Comparison of different voltage levels within the ZACplus recycler

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Abstract

When using the ZACplus recycler we can run it at an arbitrary voltage, by clamping the current to a fixed level. Here we examined and compared different voltage levels to find out the range with the best efficiency.

Introduction

The process of recharging the ZACplus as a system for seasonal longterm storage of solar energy happens during summer, by applying the excess solar energy to the zinc oxide solution within a simple electrogalvanic process. The zinc gets rid of the oxygen atoms which become released into the ambient air and accumulates at the cathode as a sponge of pure elementary zinc. During the development we use a lab-psu, which allows a current clamp and therefore arbitrary voltages. There is a broad range of possible voltages under which the reaction will run, in e.g. a bifunctional cell the open-circuit voltage while loading can be as low as 1,66V [1]. With higher electrical power consumption its possible to speed up the zinc regeneration.

But that doesnt necessarily mean that a given voltage is also the best in an economical sense, concerning the degree of efficency.

Here we are montoring the process running with three different voltages, to find out which one gives the best yield of zinc related to the most economical energy consumption.

Methods

Scale extension of the recycler

To achieve that, we first had to optimize our setup. In former experiments we simply weighted the regenrated zinc slurry but this contains the systematical inaccuracy of having residual moisture between the zinc particles that have also a certain weight which is not neglectable and leads to a better value than it has in reality. To avoid this kind of artifact we constructed a device that extends the recycler with

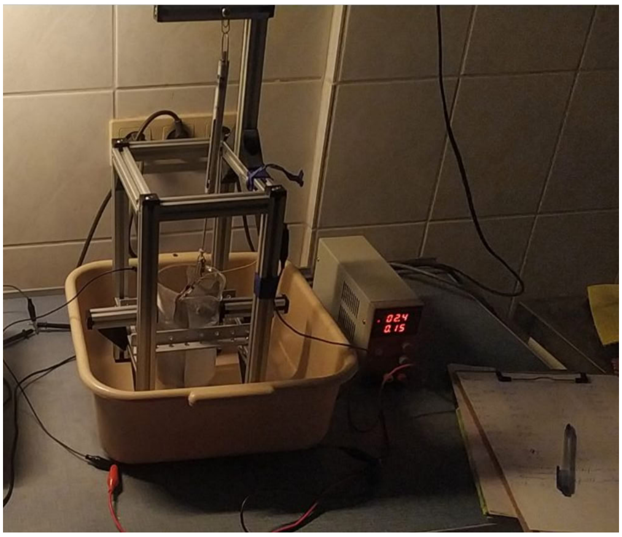

Figure 1: *recycler with spring scale extension.*

a spring scale (see figure 1), which allows a coninuous measuring during the regeneration process. The electrode to which the zinc sponge accumulates (see figure 3) is directly connected to that scale and at the same time reaches into the electrolyte or respectively into the surrounding moisture (see figure 2). Therefore we measure with each accumulating zinc particle only the net weight of that particle.

Lab-PSU setup

We measured the regeneration process three times, under the following voltage levels:

- 2.4 V
- 3.2 V
- 4.2 V

Results

The diagram at figure 4 shows a straight line for each of the three tested voltages, but without their

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Figure 2: *pre process: The electrode which hangs on the spring scale is plunged and immersed by the electrolyte. The white poweder at the ground is precipitated zinc oxide (ZnO).*

Figure 3: *post process: the regenerated zinc was accumulated as a sponge on the right electrode. The withe zinc oxide poweder has been gone.*

indivdual offsets (meaning, only the net-generated zinc weight). The slope increases with the increasing voltage.

Discussion

This means, that a given weight-increase, like e.g. 1.5 g will be reached sooner, if the voltage is higher: at 4.2V after round 150 min, at 3.6V after 420 min and at 2.4V after 495 min.

However, in this application not the reaction-speed

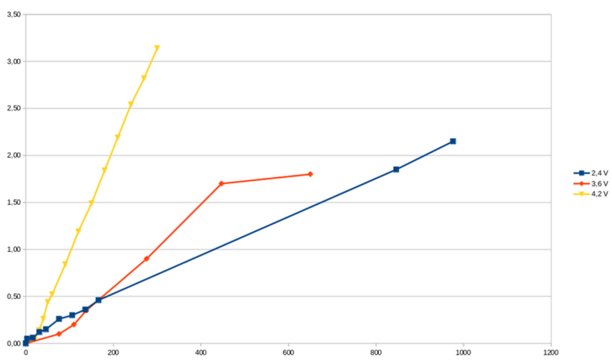

Figure 4: *The diagram shows the accumulated weight of the regenerated zinc at 2.4V, 3.6V and 4.2V*

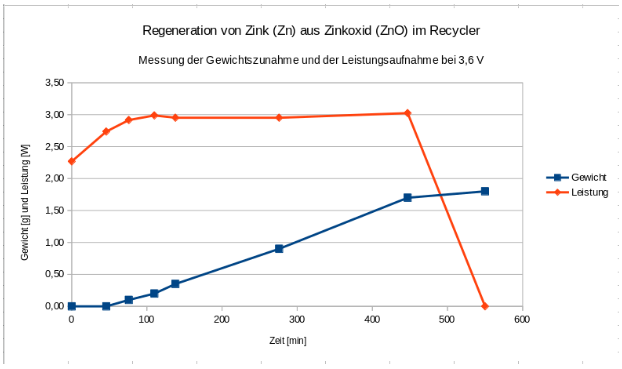

Figure 5: *Regeneration of zinc (Zn) from zinc oxide (ZnO) at the recycler measuring the increasing weight and the powerconsumption at 3.6V*

is relevant, but the optimal power-consumption (for reaching a good degree fo efficiency). In the diagram at figure 5 we show as an example the electrical output in Watts at 3.6V. The graph is linear and nearly constant at 2.9 Watt, neglecting a short tuning phase at the beginning. At the end it decreases rapidly because all the available zinc oxide is meanwhile consumed and transformed into zinc and oxygen and the weight-accumulation graph also reaches a plateau. The other both voltages are not shown here, but there also the graph was linear and nearly constant (meaning horzontal) with 0.8 Watt at 2.4V and 4.3 Watt at 4.2V.

If we refer these values on the before mentioned durations for regenerating 1.5g zinc, then we can compare them among each other. Therefore we would need 6.6 Wh supplied energy at 2.4V to regenerate the 1.5g zinc within 495 min. At 3.6V it has been 20.3 Wh and 10.75 Wh at 4.2V. Intuitivly one would expect, that the amount of energy for 3.6V is located somewhere between the both other voltages. To be sure that we dont have a measurement artifact this experiment must be repeated. But there could be other possible causes as well. If we compare just the 3.6V and the 2.4V it looks like the more time is used for the transformation one could achieve a smaller total energy consumption and therefore also a better degree fo efficiency. With increasing voltages there will occur at one point a strong hydrogen evolution (HER), so it could be possible, that this will be the case at 4.2V and the strong HER will swirl up the precipitated ZnO which therefore can be better transformed then. The electrode consists of a wire-mesh and the white powder is located on top of it and underneath (see figure 2). But only the amount of ZnO-powder on top is involved in the transformation-reaction, so any kind of swirl-up could have an influence on the result.

Conclusion / Outlooks

The upcoming experiments with the recycler will be focused on to optimizing the power-consumption, because this is essential for a good degree of efficiency. The recent experiments can be seen as a kind of trial series to get closer towards that goal, but they dont tell us anything about the reachable minimum-power-consumption, because this is dependent from other factors too, like e.g. the size of the electrode area, the distance between the electrodes, the materials they consist of, the way of how the ZnO-powder is applied to the chamber, etc. This is not worse, cause all this things mean, that there are further possibilities for optimizations.

References

[1] R. Hahn and A. Schamel. "Ein neues Energiespeicherprinzip für Elektrizität und Wasserstoff". In: *CITplus* 1-2 (2024), pp. 24–27.