Characteristics of Discharge Processes in the Lithium Batteries at Different Discharge Currents

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The multidimensional diagrams of the characteristic functions of the lithium batteries researched by now have sections of flat or quasi-flat dependence on the battery polarization (after some discharge time) in different regions of the battery polarization. The main task of this paper is to report the results on the battery discharge characteristics in the region of small and intermediate discharge currents including the interval where the passive film undergoes "destruction" / 1 /. Research of the battery discharge characteristics in this region can be interesting for diagnostic goals and can give us also additional information concerning the role of the passive film in discharge phenomena.

The experimental data reported here have been obtained by the intensive research method / 2 /. The VARTA CR 2032 lithium batteries were used at the study.

Some of the results of the research are presented in Fig. 1-4. Fig. 1-2 give us the four-dimensional diagrams / 3 / for the characteristic index -R(d(HI)/dR)/(HI) of susceptibility of the quantity HI to changes of the load resistance R for one of the studied batteries, and Fig. 3-4 do it for the characteristic polarization -R(dH/dR); all of these quantities are presented as dependencies on R, the discharge time t, and the battery polarization H. The quantity I in the paper stands for the battery discharge current, and all the derivatives with respect to R are the partial derivatives at constant values of the discharge time t.

As we can see in the diagrams of the characteristic index -R(d(HI)/dR)/(HI) in Fig. 1-2, there are at least three distinct regions of quasi-flat behavior of the index: at very small, at intermediate and at great values of the battery polarization H. They go after some intervals of the index decrease which are essential in the second and third intervals; at least inside the first and second intervals, the characteristic polarization -R(dH/dR) has sections of distinct stepped behavior (Fig.3-4).

In the regions of quasi-flat behavior of the index, the unused portion of the battery power HI can be approximated as $F(t)(1/R)^{\gamma}$. In the first region, γ_1 equals approximately 1.95 for the battery which diagram is presented in Fig. 1. Such behavior and the value of the index differ from what we could expect for the expression

$$ind_{1/R}(HI) = 2(1-H/\varepsilon) + (1-2H/\varepsilon)ind_{1/R}(r) + 2ind_{1/R}(\varepsilon), \qquad (1)$$

($ind_{1/R}(HI) = -R(d(HI)/dR)/(HI)$, r is the battery inner resistance and ε is the battery emf) in supposition that r and ε are constant, so they are connected with alterations at least r or ε during the small-current discharges. From the experimental data, we get $ind_{1/R}(r) \approx -.035$ in this region. It doesn't exclude changes of ε. The inverse characteristic time $1/\tau$ of changes of HI during discharges has also quasi-flat dependence on H in the considered region and equals approximately $.005s^{-1}$ for this battery. It points out to continuing discharge settling in the first quasi-flat region of the index and may be to continuing alterations of the battery inner medium that don't change HI dependence on 1/R but determine the characteristic time of discharge settling.

In the second region, $\gamma_2 \approx 1.5$ and $1/\tau_2 \approx .002s^{-1}$.

The given above values of γ and $1/\tau$, and some other features of dependencies of -R(d(HI)/dR)/(HI) and some other characteristic functions versus H are approximately the same for the researched group of the batteries of this type. It would be interesting to study possible changes of these features in process of long functioning of a battery or its long storage at different conditions.

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References

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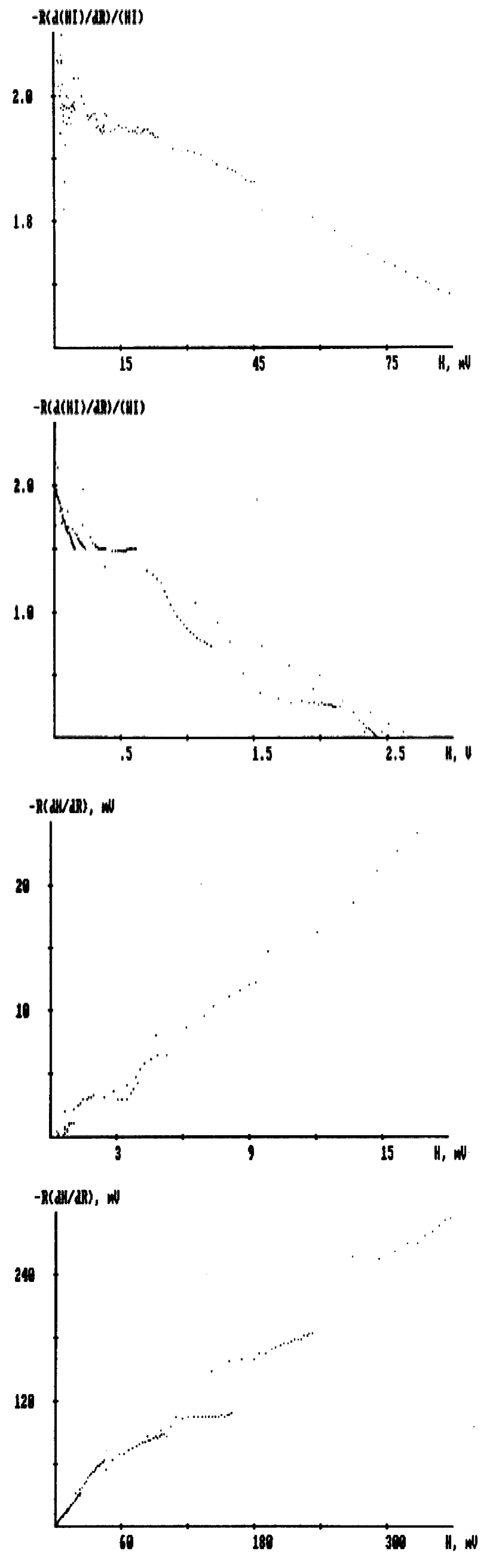

Fig. 1 – 2 -R(d(HI)/dR)/(HI) versus H for a lithium battery VARTA CR 2032.

Fig. 3 – 4 -R(dH/dR) versus H for the lithium battery VARTA CR 2032.