

Beverage-Cans as a Source of Hydrogen – Analysis of Leaching Residues

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Aluminium beverage-can are common material for secondary utilization. Their recycling is slightly complicated by presence of organic materials in them and lack of collection points (although the legislative in this case is rapidly changing to be more friendly). Another approach to deal with beverage-cans is using them as a source of hydrogen. In this manuscript, the evolution of hydrogen in 10 wt. % NaOH solution is described. The leaching residues were analysed in detail. Their chemical and phase composition were measured, and the amount of trapped hydrogen was also analysed. The beverage-cans are usually composed of 3004 and 5182. The residues after leaching contained beside organic residues oxides and hydroxides in both cases of initial alloys. Surprisingly, the amount of hydrogen in leaching residues is almost negligible.

Keywords: Beverage-can, Aluminium leaching, Hydrogen evolution, NaOH, Aluminium

1 Introduction

The beverage-cans are made from combination of aluminium alloys, typically 3004 (body of the can) and 5182 (top of the can). Their compositions are given in Tab. 1. World-widely they belong to successfully recycled material [1-4] but there are still some problems with their recycling in the Czech Republic [5,6].

A novel approach is to use aluminium beverage-cans as a source of hydrogen by leaching them in NaOH solution [9-11]. This process exhibits significant similarities with production on metallic nanoparticles by selective leaching technique. Production of nanoparticles by this method was

already described for Ag [12-16], Cu [17,18], Fe [18,19] and Ni [16,18,20,21]. For the last mentioned, it was observed that the Ni nanoparticles have the ability to trap the hydrogen in its structure. This hydrogen was released by heating the nanoparticles in temperature range 130-180 °C [21].

It was described that the waste NaOH solution after leaching can be used as a source of Al₂O₃ nanoparticles [19]. On the top of it, these particles exhibit catalytic properties [9]. The only missing part of this process is characterization of the leaching residues. The aim of this paper is to prove the feasibility of the leaching residues of beverage-cans serving as a spare source of limited amount of hydrogen.

Tab. 1 Composition of used aluminium alloys, wt. %

Alloy/ Element	Al	Mg	Mn	Si	Fe	Cu	Zn	Ref.
3004	95.6-98.2	0.8-1.3	1.0-1.5	max. 0.3	max. 0.7	max. 0.25	max. 0.25	[7]
5182	95.2	4.5	0.3					[8]

2 Experimental

The beverage-cans were used in the native, unwashed state to keep the experiment as realistic as possible. The cans were divided mechanically and the top- and bottom- parts were studied separately. The 0.33 l can contain approximately 10 g of 3004 alloy and 3 g of 5182 alloy. The evolution of hydrogen evolution was measured by volume method using a home-made device at laboratory temperature in 10 wt. % solution of NaOH. The whole body and whole top and bottom of the can were taken for the experiment. The can was mechanically divided in approximately

rectangular parts with size 3 * 4 cm to fit to the experimental apparatus. The leaching-residues were obtained by two times repeated decantation in the distilled water and once in ethanol. The chemical composition was determined by XRF using AXIOS spectrometer. The phase composition was analyzed by XRD using PANalytical Empyrean diffractometer. The hydrogen evolution from leaching residues was measured by TG-DTA-MS by Setsys Evolution. The microstructure of leaching residues was analyzed by TEM Jeol 2200FS. For all analytical techniques was used granulometric fraction of leaching residues with size less than 63 µm.

3 Results and discussion

The kinetic of hydrogen evolution, shown in Fig. 1, is comparable with similar published experiments performed for Al-Fe alloy [22]. The reaction culminated after 45 min with total amount of evolved hydrogen of 290 ml. According to the ChatGPT this amount is sufficient for approx. 3 m movement of common car. For the top and bottom part of the can, the kinetic was similar.

Chemical composition of leaching residues is given in Tab. 2. The composition of residues from body and top part is comparable with slight difference in Al content.

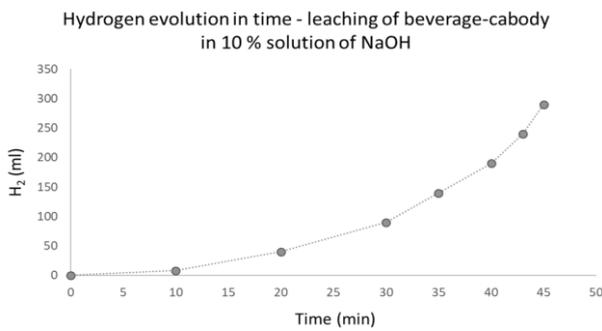


Fig. 1 Hydrogen evolution from single body of beverage-can (10 g of 3004)

Phase composition of leaching residues was extremely complex, as illustrated in Fig. 2. Both samples were composed of amorphous phase (visible from the shape of the XRD pattern) and mainly hydroxydes from elements in Tab. 2. Surprisingly, there is no evidence of presence of metallic nanoparticles. The leaching residues were therefore analyzed by TEM and the results are given in Fig. 3 and 4.

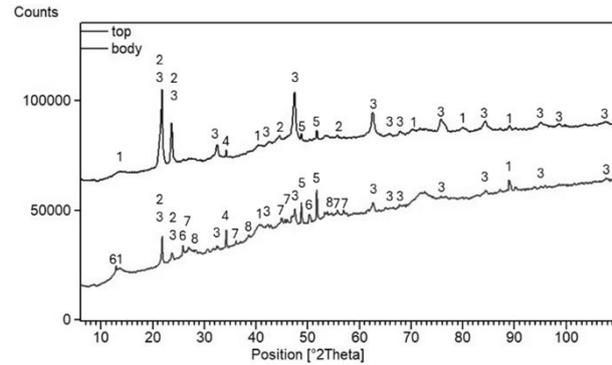


Fig. 2 XRD patterns, 1 – $Mg_{0.12}Cu_{0.63}Al_{0.25}(CO_3)_{0.125}(OH)_2$, 2- $Al(OH)_3$ Gibbsite, 3 - $Al(OH)_3$ Bayerite, 4 - $CaCO_3$, 5 – $Mn_4Al_6Si_3$, 6 - $Ca_4Al_2O_6(CN)_2 \cdot 10H_2O$, 7 – $Mg_6Fe_2(CO_3)(OH)_{16} \cdot 4H_2O$, 8 – $Ca_{1.8}CuCl_2O_2$

Tab. 2 Composition of leaching residues, wt. %

Part/Element	Al	Mg	Mn	Fe	Na	Si	Cl	Ca	Cu	Zn
body	44.54 ± 0.1	11.68 ± 0.1	12.69 ± 0.1	7.54 ± 0.1	6.25 ± 0.1	2.43 ± 0.05	2.87 ± 0.05	6.28 ± 0.07	2.94 ± 0.05	1.68 ± 0.04
top	27.14 ± 0.1	16.3 ± 0.1	16.75 ± 0.1	10.14 ± 0.09	4.97 ± 0.07	2.56 ± 0.05	4.82 ± 0.06	10.96 ± 0.09	3.23 ± 0.06	0.96 ± 0.03

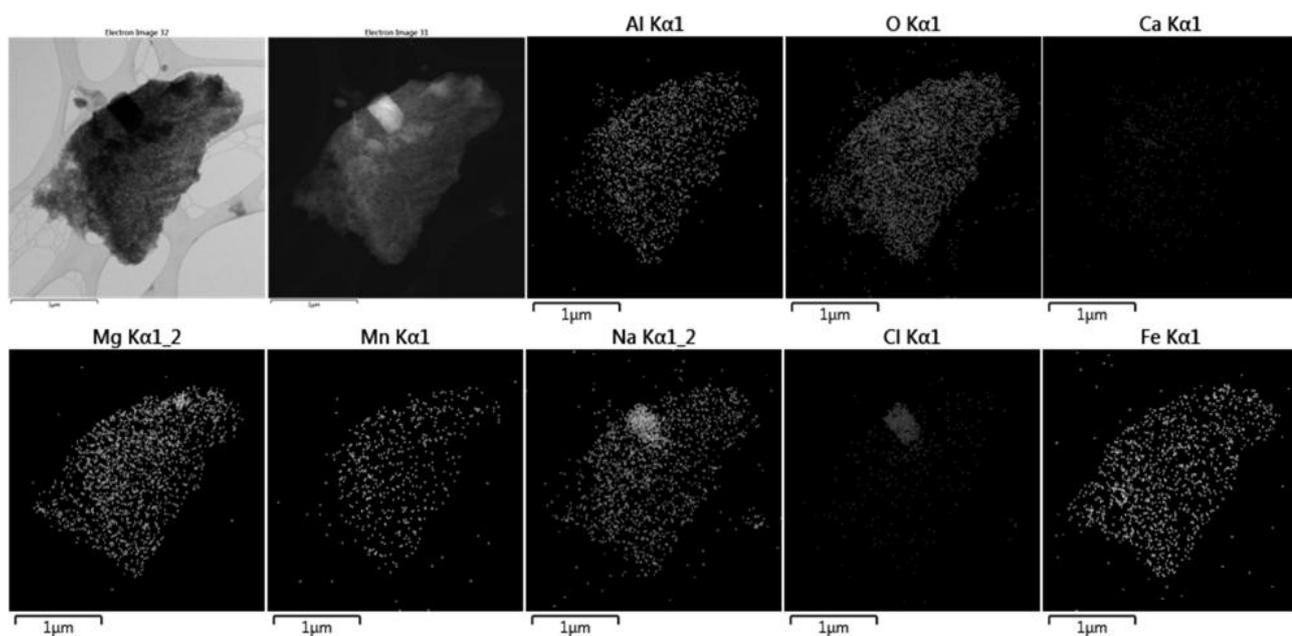


Fig. 3 TEM images (BF, DF) and EDS elemental maps from leaching residues of body part of beverage-can

In both cases, the most surprising is the presence of NaCl crystals that were not detected by XRD. According to the chemical composition, presence of Mn and Fe nanoparticles was expected but it was not

proven even by TEM nor by XRD. The results shown in Fig. 2, 3 and 4 are in good agreement that the leaching residues are mainly formed by hydrated mixed oxides.

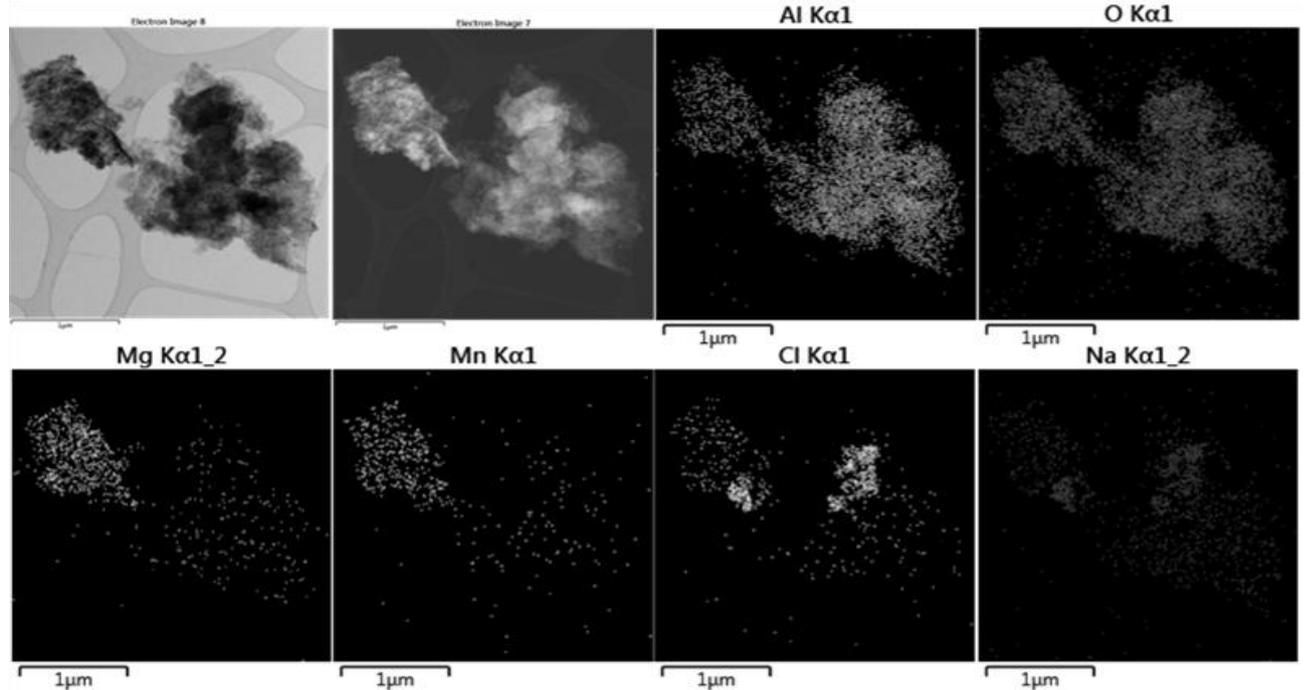


Fig. 4 TEM images (BF, DF) and EDS elemental maps from leaching residues of top part of beverage-can

Fig. 5 and 6 shows TG-DTA-MS of leaching residues. The TG green curves show constant weight up to 120 °C, then mild decrease up to 200 °C and

intensive weight decrease from 230 °C. The red DTA curves exhibit peaks at 230 °C, which means that the weight sink is accompanied by exothermal reaction.

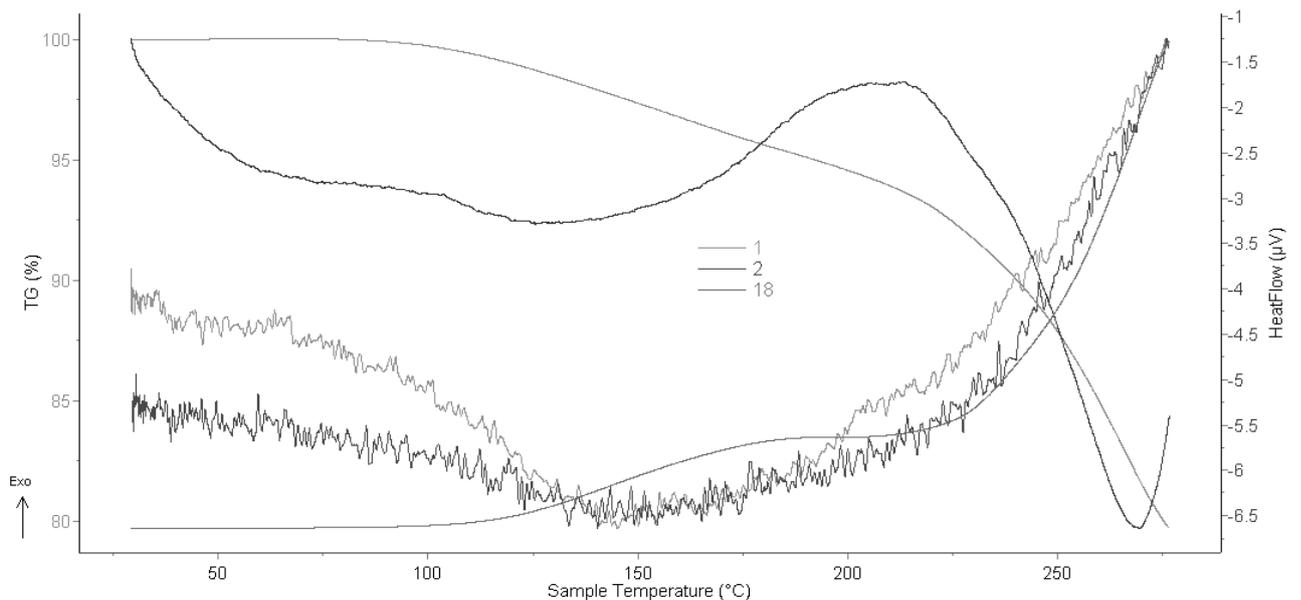


Fig. 5 TG-DTA-MS curve from leaching residues of body part of beverage-can

On the MS 1 red curves, corresponding to atomic hydrogen, we can see decrease up to 140 °C. This might be small amount of absorbed easily diffusible hydrogen. In the Fig. 5 (from the body part),

small peak of stored hydrogen evolution is visible in the range 150-160 °C. The amount is negligible for any practical use.

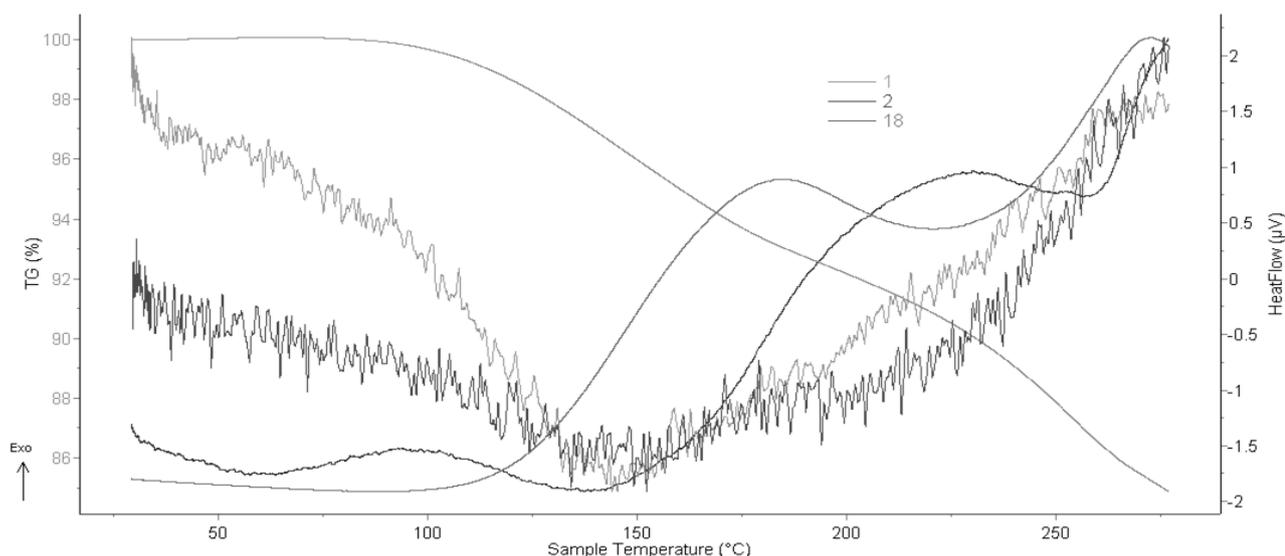


Fig. 6 TG-DTA-MS curve from leaching residues of top part of beverage-can

The peaks in Fig. 5 and 6 on the blue curve (18, H₂O) correspond to drying the crystallographically bounded water. The increase of blue, red and even magenta curves at temperatures above 240 °C is probably caused by decomposition of the residues of internal epoxid polish separating the liquid beverage and aluminium.

4 Conclusion

The aluminium beverage-cans can be successfully used as a source of hydrogen when leached in NaOH solution. The amount of hydrogen is approximately 290 ml from one 330 ml can. The evolution culminates at 45 minutes. Hydrogen evolution is independent on actual composition of aluminium alloys. Leaching residues of both body (3004) and top (5182) parts of the can had more complex composition than expected composed of mixed oxides and NaCl contamination. The amount of hydrogen stored in leaching residues was negligible. The reason is probably the fact that no metallic particles were found in the leaching residues. Nevertheless, the aluminium beverage can can be considered as promising source of hydrogen.

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