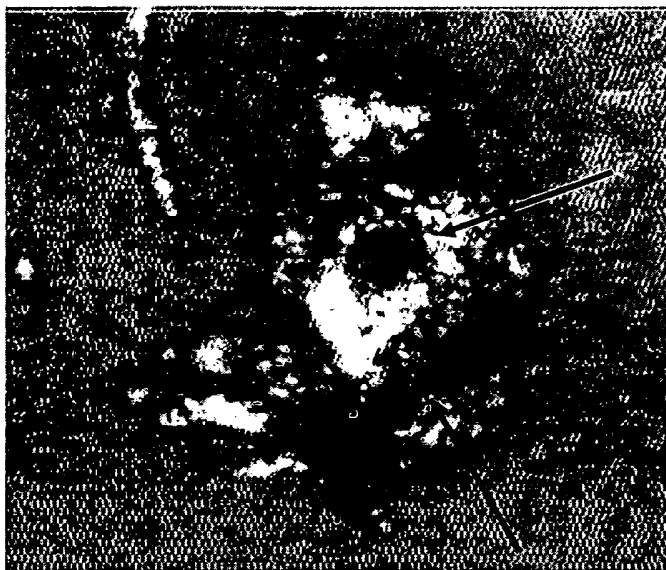
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(54) Title: ALLOYED ZINC POWDERS FOR ALKALINE BATTERIES WITH PARTICLES PIERCED WITH AT LEAST ONE HOLE



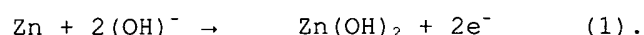
(57) Abstract: The invention concerns alloyed zinc powders for alkaline batteries and a method to manufacture such powders. The powders are characterised by the presence of particles pierced with at least one hole. This appears to benefit the high drain discharge capacity while preserving the process ability of the powder, and the shelf life and the gassing behaviour of the batteries. The invented powders can be manufactured using centrifugal atomisation in a cooled, oxygen-depleted atmosphere.

**Alloyed zinc powders for alkaline batteries with particles pierced
with at least one hole**

5 The invention relates to alloyed zinc powders, a key component for the manufacture of the anode of alkaline batteries.

Battery manufacturers are confronted with the well known problem of the formation and accumulation of hydrogen gas within the battery, which is caused by the corrosion of the zinc powder by the alkaline electrolyte. Generation of gas increases the internal pressure in the cell. Safety systems are provided to prevent the explosion of the battery, but the risk of damage due to electrolyte leakage remains. Gassing may occur before use of the battery, i.e. during its shelf life; it typically also occurs after partial discharge, a phenomenon further on referred to as "PD gassing".

The capacity of a battery depends on the capability of the zinc powder to generate zinc ions and electrons according to:



20 However, if the reaction medium is depleted in OH^- , an irreversible reaction is induced, leading to the precipitation of ZnO on the surface of the zinc particles, passivating their surface. The end result is that part of the metallic zinc will not be available for the electrochemical reaction (1), thereby limiting the effective battery capacity to a fraction of its theoretical value. This phenomenon of passivation occurs mainly at high discharge rates, i.e. when the zinc particles release a high flux of zinc ions, while only a limited amount of hydroxide ions is available at the reaction sites.

30

Several patents, such as US 6,284,410, claim good high drain discharge performances by using a fine zinc powder, as such, or in a blend with a coarse zinc powder. The high specific surface of the fine powder tends to enhance high drain discharge, but it unfortunately also limits the shelf life and increases the PD gassing.

35

The use of large flaky particles also tends to improve the high drain service and the shock resistance of the alkaline battery, as mentioned in US 6,022,639. Other shapes like spheres, teardrops and strands were studied in WO 2004/012886. Unfortunately, these shapes
5 greatly increase the gel viscosity, which leads to processing problems during the manufacture of batteries.

Low gassing, good process ability and high drain capability thus create conflicting demands. It is the aim of the present invention to
10 solve this conflict.

To this end, a new alloyed zinc powder for alkaline batteries comprising particles pierced with at least one hole in an amount of more than, either one or more, of: 10% by count in the sieving
15 fraction 250 to 425 μm ; and 3% by count in the sieving fraction 150 to 250 μm ; and 2% by count in the sieving fraction 105 to 150 μm is presented. The zinc alloy powder in the sieving fraction 250 to 425 μm preferably comprises particles pierced with at least one hole in an amount of more than 20% by count, more preferably more than 30% by
20 count, and still more preferably at least 31% by count, and even at least 36% by count. The above mentioned 'particles pierced with at least one hole' will in the remainder of the text be referred to as 'pierced particles'.

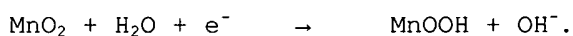
25 In a more specific embodiment, the powder comprises one or more of bismuth, indium and aluminium as alloying elements. Preferably, the alloy consists of either of: 0.001 - 0.05% by weight aluminium and 0.001 - 2% indium; 0.002 - 0.2% by weight bismuth and 0.001 - 2% indium; 0.002 - 0.2% by weight bismuth, 0.001 - 2% indium and 0.001 -
30 0.05% aluminium; and 0.002 - 0.2% by weight bismuth; and, optionally, up to 0.5% by weight of either one or both of lead and calcium, the remainder being zinc. Furthermore, a zinc powder consisting of 0.005 - 0.05% by weight Pb, the remainder being zinc, is also suitable. Said zinc may, as a matter of fact, also contain unavoidable
35 impurities, such as those allowed in so-called Special High Grade (SHG) zinc.

As a further embodiment, this invention concerns alkaline batteries comprising an alloyed zinc powder according to anyone of the above criteria.

- 5 Alloyed zinc powders suitable for alkaline batteries can be produced by centrifugal atomisation (CA), a process described in EP 1155464B1. Liquid zinc is hereby poured onto a disk, rotating rapidly in a protective oxygen-depleted atmosphere. This process results in the production of classical CA powders. For obtaining pierced particles
10 according to this invention, it is however necessary to cool the atomisation atmosphere to a temperature of less than 110°C, and preferable at a temperature of less than 100°C. This can be done by applying forced air cooling on the external walls of the atomisation chamber. Advantageously, the atomisation is performed in an
15 atmosphere having an oxygen content of less than 8% by volume, and more preferably of more than 4% by volume.

- Pierced particles allow for the use of coarser powders without penalising the high drain capacity of the battery, while preserving
20 the shelf life, limiting the PD gassing, and ensuring good processing capabilities. Conversely, pierced particles enhance the high drain behaviour compared to classical powders with the same particle size distribution.

- 25 Hydroxide ions are produced at the cathode of the alkaline battery according to the reaction:



- As explained above, these hydroxide ions are needed at the zinc at the anode, to avoid the passivating the surface of the zinc
30 particles. It is assumed that pierced particles improve the diffusion of the hydroxide ion from cathode to anode, enhancing the so-called chemical homogeneity of the alkaline battery. This important property can be evaluated by a fast paced intermittent discharge test, where the battery can rest and homogenise for only a short period of time
35 between high current discharge bursts.

Pierced particles can be detected and counted by direct visual observation under a microscope, or by using a shape analyser like the ALPAGA[®] system of Occhio SA, Belgium.

- 5 The zinc powder of the invention shows particles pierced with at least one hole. The general shape of the zinc powder particle is typically a microscopic flake, which can e.g. be curved, hollow or cuplike. Figure 1 shows a doubly-pierced particle of alloyed zinc powder according to the invention, whereas Figure 2 represents a
10 particle with a large pierced area. Figure 3 shows the particles of a classical centrifugally atomised powder. Such zinc powders are much more rounded and are typically not pierced.

- In metal melt atomisation, some authors, like A.J. Yule and J. J.
15 Dunkley in the book "*Atomization of melts for Powder Production and Spray Deposition*", pp. 15-46, Clarendon Press, Oxford; 1994, refer to the possible existence of a atomisation in two steps. The primary atomisation is the formation of a droplet from the liquid metal. The
20 secondary atomisation is the further atomisation of this droplet by air friction: the high relative velocity breaks up the droplet into smaller particles. This phenomenon is illustrated in Figure 4, which shows the liquid droplet break-up mechanism during secondary atomisation.

- 25 The process of the invention consists in applying proper atomisation conditions to freeze the zinc particles early during the secondary atomisation step in order to obtain a substantial fraction of pierced particles. This implies means to cool the atomisation atmosphere.

30 Example 1

Alloyed zinc powders were produced by centrifugal atomisation: liquid zinc alloy at 480 °C was hereto poured onto a disk of 170 mm diameter rotating at 13000 rpm in a protective, oxygen-depleted atmosphere.

- 35 Table 1 compares the percentage by count of pierced particles observed in each sieving class in a classical CA zinc powder, i.e. without temperature control, to a powder produced according to the invention. Both powders were made using the same alloy consisting of

zinc with 200 ppm In, 100 ppm Bi and 100 ppm Al. Both were atomised in an atmosphere containing 6.25% by volume of oxygen. The classical CA powder was manufactured without cooling the atomisation atmosphere, resulting in an ambient temperature of about 160 °C,

- 5 whilst the powder according to the invention was manufactured with proper cooling, at 100 °C. It is clear that the zinc powder according to the present invention has a much higher count of pierced particles, in particular in the coarser sieving fractions.

10 Table 1: Pierced particles by count versus sieving fraction in Zn powders

Sieving fraction (μm)	Pierced particles (count %)	
	Classical CA powder	CA powder according to invention
425 - 250	5	40
250 - 150	2	23
150 - 105	1	5
105 - 75	1	1
75 - 45	1	1
45 - 25	0	0
< 25	0	0

Example 2

- Electrochemical cells containing a cathode, an anode and a separator, as shown in Figure 5, were prepared using zinc powders atomised as in Example 1. A can (10) contains the annular cathode mix (11), essentially composed of MnO_2 , C and KOH. A separator paper (12) prevents shortcuts between the cathode and the anode mix (13). The current collector (14) allows collecting the electrons from the anode mix. Such a cell corresponds to a classic LR-6 battery.

The alkaline batteries were tested in 2 high drain discharge tests:

- a 1 A continuous drainage test, with cut off at 1.0 V; and,
- a 1 A intermittent drainage test with 10 seconds of discharge followed by 50 seconds of rest, with cut off at 0.9 V.

The total discharge times, normalised at 100% using the classical CA powder as a reference, are shown in Table 2.

5

Table 2: Influence of O₂ content during atomisation on the pierced particle count in sieving fraction 425 - 250 µm, and on the high drain capacity of batteries

10

O ₂ (volume %)	Pierced particles (count %)	Relative capacity (%)	
		1 A intermittent	1 A continuous
1.75	11	102	100
2.5	12	107	100
3.25	13	110	102
4	31	114	104
4.75	36	114	106
5.5	38	115	105
6.25	40	117	108

Figure 6 represents the % of pierced particles as measured with the ALPAGA® system versus the oxygen % in the protective atmosphere of the atomisation chamber. The upper curve shows the number of pierced particles in the 425 - 250 µm range, the lower curve shows the overall percentage of pierced particles.

15

These experiments confirm that the presence of pierced particles leads to very good results in high drain capacity, in comparison to a classical CA powder made with the same alloy. An oxygen content of more than 4% by volume is advantageous; it is however preferred to remain below 8%, as gassing of the powders otherwise tends to increase to an unacceptable level.

20

Claims

1. Alloyed zinc powder for alkaline batteries comprising particles pierced with at least one hole in an amount of more than either one
5 or more of:
- 10% by count in the sieving fraction 250 to 425 μm ; and
 - 3% by count in the sieving fraction 150 to 250 μm ; and
 - 2% by count in the sieving fraction 105 to 150 μm .
- 10 2. Alloyed zinc powder according to claim 1, comprising particles pierced with at least one hole in an amount of more than 20% by count in the sieving fraction 250 to 425 μm .
3. Alloyed zinc powder according to claim 2, comprising particles
15 pierced with at least one hole in an amount of more than 30% by count in the sieving fraction 250 to 425 μm .
4. Alloyed zinc powder according to claim 3, comprising particles pierced with at least one hole in an amount of at least 31% by count,
20 and preferably of at least 36% by count in the sieving fraction 250 to 425 μm .
5. Alloyed zinc powder according to anyone of claims 1 to 4, comprising one or more of bismuth, indium and aluminium as alloying
25 elements.
6. Alloyed zinc powder according to claim 5, comprising either of:
- 0.001 - 0.05% by weight aluminium and 0.001 - 2% indium;
 - 0.002 - 0.2% by weight bismuth and 0.001 - 2% indium;
 - 30 - 0.002 - 0.2% by weight bismuth, 0.001 - 2% indium and 0.001 - 0.05% aluminium; and
 - 0.002 - 0.2% by weight bismuth;
- and, optionally, up to 0.5% by weight of either one or both of lead and calcium, the remainder being zinc.
- 35

7. An alkaline battery comprising an alloyed zinc powder according to anyone of claims 1-6.
- 5 8. A process for the manufacture of an alloyed zinc powder for alkaline batteries, comprising the step of centrifugally atomising a zinc alloy, wherein the atmosphere in the centrifugal atomisation chamber is held at a temperature of less than 110°C, and preferable at a temperature of less than 100°C.
- 10 9. A process for the manufacturing of an alloyed zinc powder for alkaline batteries according to claim 10, wherein the atomisation is performed in a protective atmosphere having an oxygen content of less than 8% by volume, and preferably of more than 4% by volume.

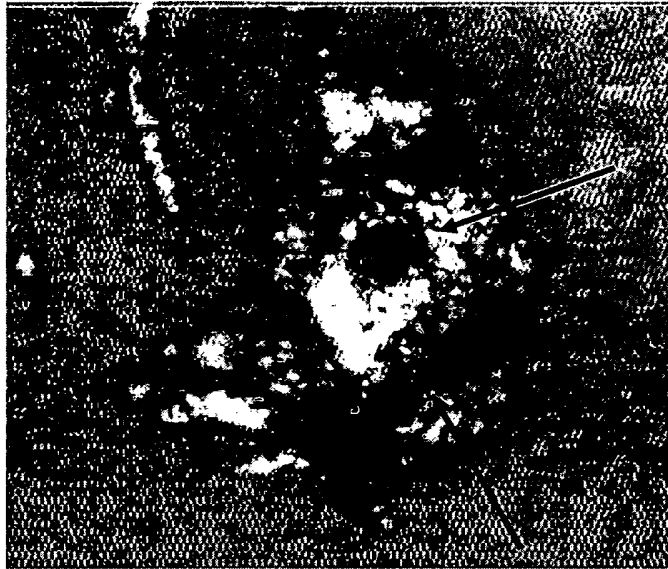


Figure 1

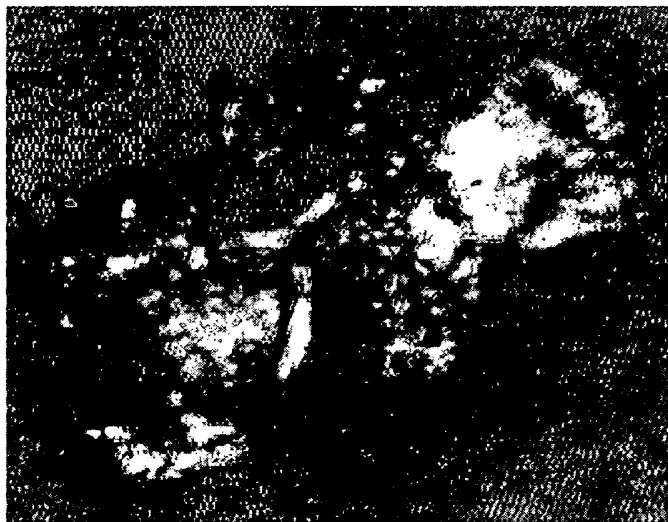


Figure 2

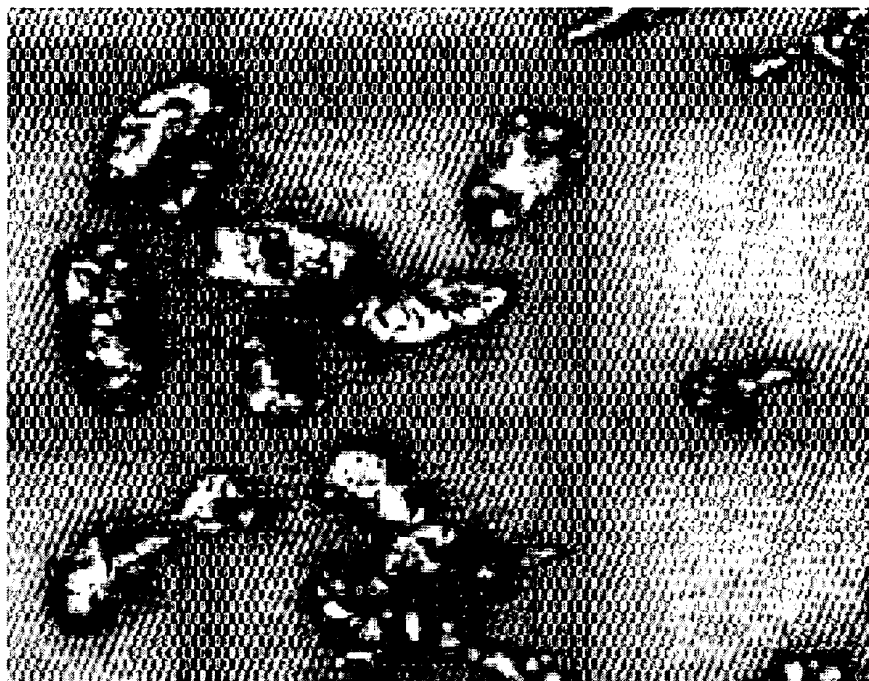


Figure 3

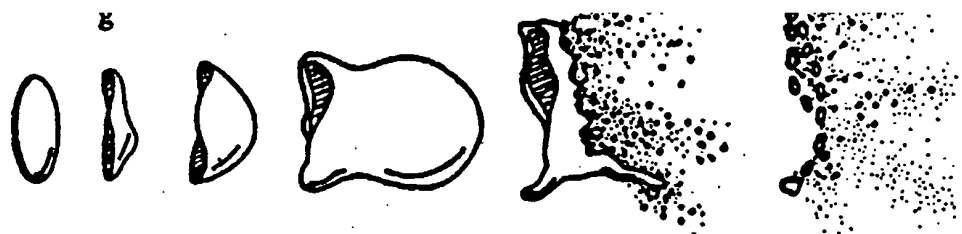


Figure 4

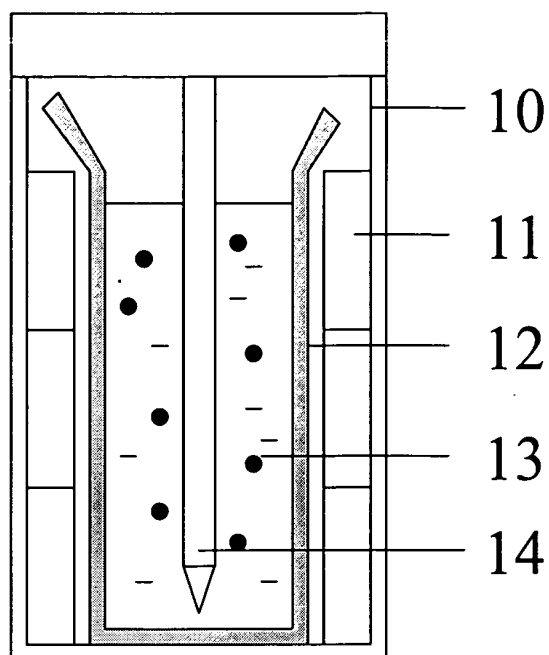


Figure 5

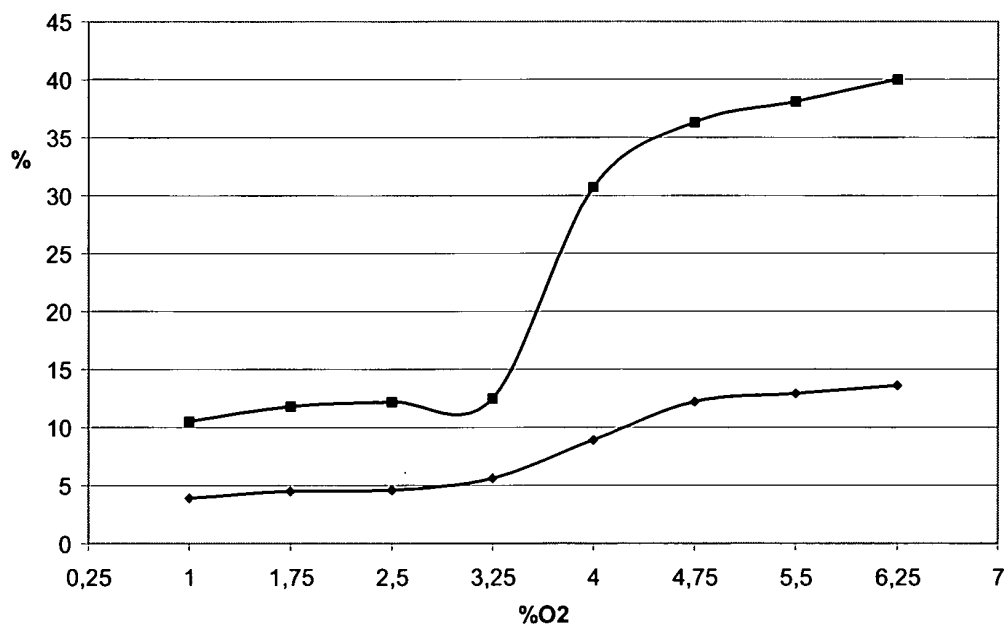


Figure 6